GIMA

Geographical Information Management and Applications

Governance of Geo-Information Flow & Coordination in Emergency Response

Eoin Keating

Supervisors:

Bastiaan van Loenen

TU Delft

Arjen Boin

Crisisplan B.V.

Scientific Professor:

Peter van Oosterom

TU Delft

Universiteit Utrecht

TU Delft

University of Twente

Wageningen UR

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"Chíonn beirt rud nach bhfeiceann duine amháin"

– Eoin Keating
Utrecht, February 2016

Abstract

Geographic Information (GI) is a proven tool to support sense and decision making for effective coordination within emergency response. The objective of this research is to capture and evaluate the use, communication, and exchange of GI between the operational and tactical levels of the emergency services within the Netherlands, in order to identify factors that may impede or facilitate GI sharing.

Because of the unpredictable nature of disaster events and emergency response, diverse datasets are required for risk and impact assessment. Several technical and non-technical issues have been highlighted from literature that effect the flow of information, however, a methodology to identify between which core components of the Spatial Data Infrastructure (SDI) and the work processes associated with the effecting factors is absent from literature. Interviews were conducted to with key actors in the emergency management infrastructure (between the operational and tactical levels) to assess the socially constructed reality of GI sharing and coordination.

The goal of the research is to offer an evaluation method that utilises the principles of the Viable System Model (VSM) in order to propose definitive boundaries within a SDI network, to assess network integrity of all the involved partners. A SDI Network Maturity Model was constructed based on SDI maturity and I.T. alignment in order to highlight the current state of the SDI network, and to provide a roadmap towards the activities that need to be further developed. The results of this research explore SDI governance and alignment with the encompassing Information Infrastructure (II), so that Emergency Managers have access to reliable and harmonised data to make informed decisions, and end-users have influence within their SDI network.

Abbreviations

COP	Common Operational Picture
COPI	Commando Plaats Incident
DBK	Digitale Bereikbaarheidskaart
DM	Disaster Management
EDM	Evaluate - Direct - Monitor
ER	Emergency Response
Geo-ICT	Geographical Information Communication Technology
GI	Geographical Information
GII	Geographical Information Infrastructure
GIS	Geographic Information System
GPS	Global Positioning System
GRIP	Gecoördineerde Regionale Incidentbestrijdings Procedure
IFV	Instituut Fysieke Veiligheid
II	Information Infrastructure
INSPIRE	Infrastructure for Spatial Information in the European Community
I.T.	Information Technology
LCMS	Landelijk Crisis Management Systeem
LOCC	National Operational Coordination Centre
NCC	National Crisis Centre
NMM	Network Maturity Model
ROT	Regional Operations Team
SDI	Spatial Data Infrastructure
UNA	User Needs Analysis
VSM	Viable System Model
WCMS	Water Crisis Management Systeem

Contents

Contents

Chapter 1

Research Introduction

1.1 Introduction

In the aftermath of the 9/11 World Trade Centre disaster a newly developed robot, the Foster-Miller Special Operations Lemming (Solem), was lowered down through a shaft in the midst of the rubble to inspect the basement of the buildings for survivors and victims. The robot was not switched on until it reached the basement. However, if the robot was active and recording images as it was being lowered down through the rubble, structural engineers could have used that data to inspect the serial numbers of metal beams in order for them to map out the puzzle of the debris so that it could be removed faster (Murphy, 2014). This is not an issue with the technology, but an issue with informational awareness between different parties.

Figure 1.1. The Foster Miller Solem robot in operation 9/11. *Source: fireengineering.com*

The response phase of a disaster consists of the immediate actions taken following the occurrence of an event (Carter, 2008), and is considered the most complex phase of the disaster management cycle from the perspective of building an informational picture of the event. This requires total cooperation between different organisations involved in disaster management such as the police, fire, and ambulance services, municipalities, provincial bodies, coordination teams, volunteers, etc. (Diehl et al., 2006). Geo-information (GI) is a vital component used in all activities throughout the disaster management cycle as locational information is the apex of the coordinated response, analysis, and management of an incident, and is used to determine where events have occurred , who is at risk, and how risk varies spatially (Zlatanova & Fabbri, 2009; Kevany, 2005; Hitlz et al., 2011). In addition, GI can assess the fundamental factors relating to a crisis such as, determining what routes are possible for evacuation and routing of resources, where to set up shelters, assessing the geographical extent a disaster can have on critical infrastructure, and the distribution of an incidents impact (Koua et al., 2009).

However, even though GI has significant benefits to offer towards disaster management, it has been highlighted from literature that the coordination and sharing of information between multiple organisations and actors remains a bottleneck to effectively assess and manage the extent of a crisis/disaster (Bharosa et al., 2010; Hernantes et al., 2013; Allen et al., 2014). Schraagen & van de Ven (2011) noted that stake-holding organisations involved in disaster management struggle with problems associated with internal and external informational awareness factors, such as; communication and information flow, authority and decision making, and coordination. These factors lead to technologies, like Geographical Information Systems (GIS), not being used to its' full potential in disaster management for reasons being; the data needed are not always available and if available, not always accessible when and where it is needed (Koua et al., 2009). Therefore, information sharing across organisations can be problematic and related issues should be framed by a range of non-technical, legal, political and cultural aspects with the focus being on how organisations can change in order to improve information awareness enabled by advances in ICT (Allen et al., 2014).

According to Zlatanova & Fabbri (2009), the most important innovations in GI technology research are characterised by the conceptual exploration of the infrastructure needed for handling geo-information to provide better certainty that **1)** the right information is **2)** getting to the right people at **3)** the right time. We live in a world where data is being generated every day on an incomprehensible scale, and it is estimated that approximately 90% of the all data in the world has been generated over the last 2 years from multiple sources and platforms (IBM, 2015) (Figure 1.2). Therefore, considerable effort must be embedded in the way we handle and share information, to ensure that the right information can be accessed when and where it is needed.

Figure 1.2. Data generation.
Source: IBM.com

1.2 Problem statement

Emergency response measures are the actions taken immediately following the occurrence of a disaster in order to limit the disasters' influence and effects on society and the environment. The type, severity and extent of a disaster are factors that contribute to the amount of organisations, actors, and resources required to be involved in order to handle the situation at hand. The effectiveness of the response mechanism is therefore directly related to the planning, training and arrangements made prior to the incident, otherwise any response will not reach its' optimal level in order to cope with an incident that affects society.

Because of the unpredictable nature of disaster and emergency events diverse datasets are required to assess the risk of an event to occur, and if a defined risk is to occur datasets are required to assess the risk an event may have on society (e.g. number of people and critical infrastructure affected, or buildings damaged). If such an event was to then occur in reality, to manage the emergency response brings an additional requirement of real-time data and the added pressure of knowing what and who is where. Therefore, no individual organisation can alone collect and keep up-to-date all of the necessary data before, and particularly after the occurrence of a disaster (Mansourian et al., 2006). An extensive collaboration amongst stake-holding organisations is essential to collect, access and disseminate the required data, and although such collaborative models exist, research into collaborative efforts have highlighted barriers regarding informational flow between multiple organisations during times of emergency response. These barriers exist as technical (such as standards and interoperability models) and non-technical (such as individual, organisational and community) issues (Mansourian et al., 2006).

These technical and social barriers that may impede or facilitate information sharing are complex and dynamic. Different people or teams may be working collaboratively on an identifiable shared problem but have complicated interactions between each other due to diverse responses, different outcome objectives, or uncertainties of the accumulated information. Researchers and practitioners require a systematic approach to identify where factors that facilitate or impede information sharing are occurring, and which core components in the infrastructure are affected in order to resolve the contributing processes that lead to the bottleneck in information sharing.

The fundamental role of the Spatial Data Infrastructure (SDI) is about the facilitation and coordination of the exchange and sharing of spatial data between stakeholders within a community of organisations, and it is suggested that SDI can be used as an integrated framework for resolving such complexity driven problems with spatial data (both technical and non-technical) (Rajabifard et al., 2002; Mansourian et al., 2006). This research will aim to provide an approach to identify where factors that impede/facilitate geo-information sharing occur within the emergency response infrastructure within the Netherlands using the SDI framework.

1.3 Objectives & research questions

The objective of this research is to evaluate the use, communication and exchange of geo-information between organisations (tactical level) and emergency responders (operational level) within the Netherlands, in order to highlight factors that may impede or facilitate geo-information sharing during emergency response.

The focus area of the research will be to capture the current design of information sharing processes with regard to geo-information between emergency responders (operational level) and information managers (tactical level), who's responsibility it is to coordinate the necessary information within the Netherlands according the Security Regions Act (Government of the Netherlands, 2010). Additionally, quantify the influence of various organisations that are critical to the information design (both from the public and private sectors), and to assess whether the current design meets the informational requirements of emergency managers in the Netherlands, by means of a User Needs Analysis (UNA). This research will be conducted in order to provide a methodology to identify informational requirement gaps between practitioners and geo-information systems in-use and/or systems under development. This requires an appropriate investigation into use of geo-information by assessing the protocols currently used in practice by GI users and specialists within the disaster management infrastructure.

Objectives:

- Capture the Geo-Information Infrastructure (GII) for emergency response between the operational level and the tactical using the Spatial Data Infrastructure model.
- Locate bottlenecks of GI exchange within the infrastructure and trace their effects using the SDI model and Viable System Model (VSM).
- Identify gaps between the SDI and the informational needs of emergency managers.
- Design an evaluation method for assessing the maturity of the SDI for emergency response.

Research Question: To what extent do the current procedures to collect, organise, disseminate and analyse geo-information during the response phase of an emergency match the needs of Emergency Managers in the Netherlands, and how may a mismatch be overcome to facilitate these informational requirements?

Questions that de-construct the main research question for interpretation formulate as:

Q1 What is the value of inter-organisation information exchange for emergency response and what mechanisms encourage the use of Geo-ICT? *(Chapter 2)*

Q2 How is GI currently used by Dutch authorities, and how does GI help support Emergency Managers in the accomplishment of their emergency response tasks? *(Chapter 3)*

Q3 How can we capture and identify factors that impede/facilitate geo-information sharing between multiple organisations and actors? What are the recommended theories? *(Chapter 4)*

Q4 What are the informational needs of Emergency Managers, what are their tasks, and in what formats are data/information currently gathered, processed and shared between them and Emergency Responders? *(Chapter 5)*

Q5 How does the current infrastructure compare to the ideal situation (from the perspective of interview participants), and does it facilitate the identified informational requirements? *(Chapter 6)*

Q6 How can we better facilitate the informational needs of Emergency Managers? *(Chapter 7)*

1.4 Research strategy

The outline of the research strategy has been adopted from Hevner et al. (2004) Design Science research. This approach deconstructs the practical problem (the main research question) into a series of sub-problems (Q1-3), where the information is then applied and tested (Q4-5) to gain new insights. The results are then evaluated and verified (Q6) by means of a feedback loop framework.

Q1 *Problem identification (Chapter 2)*. The focus of the study is established. The importance of location and the challenges of inter-organisation information sharing & coordination are discussed. Previous literature will show that coordinated information disclosure to internal and external stakeholders is a fundamental requirement for all organisations to effectively manage disaster response activities.

Q2 *Problem analysis (Chapter 3)*. The current situation of geo-information coordination is assessed within the emergency management organisations in the Netherlands. A review of the current disaster management infrastructure in the Netherlands and previously conducted case studies help to identify the challenges currently being faced with regard to information sharing strategies.

Q3 *Composition of Practice-Orientated Theories (Chapter 4)*. This section presents a review of the recommended theories from scientific papers and industry white papers that can identify bottlenecks of information flow between multiple organisations and actors. A framework is developed and applied to capture the information flow and the associated work processes of sharing and coordinating GI.

Q4 *Comprehension of User-Needs (Chapter 5)*. A User-Needs Analysis (UNA) provides an insight into the informational requirements for the operational and tactical levels. Data obtained through semi-structured face-to-face interviews, open group discussions, questionnaires and document analysis are scrutinised to comprehend what is required to disclose information between the particular levels. The work processes of geo-information sharing are captured.

Q5 *Developmental stage (Chapter 6).* The results obtained from interview participants are re-envisioned. The amalgamated theories and recommendations are applied to the identified problem(s) to alleviate the identified bottlenecks. Thus, an "ideal" situation of information sharing is generated.

Q6 *Evaluation stage (Chapter 7)*. SDI coordination is evaluated by presenting the findings of the actual (Q4) and ideal (Q5) situations to a relevant authority (e.g. information manager at Safety Region) for verification by means of a comparative framework feedback loop. Recommendations are made to bridge the actual-ideal comparison from the perspectives of the actors within the SDI.

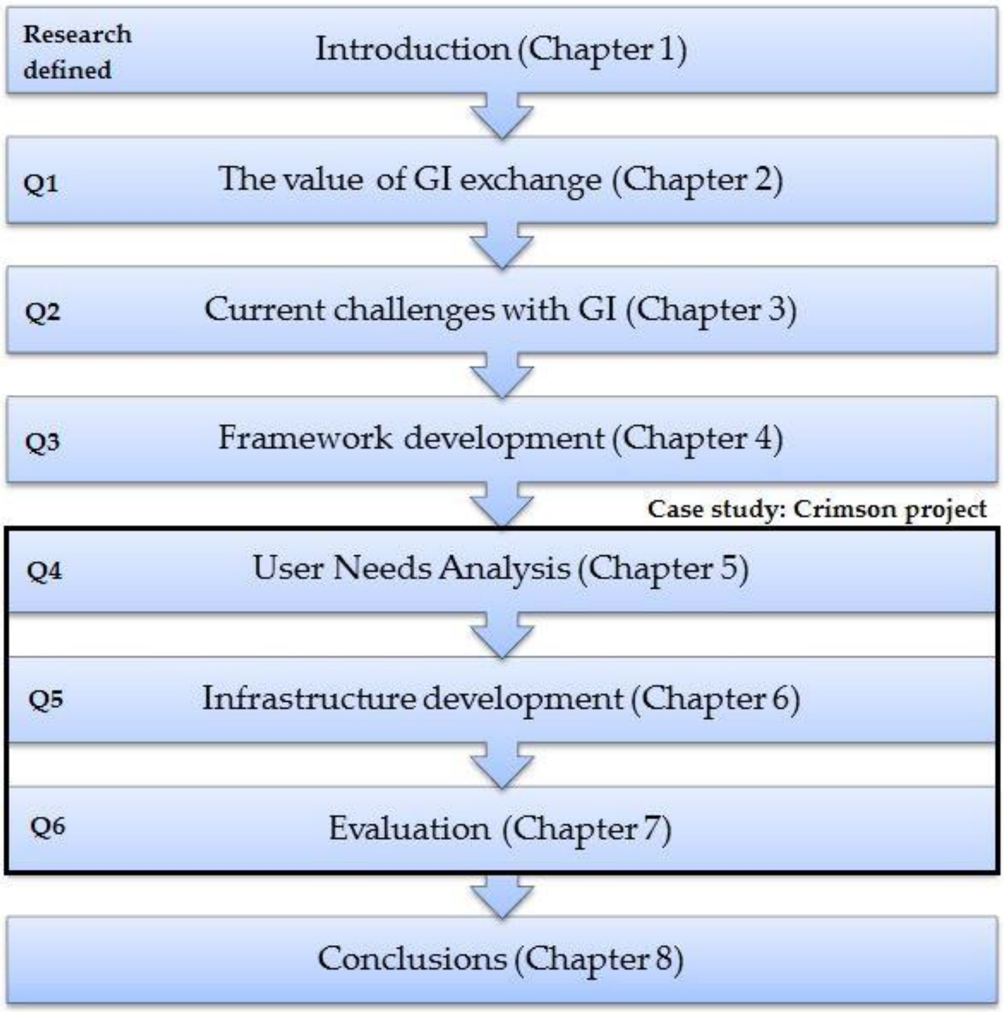


Figure 1.3. Thesis structure.

1.5 Methodology

The outlined methodology will be conducted through a User-Needs Analysis to assess the flow of geo-information between the tactical level (e.g. Safety Region) and the operational level (e.g. emergency responders), in order to highlight the informational needs of emergency managers. The SDI frameworks (product & process) will used and slightly adapted to achieve the research objectives, they will be explained in their entirety in Chapter 2, section 2.4: Geo-Information Infrastructure. The methodology can be divided into 4 components:

(M1) The big picture. Establish an overview of the current infrastructure and the roles of interviewees/stakeholders within it. Line of questioning to build an overview follows as; what has been developed? What is being developed in relation to GI? What has emerged, and what is next? Specific questions related to work processes and impacts are absent here, and still have to be generated. Use Beer's Viable System Model (VSM) (Figure 1.4.A) and the product-based SDI model (Figure 1.4.B) to map out and orientate components of the SDI from the perspective of the interview participant. The resulting diagram will be used as a heuristic tool for communicating with interviewees and stakeholders when investigating processes.

Figure 1.4.A. The Viable System Model (with emergency response example).

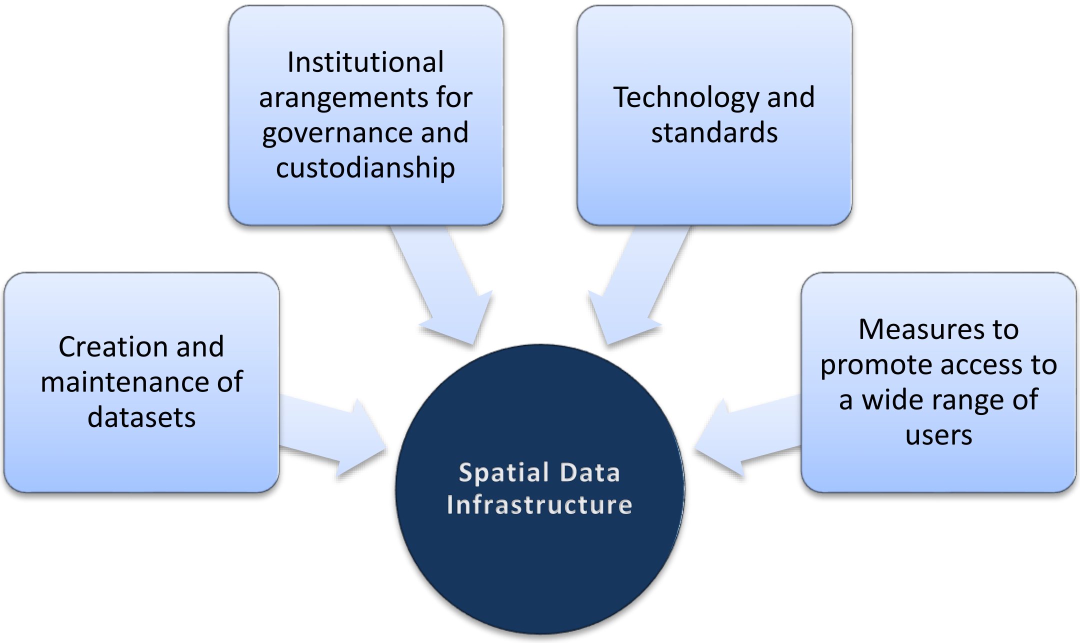


Figure 1.4.B. The SDI core components.

Figure 4. Establishing the big picture.
A) Beer's Viable Systems Model & **B)** Product-based SDI model.
Source: ***A)*** *Hilder (1995) &* ***B)*** *Masser & Crompvoets (2015).*

(M2) Process matters. Map and decompose interviewees work processes within the infrastructure to investigate how to work is done. The processes of how GI is gathered, analysed, and disseminated is the main focus of the study, as the work processes provide how a solution is attained. The processes of how the solution is attained are as valuable, if not more valuable, than the solution itself.

(M3) Identify bottlenecks. Investigate recommendations and theories that are capable of highlighting bottlenecks in the work process of the interviewees. Develop and re-envision the process diagrams of information movement through the infrastructure to visualise, analyse and resolve identified bottlenecks.

(M4) Evaluation. The current work process design (M2) (Actual-situation) and the re-envisioned design (M3) (Ideal-situation) of the information sharing processes of the target groups are presented in an "Actual-Ideal" comparative framework. The results will be presented to relevant authorities (e.g. information managers, system suppliers) who can comment on and verify the results in order to provide future recommendations for the infrastructure development.

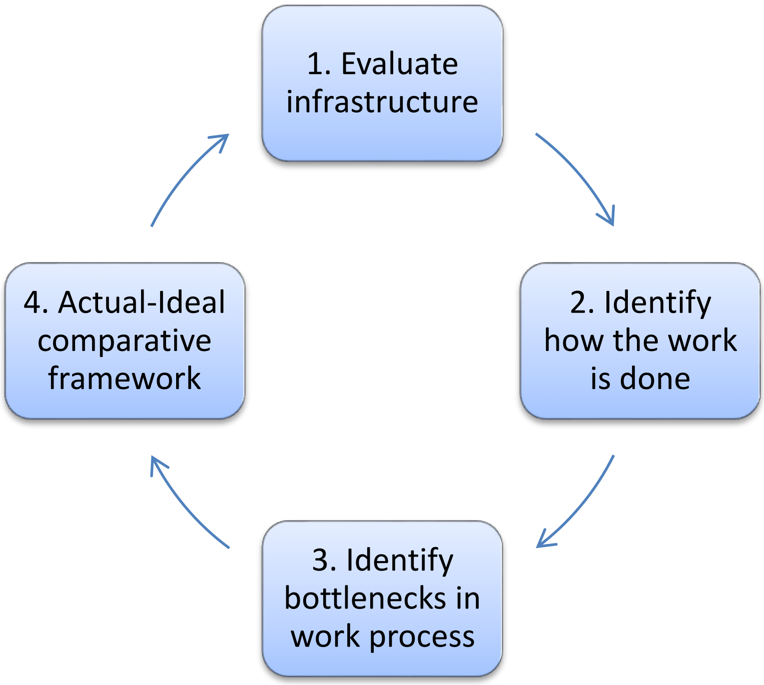


Figure 5. Project methodology to evaluate geo-information sharing & coordination.

Data collection techniques for the User-Needs Analysis will predominantly fall under the following four categories: (1) semi-structured face-to-face interviews, (2) participatory open discussions, (3) questionnaires and (4) document analysis. The target groups for data collection are: (a) Geo-ICT technicians (Safety Region), (b) managerial staff and decision makers (e.g. information managers at provincial authorities), and (c) system developers.

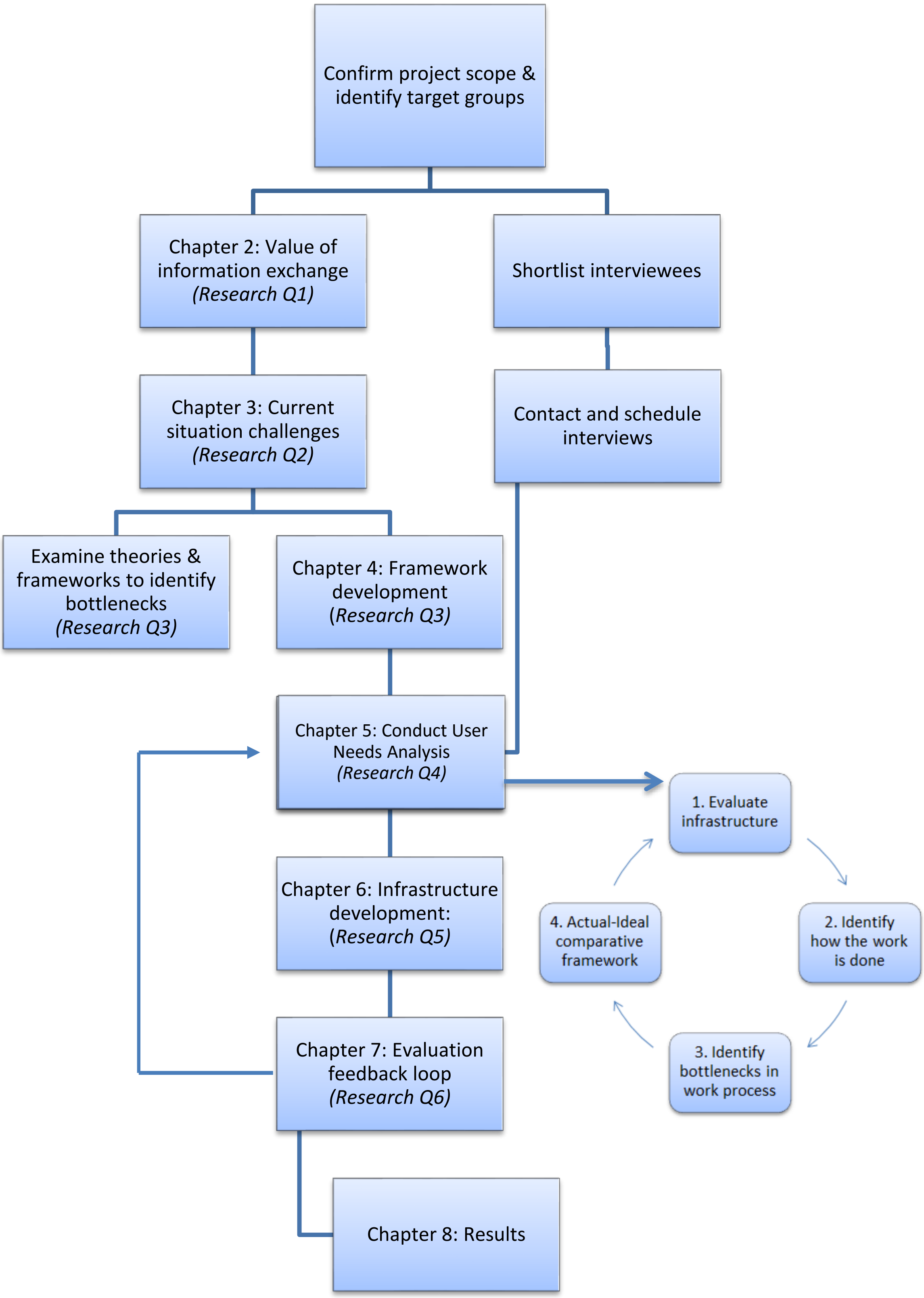


Figure 1.6. Project process diagram.

1.6 Project scope

This research will be carried out in collaboration with Crisisplan B.V. (Leiden) under the "Crimson Initiative". This initiative is being conducted under the E.U. 7th Framework Programme for technological research and development within the project termed VASCO. The VASCO project aims to develop a Decision Support-System (DSS) for tactical level decision makers in emergency response, by presenting on a digitally interactive map basic information such as; where are the emergency responders, where are resources located, and how large is the affected area. In order to develop this system, the current SDI between the Safety Regions and Emergency Responders must be assessed to identify bottlenecks in the information sharing procedures associated with GI.

Several technical and non-technical factors have been highlighted that effect the flow of information between the different components of the infrastructure, but a methodology to identify between which core components and the work process associated with the effecting factors is absent from literature. The goal of the research is to offer an evaluation method to assess and improve GI integrity, correctness and trustworthiness so that decision makers have access to reliable and harmonised data to make informed decisions. The variables of getting the right information, to the right people, at the right time will be regarded as the constraining factors in evaluating the sharing and coordination of geo-information. Primary data in evaluating these variables will be collected from the perspective of an individual who has a key role in using, sharing, and/or coordinating GI for emergency response in the Netherlands.

Chapter 2

The value of Geo-information exchange

2.1 Introduction

Geographic Information (GI) can be defined as information concerning location on the Earth's surface (Longley et al., 2015), and the term can be used synonymously with "spatial" and "geospatial" information and data. GI has long been used as a tool to understand and explore our environment that can be dated as far back to circa 5000 B.C. with the Babylonian (present day Iraq) map of the world. There are debatably older artefacts that precede the modern human species (e.g. the Dashka Stone), but regardless of whether homo sapiens, the Neanderthals or other hominins invented the map, the importance and knowledge of location transcends through to all aspects of society from navigation, to evaluating spatial risk, to locate food sources, etc.

Closer to modern day society, the invention of Geographic Information Systems (GIS) in the 1960s has allowed us to digitally intertwine location information with data that help answer fundamental questions such as, where am I, where are you, and what is where (van Loenen, 2006). This has allowed us to simultaneously visualise and analyse spatial data resulting in innovative products such as GPS and routing capabilities. The marriage with remote sensing has brought about climate and environmental modelling with applications extending to all modern professions which hold the three fundamental questions as the basis of all investigations. An example of the societal relevance in recent years was the introduction of Google Maps & Earth in 2005, and from the launch of these applications to 2011, Google Earth has amounted an excess of over one billion downloads which highlights our necessity to reference ourselves to locations on the Earth's surface.

The fundamental importance of GI is that it allows us to make and base decisions by linking properties, attributes and characteristics to locations on the Earth and is practical for all human disciplines, including disaster management. Spatial information is the initial input to coordinate an effective and efficient response. Because of the importance of location and the importance of limiting a disasters effects on society, the field of GI for disaster management has undergone significant developments over the last decades due to the evaluation of response to major disaster events (Harrison et al., 2007; Kevany, 2005 & 2008). The explosion of GIS use for disaster management can be arguably linked back to the Enschede fireworks disaster and the 9/11 WTC disaster, of 2000 and 2001 respectively. But, before discussing the relevance of GI in the field of disaster management, we must first define the area of application.

2.2 Defining Disaster Management (DM)

The Government of the Netherlands, in the Security Regions Act Part 2 Section 1 (2010), define a disaster as;

> *"a serious accident or other incident whereby the lives and the health of many people, the environment or significant material interests have been harmed or threatened to a serious degree ...".*

From the same document, a crisis defined as;

> *"a situation in which vital interest of society is affected or is at risk of being affected".*

Disaster, crisis, catastrophe, and emergency management are sometimes used synonymously and sometimes with slight differences by scholars and practitioners (Hitlz et al., 2011). There may be many definitions to the field of DM but most refer to factors including; disruption to society, effects on human and other specie's health, effects on critical infrastructure (government, communications, and essential services), and community requirements such as medical assistance, shelter, food and other resources. For the purpose of this research, the definition for disaster management will be defined as (Carter, 2008):

"The applied science which seeks, by the systematic observation and analysis of disasters to improve measures relating to prevention & mitigation, preparedness, emergency response, and recovery".

Prevention & mitigation, preparedness, emergency response, and recovery are a series of intertwined activities that are considered as a continuous event known as the disaster management cycle (Figure 2.1) and can be defined as (Carter, 2008):

- Prevention & Mitigation - Measures taken to impede the occurrence and/or avoid the potential effects of a disaster on society and the environment.
- Preparedness – Measures which enable governments, communities and individuals to respond rapidly and effectively to disaster situations.
- Response – Coordinated actions taken immediately prior to and following disaster impact, with available information & resources.
- Recovery – The process by which communities are assisted in returning to previous capacity before a disaster struck.

Figure 2.1. The disaster management cycle.
Source: mjcetenvsci.blogspot.nl

Disaster management is therefore considered as a continuous event of intertwined activities that are unpredictable and changeable. All four activities require fast discovery, sharing, integration and analysis of data between multiple organisations to improve the measures within the disaster management cycle. By understanding how GI sharing operates in practice during the emergency response phase of the cycle, clearer insight can be assessed into the factors that may hinder or facilitate the value of GI coordination and sharing.

2.3 The catalyst for GI in Emergency Response

Effective emergency response requires acquisition and dissemination of GI for individuals and responsible organisations to maintain awareness of how an event interacts with the spatial characteristics of the natural and urban environments (Koua et al., 2009). Over the last decade we have witnessed the growth of GI technology as so much that emergency responders, and emergency managers, cannot possibly adopt and make effective use of all the available GI capabilities in practice (Kevany, 2005). This trend is predicted to grow as data generation and new GIS technological platforms become better equipped with spatial analytics, information visualisation, and predictive modelling (Tomaszewski et al., 2015).

The American National Research Council concluded that issues relating to the effective use of GI reside with technical integration of systems (interoperability), human resource training, coordination of data sharing policies (institutional arrangements), planning and preparedness (information awareness), and that particular attention must be paid towards how the investment of resources is put into technology (NRC, 2007). This suggests that the majority of issues in making effective use of technologies resides with problems in the human institution in coordinating informational resources.

As a species we are relatively simple and straightforward in that we require the physiological necessities of food, water and shelter as a basis to live contently (Maslow, 1943). Yet, once we are placed in social systems, and further compartmentalised into social classes and organisations within a social system, our cognitive biases alter our perception in how we view other members of our species, thus turning us into heuristic beings or "generalisers". Cognitive biases reduce the computational time and effort of the brain but these shortcuts can lead to severe and systematic errors in all aspects of our interactions (Tversky & Kahneman, 1974). These biases cannot be excluded from the human institution as there are necessary for filtering the constant barrage of stimuli that we expose ourselves to everyday, and are a result of design in human physiology, our individual traits, and social conditioning from our respective upbringings. As such, cognitive biases affect our awareness and allow us the see what we can perceive, but also ignore what we deem to be irrelevant.

This physiological structure contributes as to why GI has become such an important tool to interact with the environment, as it quickly allows us to spatially orientate ourselves and assess our environment and GI has the potential to contribute to decision making in all aspects of the disaster management cycle. Particularly after an event has occurred, responders, emergency managers, and all involved organisations, want to know where impacts are greatest, where critical assets are stored and where infrastructure is damaged as to be optimally effective in response (NRC, 2007). GI can quickly visualise the situation to a viewer so they can assess and orientate themselves to these specific questions, and thus reducing the cognitive effort of the brain to lead to faster and more accurate decision making (Ellis & Johnston, 1999). Because of the unpredictable and complex nature in which disasters occur, multiple organisations need to share diverse datasets and information, often in an ad-hoc manner, that results in improvised and emergent collaborations between multiple groups of professionals (Ley et al., 2012). All of these varying organisations rely on stable ICT infrastructures that have been tailored to their specific requirements (Reuter, 2015), thus this autonomous development of ICT has resulted in problems with efficient shared access to information, both technically and socio-technically related when collaboration is necessary (Bharosa et al., 2010).

These technical and social problems have led to the structural development in ways to organise various forms of spatial data sets from various sources, to allow users to easily access, disseminate and make use of the required geo-information (van Loenen, 2006). The organisation of spatial data includes the frameworks, networks of people, technologies, standards, and policies that surround the sharing and use of such data. This conglomerate of components is required to utilise the full potential of spatial data, and is known as the Spatial Data Infrastructure (SDI).

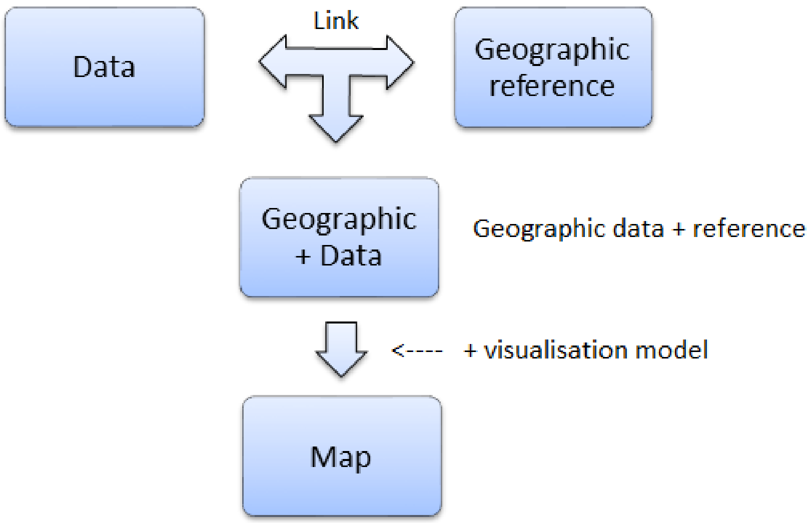


Figure 2.2. From data to map.
Source: van Loenen, 2006.

2.4 The Spatial Data Infrastructure

The term "infrastructure" is defined from the Oxford dictionary as, "the basic physical and organisational structures needed for the operation of a society or enterprise" and comprise of the basic facilities, services, and installations needed for the effective functioning of a community or society (Masser & Crompvoets, 2015). Physical infrastructure includes roads, railways, ports, etc., while organisational infrastructure includes the facilities to support society like government, police service, health service, etc.

An information infrastructure provides the foundation for people to access and share information in an information society between the physical and organisational infrastructures (van Loenen, 2009). An information infrastructure refers loosely to all the contributing components involved in the creation, movement, storage, and destruction of data, these components can include technology systems, software, analysis tools, people, etc. Regardless of the infrastructure function, its goal is to provide goods and services. The fundamental role of an infrastructure is to allow the movement of information and resources to where they are needed and an infrastructure encapsulates all factors that contribute to the movement of information and resources within the structures and facilities of a country or organisation.

Infrastructures are not stand-alone elements as they are interconnected and share common parts to carry out their specific functions (Figure 2.3). This interconnectedness can result in a complex relationship between infrastructure components, in such that component parts are combined together to form an end product that is completely different to the initial input of components. This is considered as being a complex system as the components are massively entangled together so that they cannot be recognised and the whole of the system is different from the sum of its parts (Eoyang, 2006).

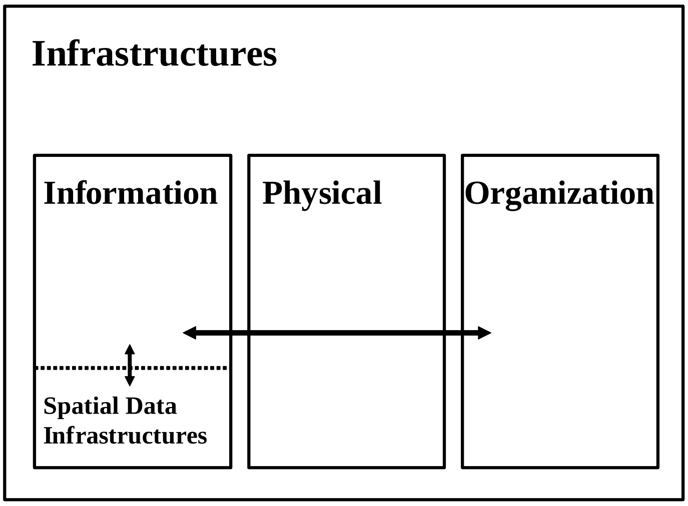


Figure 2.3. Types of infrastructures and their interconnectedness.
Source: Brengt, 2015.

The addition of human factors interaction, which is in itself a complex system, brings additional levels of complexity to the system as a whole. People that interact with a system are considered as self-organising "free agents" that can behave in unpredictable ways, but are also interconnected in that they can influence the behaviour of other agents that produce system wide behaviour and patterns (Olson & Eoyang, 2001). In essence, people can interact with an infrastructure on an individual level that results in change for the system on a larger scale. The interactions themselves are unpredictable but the outcomes can be recognised as patterns and can have variable influence on many levels from the individual, to the organisational, national, and even global levels. The level of complexity within an infrastructure therefore depends on its context and how it is viewed by an observer, for example, a light switch can have two states, on and off. But if the light bulb does not work, the electric cables are cut, or if the electricity network that the light switch is connected to is down, then the complexity of the light switch is increased from its initial state of, on or off.

The Spatial Data Infrastructure (SDI) is a sub-component of an information infrastructure (Figure 2.3). The term was first coined in 1991, and later defined by the U.S. National Research Council as "the means to assemble GI that describes the arrangement and attributes of features and phenomena on the Earth. The infrastructure includes the materials, technologies, and people necessary to acquire, process, and distribute such information to meet a variety of needs" (NRC, 1993). The SDI framework details in how people interact with other individuals and organisations through information systems (such as GIS) to coordinate and share spatial information, and it is a concept used to promote the standardised access to spatial information (van Loenen, 2006).

The SDI concept has been defined in different ways over the last decade, van Loenen (2006) defined the SDI as a Geo-Information Infrastructure (GII) which is regarded as a framework continuously facilitating the efficient and effective generation, dissemination, and use of the needed geographic information within a community or between communities. Rajabifard et al. (2002) state the SDI is an infrastructure intended to create an environment that will enable a wide variety of users to access, retrieve, and disseminate geographic information in an easy and secure way. Rajabifard & Williamson (2001) defined an SDI as a data infrastructure for using and sharing GI, and includes all policies, agreements and standards involved, as well as metadata, users, and tools.

However it may be defined, the fundamental role of SDI remains true in all definitions and is about the facilitation and coordination and sharing of spatial data between stakeholders within a community so that information may be accessed when and where it is needed without the duplication of effort. SDI's are considered as complex systems as they are created by people and they emerge when organisations learn to share and coordinate information between each other, such that the infrastructure produces an environment where it is a constantly changing, people focused, self-generating, self-organising network and the life of the SDI resides in the networks of people or in the communities of practice (Bacastow et al., 2008). This means that organisations rely on the expertise of other organisations to coordinate and share data, and therefore authority or control cannot be fully allocated to one organisation but to the entire network of involved people. Much of the complexity of SDIs is owed to this.

2.5 SDI components

An SDI is a network of continuously evolving infrastructures that is not owned and controlled by a singular organisation, but it is supported and sponsored by a community of stakeholders (Bacastow et al., 2008). To understand a SDI requires understanding the context of the environment in which it is being used, the components that contribute to its functionality, and the drivers that the community of stakeholders are influenced by (Rajabifard et al., 2002). By understanding these concepts it is possible to define the relationship between people and spatial data. GIS is regarded as the facilitating technology to collect, store, visualise, and analyse GI and a well-defined SDI can facilitate the access, retrieval and dissemination of data through the technical components of policies, standards, and access network (Mansourian et al., 2006). Figure 2.4 illustrates the core components that are recognised as patterns in all SDIs and in the interactions people have with spatial data

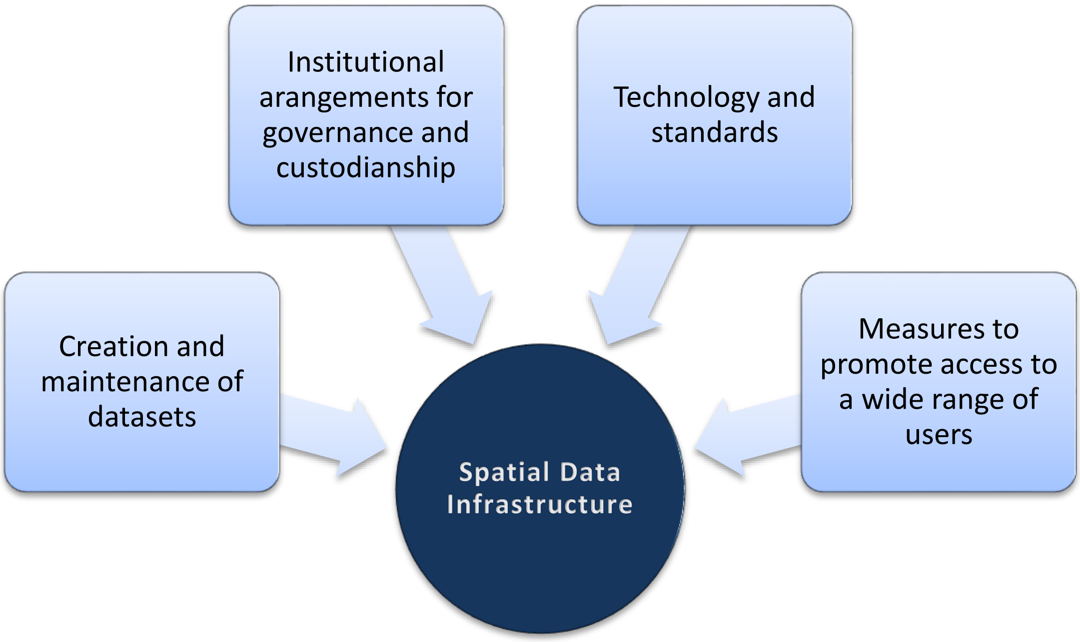


Figure 2.4. SDI components
Source: Masser & Crompvoets (2015).

Creation & maintenance of datasets

The first component, the creation and maintenance of datasets, can be thought of as identifying the spatial data required for the necessary application and environment in which the data is being used. Data is at the heart of a SDI as its primary objective is to facilitate access to spatial data, and without it the SDI would become void. Two distinctions of spatial data can be categorised as framework and thematic datasets (van Loenen, 2009). Framework datasets can be considered as the foundation data. "Foundation data is the authoritative GI that underpins, or can add significant value to, any other information; and supports evidence-based decisions across government, industry and the community" (ANZLIC, 2014). Fundamental data and foundation data can be used interchangeably, and describes the base spatial layers required for most applications. ANZLIC (2014) have described 10 such GI-based themes (Figure 2.5), and include land type, elevation, water boundaries, transport, location names, addresses, administrative boundaries, building and property information, reference information, and remote sensing imagery. It is then necessary to include domain specific thematic datasets required by the user in addition to the foundation framework datasets.

Figure 2.5. 10 foundation GI themes.
Source: ANZLIC (2014); in Masser & Compvoets (2015).

Institutional arrangements
Amongst the most difficult obstacles identified from literature has been in the creation of the technical and sociotechnical systems that allow the simple process of sharing critical data between the responsible organisations (Harrison et al., 2007). The second component of Masser & Crompvoets (2015) SDI core components includes the institutional arrangements. These are the policies, systems, and processes that organisations use to legislate, plan, and manage their activities in coordinating and sharing information efficiently and effectively to fulfil their respective mandates (UNDP, 2015). These arrangements define the way a SDI is embedded within an organisation, or a network of organisations. The management of responsibilities, custodianship requirements, and access policies relating to the datasets define on how they are collected, maintained, disseminated and used, and are essential arrangements that must be defined in order to contribute to the success of a SDI (van Loenen, 2009).

Technology & standards
The third component are the technologies and standards used to access, visualise, and disseminate the required data, and identifies the hardware and software components used to do so. As technology is constantly changing and developing, as too are the data collection methods, interoperability between hardware and software entities is a constant requirement factor of this component, and it is the main technical requirement for ongoing developments in technologies. Successful GI technologies reside with the ability to rapidly access core datasets and a common coordinate system that can serve as a foundation for the development of subsequent useful applications without confusion (Harrison et al., 2007).

Accessibility & usability

The final component involves making the data accessible and understandable to people that use the data. Guides, specifications, training, metadata catalogues, privacy, licensing, and pricing are directed towards the users with ease of usability and access considered as the main criteria to promote the effectiveness of the data. Here, the people that interact with the SDI and all factors affecting them, the social, and technical elements that facilitate and impede access and usability of the data can be framed in this component.

2.6 SDI assessment

As SDIs are considered as complex systems (Grus et al., 2007) it is better to think of the patterns that they develop over time, and the dynamics shared amongst the involved organisations. These developments and patterns within a SDI occur gradually over time as issues surrounding aspects of the previously discussed SDI components are dealt with and improved. The involved network of people and organisations choose what to pay attention to and respond to what problems are relevant to them at a certain time, meaning that SDI developments are constantly being influenced on a local scale that has implications for the system as a whole on a larger scale (van Loenen & van Rij, 2008; Chan et al., 2001).

The SDI literature recognises that due to the infrastructure complexity, a SDI may not be solely understood simply from the components of the SDI model. Although SDI assessment is still a developing concept, the Multi-View Framework to Assess SDIs (Crompvoets et al., 2008) discuss that assessment goes beyond measuring the performance of an individual component but to a higher level of measuring the results of component integration, and thus measuring the greater value an SDI produces.

Grus et al. (2007) researched multiple aspects within the Multi-View Framework, to assess SDI performance and to further understand their functionality. The framework is embedded in complexity science and evaluation practices to get multiple perspectives on the factors associated with, and contributing to the dynamic nature of a SDIs. The framework is thus equipped, not only to evaluate SDI performance, but to explore the functionality of the SDI to improve on SDI development. Table 1 presents an overview of the assessment approaches implemented from the framework.

Previous assessments have been constructed from different observational perspectives to assess SDI development, and noteworthy pattern in all assessments is that it is beneficial to distinguish the technical aspects from the social to help clarify complexity issues. The framework is still under-development as not all aspects have been assessed, however, noteworthy assessments from the Multi-View Framework that are relevant for this research include the 'organisational' and 'end-user perspective' approaches.

Van Loenen & van Rij (2008) researched organisational aspects and correlated the development of the SDI to its maturity and categorised the relation into four stages; standalone/initial stage, exchange/standardisation stage, intermediary stage, and network stage. The result model is not a linear relationship as they found that the identified patterns of maturity in each stage can assist in further developing and strengthening SDI strategies while keeping aligned with an organisations objectives.

Nedović-Budić et al. (2008) developed an approach to identify how useful GI within a supplied SDI meets a user's particular needs, thus SDI effectiveness is only as good as the perceived added value that the supplied GI brings to the user.

Table 1: Summary of assessment approaches for the Multi-View Framework (Grus et al., 2008).

Assessment approach	Goal	Method	Applicability	Assessment purpose
SDI readiness	To assess if the country is ready to embrace the SDI development	Survey	Applicable	Developmental Knowledge
Cadastral	To measure five evaluation areas of LAS	Survey	Needs improvement	Knowledge Accountability
Organisational	To measure the SDI development from the institutional perspective	Case study	Applicable	Developmental
Performance based	To measure the SDI's effectiveness, efficiency and reliability	Not available	Needs improvement	Accountability
Clearinghouse Suitability	To measure the development and impact of SDI clearinghouses worldwide	Survey, key informants	Applicable	Developmental Knowledge
State of Play	To measure the status and development of SDIs	Document study, survey, key informants	Applicable	Developmental Accountability
User's Perspective	To measure the SDI'S effectiveness from the user's perspective	Case study	Needs improvement	Accountability, Knowledge
Metaphorical	To analyse organisational and management aspects of the SDI	Literature review	Needs development	Knowledge
Legal	To measure compliance, coherence and quality of the SDI legal framework	Case studies	Needs improvement	Knowledge

2.7 Summary

It has been established that GI is the initial input used in all aspects of the disaster management cycle as it can provide significant advantages by spatially orientating decision making. To facilitate this need for an effective response, emergency responders and managers want to know where a disaster has struck, where its impacts are greatest, where critical assets are stored, and where critical infrastructure is damaged. Rapid compilation and analysis of a broad range of information from a wide variety of data providers is crucial for situational assessment to support this decision making.

The SDI framework can be used to create an environment that can facilitate the need for rapid compilation of spatial data, and can enable a wide variety of users to access, retrieve and disseminate GI in an easy, useful, and secure way to coordinate a response to a disaster event without confusion. The life of an SDI resides in the human institution within the formal and informal relationships between people and organisations, and thus, these relationships add levels of complexity to the infrastructure in how GI is accessed and shared. By integrating the components of the SDI framework in the domain of emergency response, the process of rapidly building an informational picture can be made easier by gathering information from a wide variety of sources.

Organisations can lack informational awareness of datasets, and if they are aware, additional problems may arise with ownership, pricing, lack of metadata, interoperability, lack of incentives, tools and guidelines for sharing (Harrison et al., 2007). The SDI framework can identify these issues to promote access to data, and this has considerable implications for the social and environmental benefits of a coordinated response if such information can be accessed and shared to facilitate decision making.

Current DM Infrastructure

3.1 Introduction

In the previous chapter we explored the importance of GI and how it relates to sense and decision making in emergency response. The SDI framework was discussed in how it can facilitate the coordination and sharing of spatial information within a network of organisations, and how the people that interact with the infrastructure can bring about complexity issues. To better understand the complexities with the use of GI data and technologies, this chapter presents a review of challenges found in literature in coordinating and sharing information. An overview is presented of the current emergency management infrastructure in the Netherlands, by examining the core components of the SDI model. Case study observations conducted to gain an insight into the problems relating to sharing and coordinating GI in practice are reviewed.

3.2 DM SDI in the Netherlands

The Dutch Government define crisis management as:

"the whole range of measures taken and provisions made by central government working together with other organisations – in preparation for, during and after intersectoral crises – with a view to safeguarding national security" (Government of the Netherlands, 2013).

This definition is closely related, if not synonymous with the disaster management definition used in this research (section 2.2). It is stated that a disaster is a particular type of crisis and therefore disaster

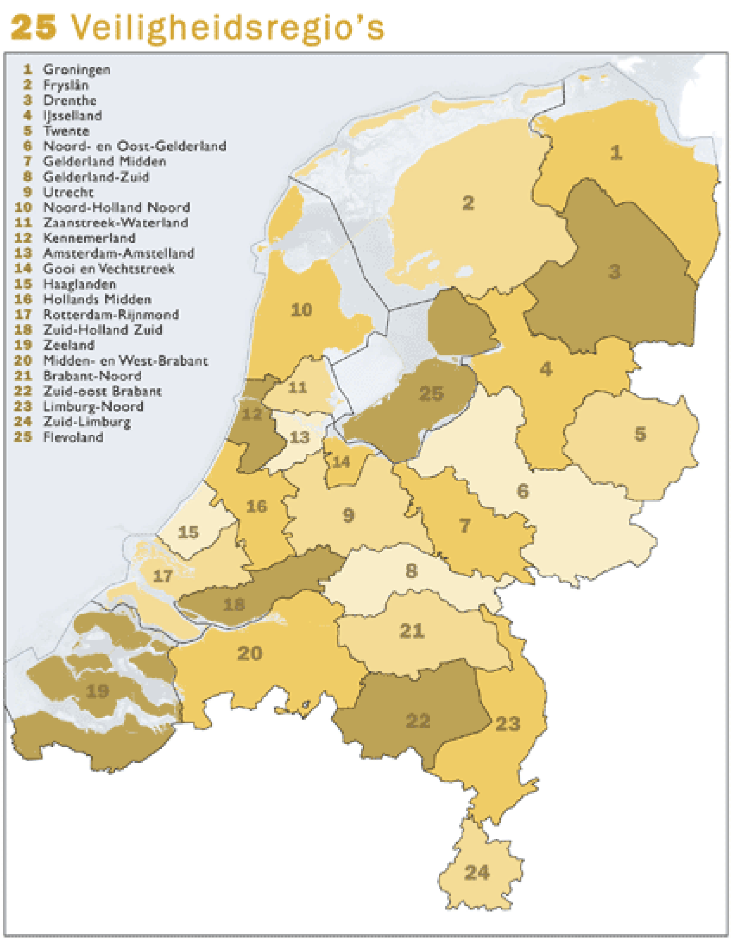


Figure 3.1: Safety Regions of the Netherlands.
Source: imergis.nl

management is part of crisis management.

The Netherlands has 25 Safety Regions (in Dutch, Veiligheidsregios) (Figure 3.1) that are composed of a conglomerate of municipalities and it is the role of these tactical level organisations to organise the required information for disaster management. Under the "Wet Veiliegsheidregio's" Act Part 2 Section 22 (Government of the Netherlands, 2010), it states that:

"the management boards of the safety region are jointly responsible [with the government] for establishing a uniform availability and means of communication, including an assessment of the need of information, and the determination of frameworks, standards and quality measurements with a view to the exchange of within and between [the relevant] organisations".

GRIP levels

The Netherlands has a national contingency plan for dealing with disasters known as The Coordinated Regional Incident Management Procedure (in Dutch: Gecoördineerde Regionale Incidentsbestijdings Procedure) and abbreviated as the "GRIP" levels. It is an organisational structure for dealing with the scaling up of disasters and is used in all 25 Safety Regions to define who is responsible for the coordination and decision making (Government of the Netherlands, 2013). When emergency service operators arrive at the scene of an incident, they report it to the local Safety Region, and it is the responsibility of the particular Safety Region to scale the response accordingly to a level of the GRIP. An overview is presented in Table 1.

GRIP 0

GRIP 0 is not technically a classification within the GRIP structure but it is used to donate the day-to-day operations of the emergency services. Here, they operate mostly as single entities and consult informally at the scene of an incident to decide on the appropriate actions to be taken.

Figure 3.2. GRIP 0 representation of operations

Source: Crisisplan B.V.

GRIP 1:

If it is required that more collaboration and coordination between the emergency services is needed in response to an incident, then the on-scene mobile unit, COPI (Commando Plaats Incident, in English: Incident Command Site), is dispatched to the scene of the incident. The COPI leader is often from the fire or police services, and the COPI team consist of a fire officer, police (and/or military) officer, ambulance officer, an information manager, and an information officer. Level 1 involves one municipality and it is the responsibility of the COPI leader to communicate and coordinate between the emergency operatives while also informing the highest authority that is the municipal mayor.

GRIP 2:

If an incident has grown from its source and a greater area is now effected, the GRIP level is scaled to level 2 and the ROT (Regional Operational Team) is now involved, and may involve one or more COPIs. The COPI is responsible for dealing with the source of an incident whereas the ROT is responsible for the dealing with the affected areas away from the source. The ROT consists of; an operational leader; fire team; police team; ambulance team; population care team; an information management team; and an information officer team. The regional operational team is responsible for dealing with the operational management and coordination of emergency services away from the source of an incident to deal with any effected areas. The COPI and ROT must advise and take instructions from the municipal mayor.

GRIP 3:
The ROT is still responsible for the operational coordination, but if government control over an incident is required within one municipality, the GBT (Gemeente Beleid Team, in English: Municipal Policy Team) provide policy coordination on a local level from the responsible Safety Region. The municipal mayor is still the highest authority. The GBT consists of executives from the fire, police, and ambulance services to support the municipal mayor in decision making.

GRIP 4:
When an incident involves more than one municipality and exceeds the authority of one municipal mayor, then the affected Safety Region is elected as the highest authority and policy coordination is now on a national level. The RBT (Regionaal Beleid Team, in English: Regional Policy Team) replace the GBT to coordinate policy.

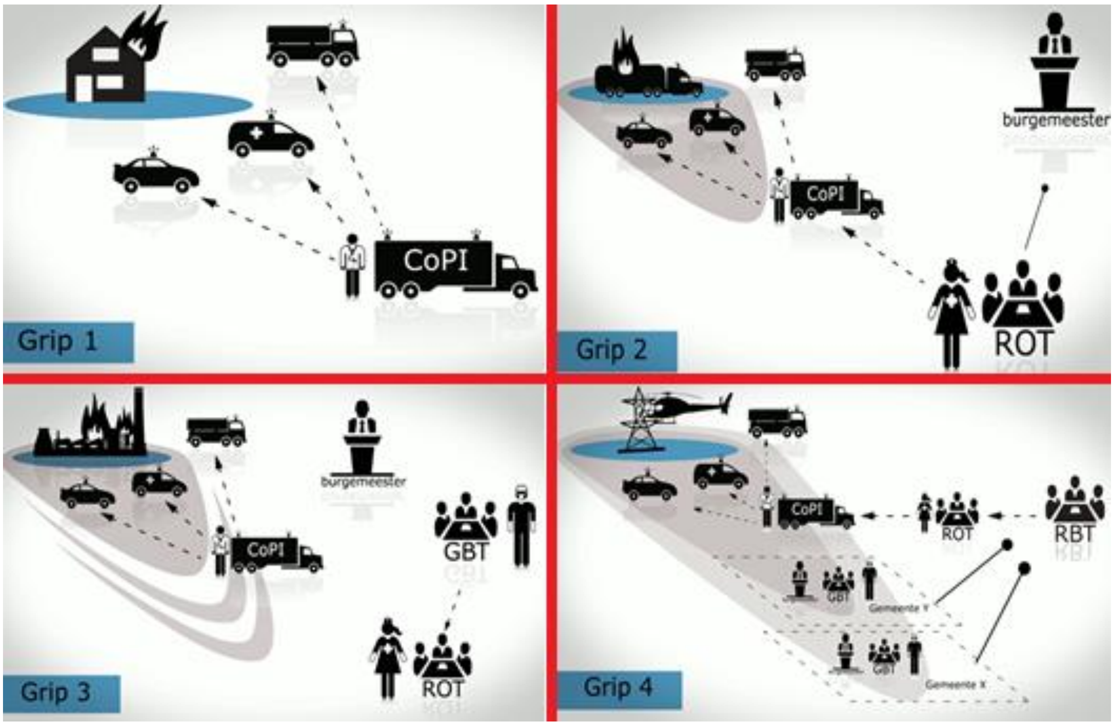


Figure 3.3. GRIP levels 1-4.
Source: Crisisplan B.V.

Table 2: GRIP structure.

Level	Scale of incident	Teams
GRIP 1	Incident response (source/on site)	COPI
GRIP 2	Incident response source and effect area	COPI + ROT
GRIP 3	Threats to welfare of the public (one municipal area)	COPI + ROT + GBT
GRIP 4	Threats to welfare of the public (more than one municipal area)	COPI + ROT + RBT

3.3 Measures to promote access & usability

The net-centric way of working is a new concept used by the Dutch emergency services that allows information to be accessed and disseminated quickly between heterogeneous stakeholders, accessible through the LCMS using a Common Operational Picture (COP). The net-centric method is currently in use by all 25 Safety Regions, the National Crisis Centre (NCC), National Operational Coordination Centre (LOCC), Gemeente and external partners such as water boards and other critical infrastructure partners.

3.4 Institutional arrangements

Currently, the core body of geo-information for emergency response is obtained from the provincial and municipal bodies by means of collective servers (e.g. PDOK.nl and Dataland.nl), and supplemented by critical infrastructure partners (IFV, 2015). The responsibility for obtaining and distributing geo-information to the emergency services belongs to Geo4OOV, an established partner to the Safety Regions from IFV. IFV uphold the doctrine of net-centricity and organise the themes of projects within the programme of Geo4OOV. The following table illustrates an overview of the core datasets and sources on the Geo4OOV server, that are available to Emergency Managers:

Table 3: GI datasets & source overview.

Type	Source	Dataset
Base maps	PDOK	BAG, BRT, BGT.
Core records	PDOK	Population statistics, postcodes, admin-boundaries.
Risk maps	Dataland	Hazardous materials, flooding, vulnerable objects.
Objects (Points of Interest)	Emergency services & Imergis	Fire, police, and ambulance stations. Government services and emergency management infrastructure.
Infrastructure	Multiple partners	Waterways (Rijkswatersaat), road/highways (ANWB), Railways (ProRail), Energy etc..

3.5 Creation & maintenance of datasets

Other than the supplied geo-information, the emergency services are mainly focused with creating dynamic geo-information (i.e. creating geo-information on an event as it develops). However, this only occurs once a GRIP level incident has been declared. The creation of such data is facilitated by the web service of Landelijk Crisis Management Systeem (IFV, 2015), while the value and sustainability of such information after an incident has occurred is unknown.

3.6 Technologies & standards

In this section, the GI-based technologies currently used and available to the Dutch authorities for disaster management are reviewed.

C2000 – Radio communication:

In 1992, the Netherlands and Belgium initiated the movement to develop a new radio communication network for emergency services. An objective of this initiative was to base the communication system on a common European standard to provide cost, supplier, and technical advances as well as to avoid competition from the USA and Japan (Hommels & Egyedi, 2010). The Dutch were the first to commit to the development and implementation of the system during the 1990s, and from 2001 it was decided to use the TETRA (Terrestrial Trunked Radio) standard developed by ETSI, for the Dutch C2000 system. The standard allowed for trans-border communications between emergency services, and thus a political campaign ensued to promote the standard to other members of the European Union. TETRA is an open standard and is now the dominant (de facto) standard for radio communications in Europe, and even outside the continent (TCCA, 2015). It is understood that this technology is not a GI technology, yet it is an important tool for information sharing as it provides the means and capabilities to verbally share and gather information of an incident.

Figure 3.4. C2000 radio communication.
Source: deVolkskrant.nl

Geïntegreerd Meldkamer Systeem (GMS):

GMS (Integrated Emergency-room System) is a multi-disciplinary incident reporting system used by the Dutch police, fire, and ambulance services. The primary function of the system is to capture all messages arriving at the tactical level (e.g. emergency room of the Safety Regions) and to disseminate information accordingly to the operational level via the C2000 system (Houben, 2005). The system has GIS incorporated into it, allowing the system operators to input an incidents location and to view where emergency vehicles are in real-time (VRGZ, 2015).

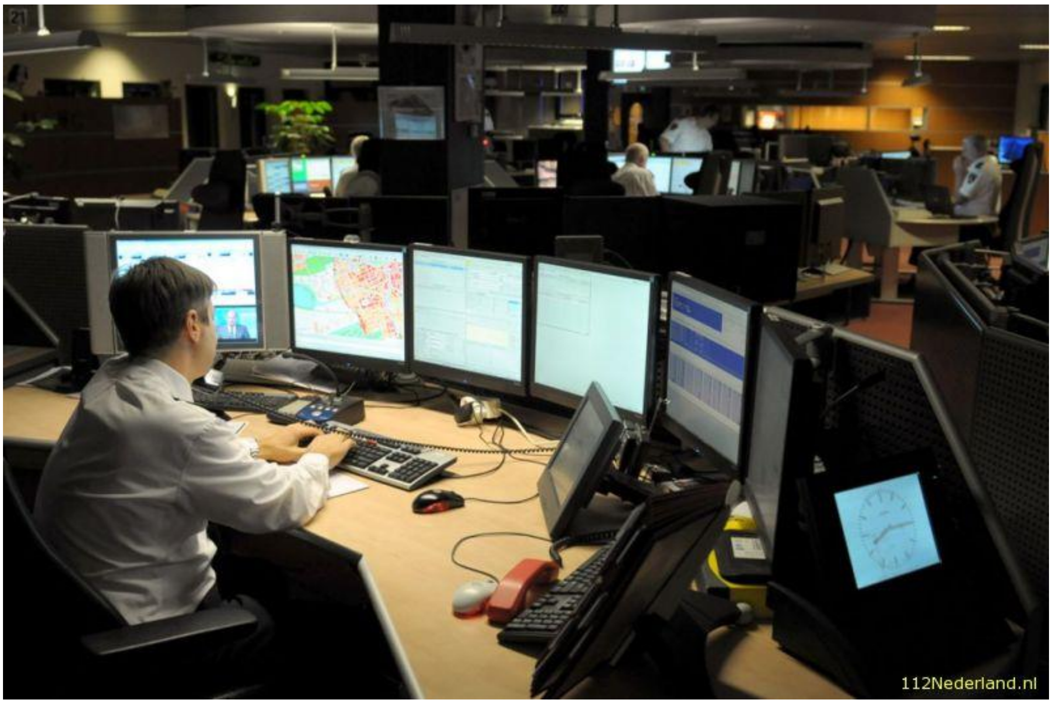


Figure 3.5. Geïntegreerd Meldkamer Systeem (GMS).
Source: 112groningen.nl

Landelijk Crisis Management Systeem (LCMS):
The LCMS is a secure website offered to all 25 Safety Regions in the Netherlands to support a Common Operational Picture (COP) between multiple and varying degrees of organisations, and thus supports the concept of "network-centric" operations (IFV, 2015). It is a relatively new addition to the Dutch disaster management infrastructure as although it is in operation, it is still under continuing developments and there is a need for harmonisation of the system across the Safety Regions.

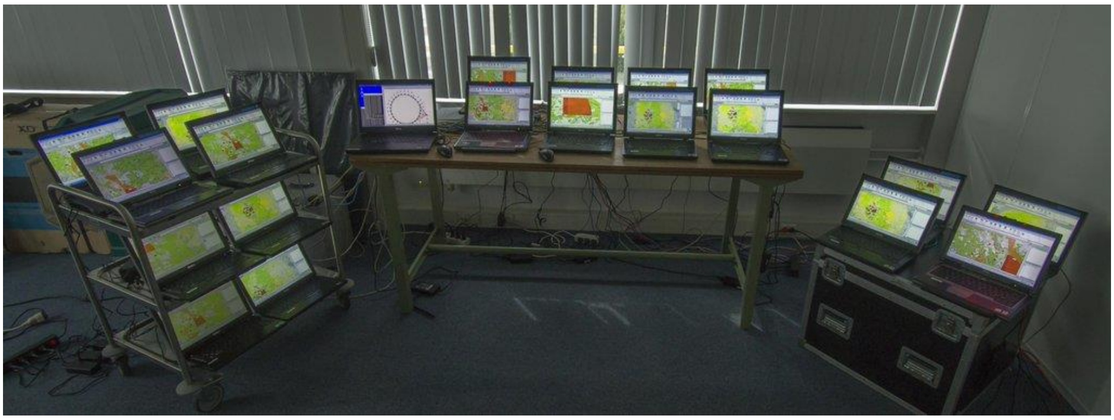


Figure 3.6. LCMS application on laptops
Source: @lcms: twitter

3.7 Challenges

Currently, the challenges that affect disaster response are considered a well-documented field of observation (Militello et al., 2007), however, within this field it is suggested that there are not many studies nor a lot of empirical data available on the coordination and sharing of information during disasters (Bharosa et al., 2010; Mishra et al., 2011; Hernantes et al., 2013; Allen et al., 2014). Therefore the factors that may impede or facilitate information exchange through the use of information systems are scarcely understood as they can be changeable, scenario dependent and dynamic in nature. As identified in Chapter 2, information management is the foundation for an effective response to a disaster event, yet it is still a fragile discipline given its severe importance, as even small misunderstandings can have considerably enormous consequences. Information that is collected, processed, and analysed for the purpose of coordinated response is clearly intended to contribute to improve the livelihoods of people affected by a disaster, but it can also endanger the lives of the very same people if the information is inaccurate, misleading, or mishandled (van de Walle et al. 2009; van de Walle & Comes, 2015).

Militello et al. (2007) researched individual component challenges to large-scale coordination in an Emergency Operation Centre (EOC). They identified three primary challenges associated with effective information sharing, which are; asymmetric knowledge and experience; barriers to maintaining mutual awareness; and uneven workload distribution and disrupted communication. While the most significant observation was the "silo" effect of information building between teams. It was observed that participants exchange and share information with their respective emergency organisations by means of direct phone calls or radio contact as the dominant communication platform. Other factors such as the layout of the EOC and the noise level within it, can promote miscommunication. To better support a team with asymmetric knowledge Militello et al. (2007) recommend the use of "easy-to-learn" artefacts such as paper maps, as "it is unrealistic to assume that EOC members will easily remember how to operate software tools that are used infrequently while in the midst of a rapidly developing crisis". However, this is seen as an alternative as they support the use of shared displays for information sharing, but only if the information system does not have to rely on a vulnerable data infrastructure.

Bharosa et al. (2010) researched obstacles to information sharing on the levels of the individual, organisation, and community, and all three levels contain social and technological elements. The authors concluded that there are multiple factors affecting information coordination and sharing and no single factor can alleviate identified bottlenecks, as resolving a problem at one level is unlikely to improve the situation at another level. Factors found to be influencing the individual level were; workload; motives to use information systems; rank; trust in information systems; perceived information and system quality; and familiarity and training with information systems.

Mishra et al. (2011) analysed information sharing from three dimensions of social, temporal and technical factors. They found trust to be a significant social factor affecting information sharing, while also information and data deemed to be confidential greatly inhibited information sharing if only one organisation was privy to it. The authors recommend improving on trust building capacities to improve information sharing between multiple organisations, and methods to ensure technology and data reliability when temporal factors such as timeliness and relevance are pressing issues.

Hernantes et al. (2013) modelled stakeholder collaboration activities in support of crisis management practices, and identified four interrelated complexity issues relating to the lack of trust between organisations to share information effectively. These trust factors, are; heterogeneity; multiple and inconsistent boundaries; resilience building; and knowledge transfer and sharing. A "tentative model" was developed based on their findings, highlighting the most relevant cause and effect relationships of crisis learning and knowledge sharing process. There are multiple factors including perceived risk, risk tolerance, experience, readiness, trust, etc, and mistrust was found to result in less openness between stakeholders and hinder information sharing.

Allen et al. (2014) used Activity Theory to describe the problems related to information sharing and interoperability between emergency responders and emergency managers, in responding to and managing an incident. They argue that the technology structures impede information sharing and recommend three ways to promote interoperability by; using technologies in day-to-day routine; incorporate common standards, values, and language; and redesign systems to move to alternative decentralisation forms of information organisation (e.g. network-centric).

From all reviewed case studies there have been acknowledgements to the fact that emergency managers can ignore using information systems (including GIS) to build up an informational picture of an event, mainly due to the system inhibiting the user from trusting any spatially orientated decisions from the system. This results from the ability to trust the data, and the cognitive processing capabilities of people using such systems as data excludes the emotional indicators we need as part of our sense making and communication (Weick, 1985 in; van de Walle et al., 2009).

Although it has been shown that GI can significantly improve spatial orientation and sense making, with the added pressure of constraints such as time, information overload, data quality elements, and situational awareness, these external factors can influence performance of the decision maker using information technologies (Boin et al. 2005; Mäkelä, 2006). Trust issues with data may emerge when it is incomplete, un-accessible (due to technology, legal, or cost aspects), or that the data cannot be validated or verified quickly. This may lead to the preferred usage of paper maps, whiteboards, and direct telephone calls to allow the decision maker to build up their own informational picture of what is happening.

However, these "analogue" methods can have negative repercussions as it is difficult to pass on the information gathered on these formats, leading to what is known as the "silo" or "stovepipe" effect. These two terms can be used interchangeably, and are used to describe the inadequacy of information sharing between people, teams, or organisations. A person/team can independently build up their own informational picture away from others who are doing the very same, they do this by contacting other teams to gain information, and only share information when directly contacted themselves (Bharosa et al., 2010).

3.8 Summary

The Netherlands has defined a contingency plan for emergency management known as the GRIP structure, which outlines who is the responsible organisation for the coordination and decision making in response to an incident. It is unknown how this hierarchical model affects the SDI of the collaborating participant organisations, however the GRIP structure creates an assumption for the observer. The structure outlines who should be contacting who for information sharing, and identifies key personal within teams for information coordination (e.g. information manager at the COPI, & information coordinator at ROT). The assumptions from the GRIP level structure can thus be tested specifically towards how they share and coordinate GI between the defined communication channels, and whether the reality is far different from policy. Factors affecting information coordination and sharing were investigated from literature, where it was found that multiple factors can affect such a complex and fragile process. The factor of "trust" was found to extend to both the technical and social elements and was found in all reports to be a reason for either ignoring or using the information. Trust was found to be a dominant factor for emergency managers to either use or ignore information coming from information systems.

Chapter 4

Framework development

4.1 Introduction

Up to this point it has been explored in chapter 2 how GI can assist in sense and decision making in emergency response, and the SDI can provide an environment to promote access to GI. In chapter 3 we saw how difficulties associated with the sharing, coordinating and trust of GI can inhibit the very same process. The objective of this research is to evaluate the use, communication and exchange of GI between multiple organisations (tactical level) and emergency responders (operational level) within the Netherlands as currently there are very few studies and not a lot of empirical data available on the coordination and sharing of information during disasters. There is sparse knowledge on the factors that may impede or facilitate information coordination and sharing.

4.2 Methodological background

A common starting point in evaluating complexity issues is to recognise and appreciate that all factors of the infrastructure stemming from the physical and social elements, and how they interact, cannot be fully monitored. Therefore complete certainty of all influencing issues is an unmanageable task from the perspective of a single evaluation. It is therefore more beneficial to define boundaries and to focus on well-defined process interactions between entities in the system, this process is called System Analysis (Enserink et al., 2010).

System Analysis extends from the research of Systems Science and it is a multi-disciplinary field that uses multiple methods to analyse simple to complex systems in the environments of nature and society. This discipline includes theories of general systems theory, system dynamics, complex adaptive systems, and cybernetics, and a concise overview of its birth and developments is given in Midgley (2006).

Systems Analysis decomposes the system of study into its component parts to analyse their respective performance and their interactions that contribute to the success of the system as a whole. The method argues that the understanding of information systems can be further developed if system-based evaluations and interventions are directed towards understanding the inter-relationships within the system, by engaging with multiple perspectives, and reflecting on who or what benefits/suffers from an inquiry, i.e. reflecting

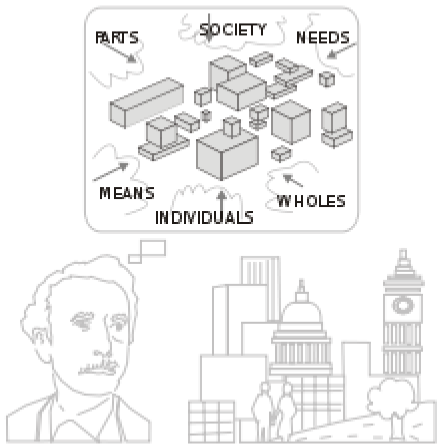


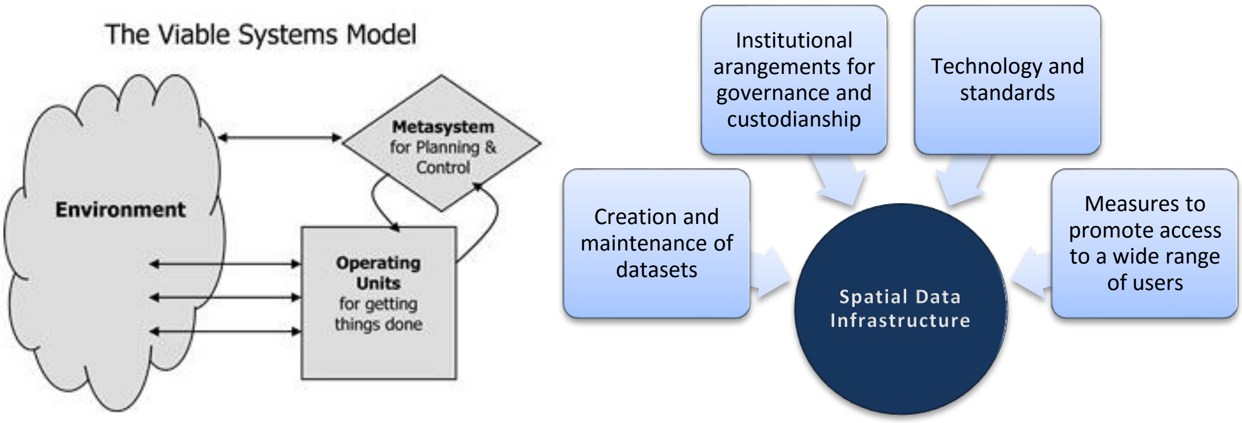
Figure 4.1. Systems Thinking impression.
Illustration made by Marcel Douwe Dekker

on the defined boundary choices (Jackson, 1992). By using such an approach, it is possible to understand the complexities affecting an infrastructure, expose multiple perspectives and the assumptions of the defined and undefined goals of a system (Eoyang, 2006).

As previously stated in chapter 2, the SDI framework can facilitate and promote the access to GI and the life of an SDI resides within the formal and informal relationships between people and organisations. Therefore the factors that may inhibit/facilitate the performance of the SDI will be analysed on the interrelationships that share & coordinate GI, and this analysis will be engaged from the perspectives of the "actors" (i.e. interview participants) within the network. From chapter 3 it was discussed that multiple factors can influence the information sharing process, thus in this research factors affecting GI coordination and sharing will be examined in the field of disaster management. It will be the responsibility of the interview participant to identify the impediments to sharing GI.

4.3 Methodology

The methodology will aim to assess the SDI from the perspective of GI flow and coordination, in the domain of emergency response, by mapping the casual relationships of key actors within the emergency response infrastructure. The Viable System Model (VSM) is used to capture and structure the operational and tactical levels, and the SDI model components are then investigated between these communication channels to identify the factors that facilitate and impede the sharing of geo-information, as the efficiency of an SDI is reliant on the effectiveness of the relationship between the involved individuals and organisations.



A. **B.**

Figure 4.2. A. The Viable Systems Model (VSM) & **B.** Product-based SDI components.
*Source: **A.** cio.com **B.** Masser & Crompvoets (2015).*

The Viable System Model

To establish an overview of the infrastructure an interviewee is involved in, the participant will be asked to map out their role and their casual interactions with people within their team, and the teams they interact with. To understand how the participant interacts with their environment, their team members, technologies, and other organisations, the Viable System Model (VSM) (Figure 4.2.A) will be used to map out these casual relationships. The

VSM, developed by Stafford Beer in the 1970s, extends from the cybernetics field, and has three basic elements of operation, environment, and management. The goal of the model is to allow an observer to cope with complexity in organisations, so Beer developed the model based on human physiology of the nervous system. For example, the eye (operation) interacts with the environment and sends messages (communication channel) to the brain (management). This way the model claims that all self-organising systems adhere to its components, either systems in nature or organisations, as living organisms (agents/organs) are given purpose once placed within a system (Hilder, 1995).

In and between the components of operation and management, Beer defines five systems (of equal importance) that must be present for the organism/system/organisation to remain viable. The viability of a system underpins its effectiveness, and the effectiveness is compromised if any of the five systems are absent (Preece et al., 2015). The VSM is an "observer dependent" model, meaning the purpose of the system (the SDI) is determined by an involved actor from their perception of what the SDI does. The five systems within the VSM are as follows (Beer, 1979):

System 1: ***Operations***

Regarded by Beer as the muscles and organs of the system. Individuals involved in System 1 carry out the basic operations of the system in order for it to function e.g. IT services & operations. In an SDI, System 1 can be defined as the end-users of geo-information.

System 2: ***Coordination***

The nervous system. System 2 connects the execution of the basic operations to the meta-management and is responsible for monitoring System 1 operations. Institutional arrangements can be the building blocks of baseline agreements between the involved parties within an SDI network. If such agreements are in place it would be the responsibility of System 2 to monitor and control the processes to ensure that the agreements are adhered to.

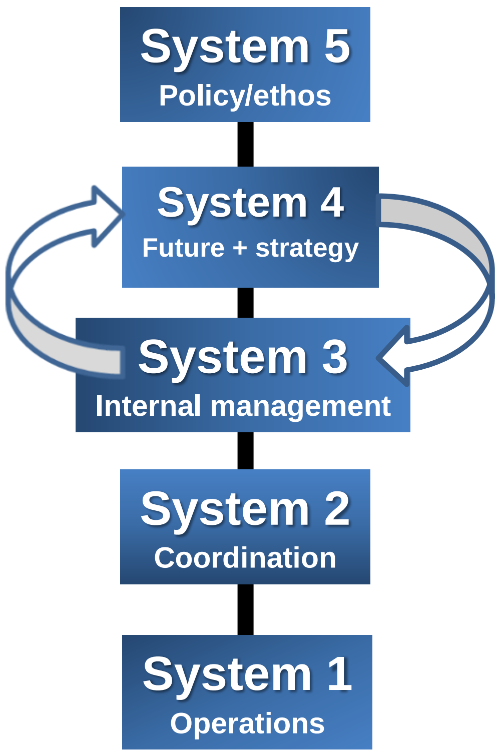


Figure 4.3. VSM sub-systems

System 3: ***Internal management***

System 3 is the management structure for Systems 1 and 2 responsible for managing resources, staff, budget, and assessing the efficiency of operations. System 3 implements defined guidelines and strategy for System 1 activities while evaluating and auditing infrastructure components to carry out the defined strategy.

System 4: ***Future/planning***

System 4 is connected to the environment and can be regarded as the research and development component and should be concerned with how the system must adapt to remain viable. Assessments such as data requirements and user needs can determine what is working and what is not working within an SDI.

System 5: ***Guidelines/policy***

System 5 conveys input from System 3 and 4 to process internal information with outward sensing predictions to provide guidelines for the entire system as a whole. Both the internal management and future planning components provide short term and long term requirements respectively, and thus it is the responsibility of System 5 to ensure stability between the two.

Assessing the SDI

Once the infrastructure is mapped out, and the participant is satisfied, additional questions will be directed at the work processes in creating and moving geo-information across the identified communication channels from the heuristic diagram. The SDI for emergency response is assessed from the perspective of geo-information flow and coordination to comprehend the value it offers to information managers, and to identify associated bottlenecks. Once the casual relationships have been mapped using the VSM, questions relating to GI examine the SDI performance from the perspective of the interview participant. Questions that guide the interviews relate to the following:

- What geo-information, within an emergency incident, do you need and use to perform your job responsibilities?
- What geo-information do you use when making decisions in an emergency incident?
- Where does this geo-information come from and how do you get it?
- Where is this geo-information stored once you have it?
- Who looks at the geo-information with you?
- Who needs/requests geo-information from you?
- Is the geo-information you gather, information you would routinely share within your organisation?
- How does the geo-information sharing process currently happen?
- Do you keep a record of how the geo-information guides your decision-making processes?

Geo-information performance

Interview participants are asked to rate the performance of GI in relation to the processes of 1) checking, 2) using and 3) sharing geo-information. Within these 3 categories there were 7 performance indicators based on humanitarian information management systems and principles (Van de Walle et al., 2009) including reliability, accountability, semantics, accessibility, sustainability, timeliness, and relevance. These performance indicators allow the infrastructure actors to comment on the existing performance of the GI, while also allowing them to elaborate on how they would like certain aspects improved. An overview of the assessment represented in Table 4.

Table 4: GI Performance Indicators.

Performance Indicator	Description
Reliability	Perceived trustworthiness of represented GI.
Accountability	Allocation of responsibility for GI.
Semantics	Comprehension of GI between various partners.
Accessibility	Ease of access to GI and information.
Sustainability	Ability to archive GI for evaluation purposes.
Timeliness	Perceived ease of keeping information up-to-date.
Relevance	Ease of keeping GI up-to-date for information needs

4.4 Summary

The methodology extends from the fields of cybernetics and SDI research, and the applicability of the VSM and SDI are used in conjunction with one another to assess GI flow and coordination in the emergency response infrastructure. The end result is essentially a GI network analysis that is trying to identify factors that impede and facilitate GI sharing and coordination. A constraint is anything that limits a system (e.g. organisation, group, process etc.) from achieving higher performance relative to its goal (Rahman, 1998), and thus a bottleneck is identified in the same way as a constraint. The identified factors/constraints will be examined, and presented in an Actual/Ideal comparison where relevant authorities can comment and reflect on the SDI network analysis.

Chapter 5

User Needs Analysis

5.1 Introduction

From chapter 4, the goal was to review recommended theories to identify factors that impede and facilitate information sharing. The objective of chapter 5 is to understand how geo-information is supported and used in practice to facilitate emergency response by applying the methodology from chapter 4. To achieve this understanding a series of interviews were conducted with key actors in the emergency response infrastructure. Particular attention was centred towards current SDI governance to gain an insight into current user needs regarding to geo-information.

Target groups

Three Safety Regions and one water-board were approached for interviews. Under the Safety Regions Act (Government of the Netherlands, 2010) it is the responsibility of the Safety Regions to organise how they share information to coordinate and respond to an emergency incident. Under the Charter of Fundamental Rights, Article 8 (EU, 2012) all participants are anonymised, and their funtional roles are as follows:

1: COPI leader ***(op)***/fire officer ***(tac)*** (emergency services)
2: Information manager ***(op)***/information coordinator ***(tac)*** (emergency services)
3: Information manager ***(op)***/information coordinator ***(tac)*** (emergency services)
4: Functional manager/plotter ***(tac)*** (emergency services)
5: Safety Region Director (emergency services)
6: Head of communications/ information manager ***(tac)*** (emergency services)
7: Calamity coordinator (water board)

Roles: op = operational level
tac = tactical level

The Viable System Model (VSM) and SDI model were used to structure and explain the communication of geo-information in and between the operational and tactical levels. The following diagram used the VSM to structure the communication channels, and the SDI model was used to assess and understand how geo-information is used and moves through the infrastructure.

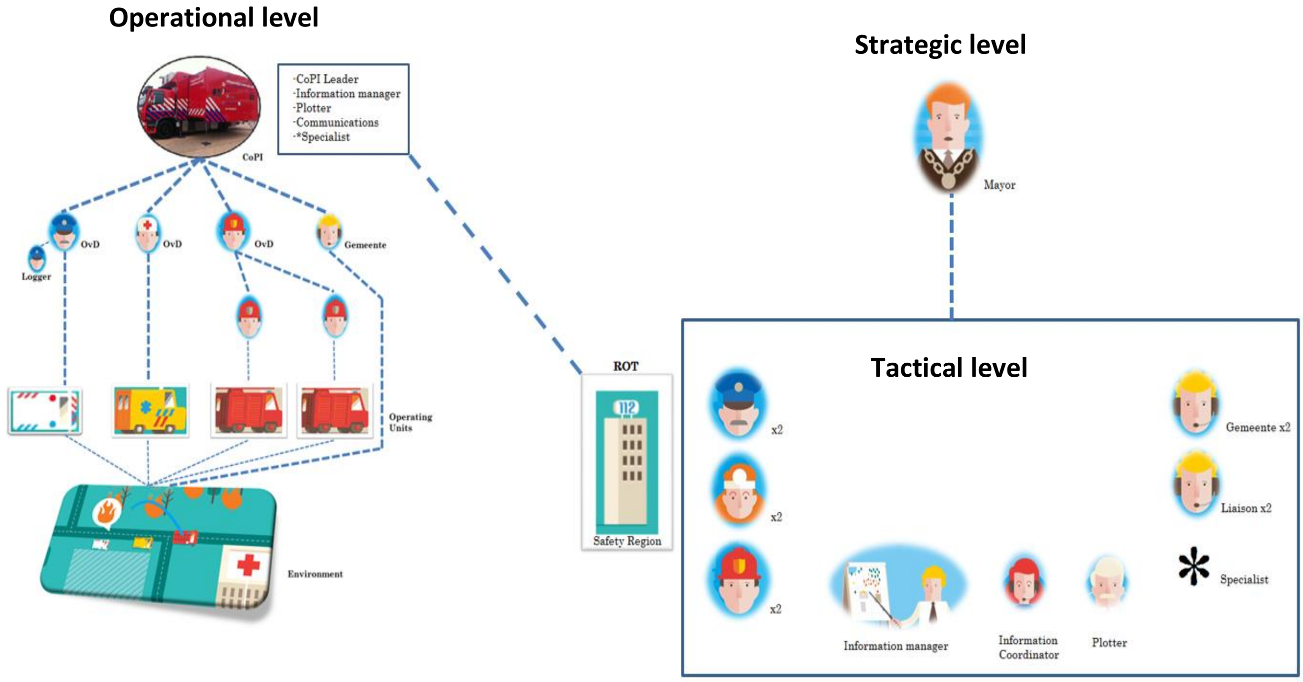


Figure 5.1. Map of actor infrastructure for emergency response

5.2 Overview of key findings

The interview participants have shown that LCMS and geo-information are important tools in the net-centric way of working, and that information sharing and coordination in emergency response have never worked as efficiently as it does today. Geo-information is not used by the operating units once on-scene, but they verbally pass on information to the COPI to construct dynamic geo-information on how an incident is progressing. This created geo-information supports the processes of sense and decision making by spatial orientating information for emergency services away from the scene of the incident.

At the same time, LCMS is a new concept for the emergency services and the theme of information management and systemic review must adapt with end-users and top management. The emergency services and their external partners share different cultural perspectives of reactive (emergency services) and proactive (critical infrastructure partners) use of geo-information, and it was expressed in several interviews that this difference in cultural perspectives and semantical understanding can significantly hinder the performance of information sharing.

A limiting factor is that the governance of each organisation is heterogeneous even when they are thought to be homogeneous, and that unidentified cultural differences with information management hinders collaboration. The following areas were identified as potential improvement areas in the SDI network and governance structure, as assessed from interviews:

- Alignment of GI delivery team members (i.e. plotters) both internally (emergency services) and externally (critical infrastructure partners) with the domain silo they are responsible for.

- Build out GI process areas related to plotter domain silos in LCMS, and create baseline agreements documented and agreed upon by all parties for information delivery and access (e.g. response times, security precautions, semantics, regular testing).

- Implement self-improving or self-assessing processes to monitor whether parties adhere to baseline agreements by assessing communication and having checkable controls for an internal review or audit on how LCMS performed during an incident.

- Upon successful implementation of internal evaluation and monitoring processes, identify and automate and/or implement new processes that will improve aspects of the SDI network related work process with LCMS, based on findings from an internal review.

5.3 Current situation of SDI

Geo-information provides enhanced sense making capabilities, and LCMS is the primary service to coordinate and share multi-relevant information between the emergency services. From the conducted interviews it was understood that all four components of the SDI model (1. creation and maintenance of datasets; 2. institutional arrangements; 3. technology and standards; & 4. measures to promote access and usability), are currently in-place and their integration produces substantial value to support sense and decision making processes for emergency response.

The effectiveness of the SDI integration was assessed using the Viable System Model based on the presence of the 5 sub-system components. Qualitative evidence suggests that System 3 (internal management), and System 5 (system guidelines) for Geo-ICT are either not present, or if present the communication between the components are interacting on an ad-hoc basis suggesting that the SDI is not yet a viable system, as structured communication is a prerequisite for a viability within a system or network (Espejo & Gill, 1997) .

Framework GI datasets are efficiently stored and accessible from the Geo4OOV server, while dynamic information must be gathered from a pool of sources outside of LCMS. This allows the SDI to function for operational purposes, while the net-centric way of working coordinates the required information. The lack of a structured internal review, performance assessment, and communication within the interviewed Safety Regions hinders understanding the true value LCMS provides and thus affects how the emergency operations embed the use of LCMS.

5.4 GI usage

Geo-information sharing between involved within emergency response is primarily utilised only if a GRIP level incident has been determined. The operating unit's geo-informational requirements rely on location information, and structural geo-information (e.g. location and route to incident, water source location, access/entry points, hazardous material storage, building plans) and supports the process of sense making and building up a mental picture as they are on route to an incident. For the fire services, DBK (Digitale Bereikbaarheidskaart) is an important system that enables this sense making process for their operational units on the way to the scene of an incident.

Once on-scene, geo-information is rarely used by the operating units as the emergency services act independently of one another and are only concerned with the information requirements of another emergency service once there responsibilities overlap. Geo-informational requirements for the operating units require very little to no geo-information support once on-scene. Geo-information is created on an incident from the coordinating unit (COPI) by gathering verbal information from the operating units and this verbal information is transformed into dynamic geo-information and textual information within LCMS and is shared with the tactical level.

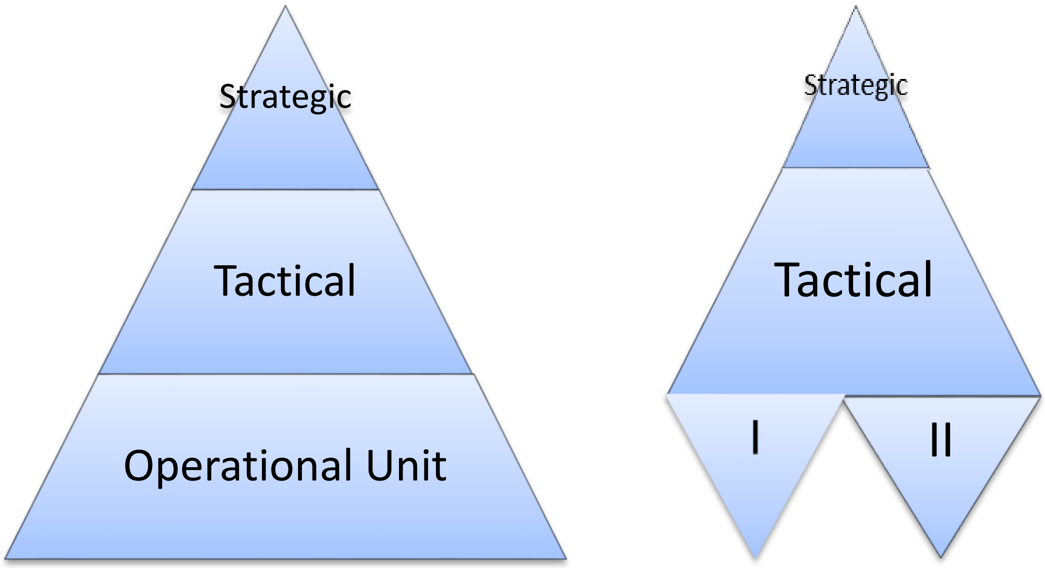


Figure 5.2. Geo-Informational needs **Left)** Going to scene & **Right)** On-scene.

The tactical level value geo-information as it allows them to easily understand and see how an incident is progressing. Geo-information is an important tool used in the net-centric way of working as it creates one reference point for the emergency services at the tactical level, and as a result are better facilitated to coordinate requests and understand information coming from the operational level.

By using one system and one map for a reference point, the net-centric community validate the presented geo-information by constantly discussing and investigating the mapped elements. LCMS brings, in some way, a form of structure to the ad-hoc information picture as new information that is brought into the system leads the actors in their decision making processes. Geo-information at the tactical level is highly sought-after, both from on-scene sources and for information on potential risks in the surrounding area of the incident site. This is where an effective SDI can promote quick access to information and the efficiency of this network entirely depends on the established relationships between the involved stakeholders and data providers.

5.5 Evaluate - Direct - Monitor (EDM)

From the actors interviewed in this research, there is a constant demand for improved usability of LCMS. The overall theme for better usability is to see less textual information and more geo-visualisation with supporting text as to increase the capacity for sense making. Currently within the Safety Regions, after the occurrence of a GRIP level incident, there is a performance review of how the emergency response was executed. However, this review does not fully extend to the performance of LCMS, nor to entire information management paradigm. Such an assessment would be a new concept to the emergency services and therefore in order to structure a successful User-Needs Analysis would require the implementation to be coordinated from a holistic approach across all Safety Regions.

To change the cultural behaviour of the emergency services to undertake such a review would require top-down management support and approval of the initiative. The benefits of a user assessment would provide insights into which information and information formats were effective during an incident, which information was vitally missing or took too long to acquire. By cataloguing information & geo-information performance within an incident can better facilitate the emergency services to understand their own informational requirements, while providing LCMS developers structured reasoning and better understanding on how to broaden the pool of information sources.

From the participating Safety Regions in this research, all stated that this is something needed to be done, but none could say that it is currently a component of their evaluation efforts and therefore a holistic framework within across all Safety Regions is absent to evaluate and monitor operational & tactical processes with GI.

5.6 Governance

Although they are considered to be homogenous, the way the Safety Regions internally manage themselves and interact with their respective crisis partners are heterogeneous from one another. This has an influence on the effectiveness of how GI is used within a particular Safety Region as the amount of standard training sessions per-year with LCMS, the GI sharing capabilities with external partners, and internal management of GI vary considerably between the Safety Regions. This was evident between all 3 of the Safety Regions that participated in the study. Setting baseline requirements/procedures for a GI structure requires a culture change from reactive mind-set to pro-active planning for the emergency services to understand and meet their own requirements.

Internal information system management is a new concept for the Safety Regions, as only 10 years ago it was considered an enormous improvement to have been able to access Google maps in the field. In order to set holistic baseline agreements for all Safety Regions (e.g. requested information response time, number of required trainings per year with information systems, internal user requirements, and guidelines for external partners), a homogenous governance structure towards geo-informational systems and I.T. in general needs to be determined in order to provide a clear reference point for all Safety Regions to incorporate the use of an EDM structure.

The physical technological component, as in how technology helps the emergency services carry out their required functions, needs to be intertwined with the people who carry out those functions. GI governance must be achieved in the same way to understand the value that it brings to the operational processes. GI governance must remain in compliance with the overall I.T. governance and organisational strategy for the Safety Regions, so that it is incorporated effectively into standard procedures.

5.7 Accessibility issues

An expressed risk of the current infrastructure is that it creates an "in or out" environment for the ability the share information as a user must have an account to access the information platform. This poses potential risk for information silos to upscale from internal response teams to stakeholders with different information systems, or potential users lacking an account. Data layers are accessible from the Geo4OOV server within LCMS, however to access data that is not in this catalogue must be achieved outside of LCMS. GI users have expressed their need to incorporate dynamic data sources, such as social media, which is currently at the discretion of the plotter whether such information is utilised as it must be accessed outside of LCMS. Functional GI end-users are currently campaigning to ultimately have more influence on how the SDI develops.

Sensitive information needed for planning purposes of high priority events is a privacy requirement for some Safety Regions with highly urbanised areas. LCMS is an effective tool for planning purposes but the inability to keep sensitive information within one Safety Region affects user satisfaction, and ultimately the capacity of trust that is placed upon it. A pragmatic approach would allow the net-centric doctrine to be upheld, but with ability to privatise sensitive information for the planning and monitoring of one-off high priority occasions. The ultimate goal of GI sharing is envisioned by interview participants to flow easily between different partners, and relevant information for particular teams can be easily accessed and disseminated, regardless of the information format or information system being used.

5.8 LCMS performance

In order to get the actors discussing on how they perceive GI to perform within LCMS and how they would like certain aspects to be improved, they were asked to rate the performance of 1) checking, 2) using and 3) sharing geo-information. Within these 3 categories there were 7 performance indicators based on humanitarian information management systems and principles (Van de Walle et al., 2009) including reliability, accountability, semantics, accessibility, sustainability, timeliness, and relevance. The actors were divided into two groups of 1) non GI specialists, who necessarily do not fully comprehend the complexity of spatial information, and 2) GI specialists, who are aware of spatial data characteristics.

On the GI performance indicators, reliability is how the actors perceive the trustworthiness of information they see within LCMS. Accountability reflects how easy it is perceived to locate an individual to correct misinformation in LCMS. Semantics assessed the comprehension of information between internal and external partners. Accessibility on how easy it is to access GI within LCMS. Sustainability reflects the ease of storing GI for evaluative purposes. Timeliness is how easy it is to keep information up to date, and finally relevance assessed if the presented information meets the actors information needs.

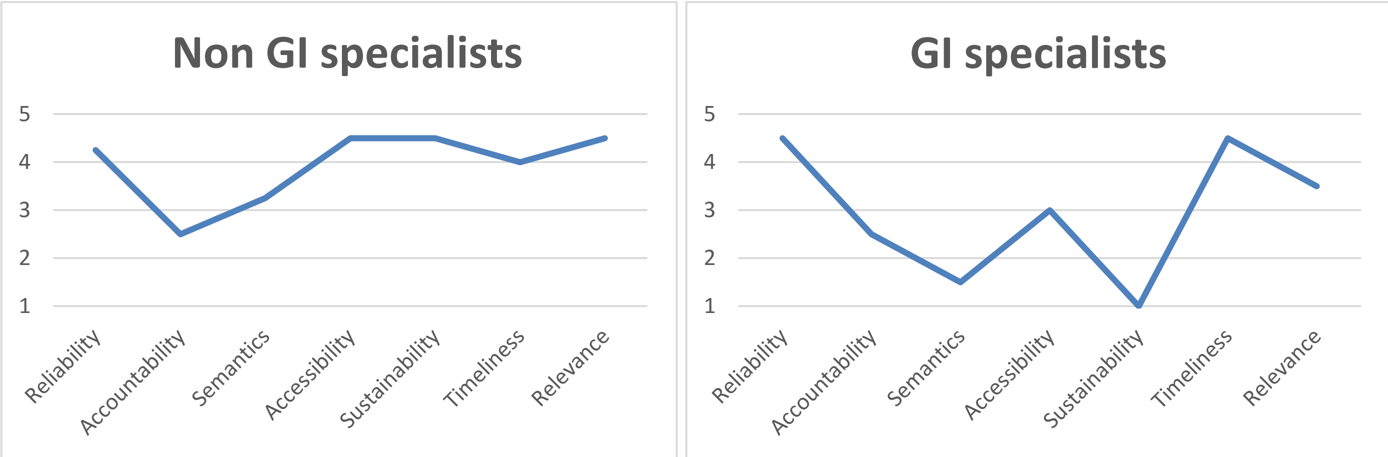


Figure 5.3. Results of LCMS performance. 1=Difficult, 5=Easy.

The performance assessment was used to get the actor's perception on certain information characteristics to get them to comment on the GI management. The Non GI Specialists account for the majority of end-users yet, results of the assessment between perceptions differ, with semantics, accessibility, and sustainability deemed as difficult processes concerning GI.

5.9 Actor analysis

From the conducted qualitative interviews it is necessary to formulate and structure the problems expressed by the participants to highlight the perceived existing situation and their respective desired objectives or situations. This problem formulation allows a systemic overview of the different actors by examining their interests (i.e. their responsibilities), desired situation (i.e. changes they would like see), the existing gap (i.e. their perception on the current situation), causes (i.e. what is preventing them from achieving the desired situation), and finally possible solutions (i.e. the actors ideas on how to improve on the current situation). Table 5 summarises and compares the conducted qualitative analysis to identify problem comparisons.

Table 5: Overview of actor analysis

Actor	Interests	Desired situation	Existing gap	Causes	Possible solutions
1 **COPI leader Fire officer** *Experience: 10+ years*	Coordination of actions between the involved emergency services.	Less time spent on verifying information.	Information not always available, or source unknown.	Requesting information from external organisations takes too long.	Information needs and sources are identified and information is readily available on a server or in the system.
2 **Info mngr. Info coord.** *Experience: 2+ years*	Text input into LCMS and creation of C.O.P with multi relevant information.	To see more scheduled training with individuals from other emergency services.	Dealing with your own emergency service is something different than with other emergency services.	Organisational culture of reactive response in Safety Regions inhibits pro-active planning.	Implementation of governance structure that promotes critical reflection of internal processes.
3 **Info mngr. Info coord.** *Experience: 10+ years*	Text input into LCMS and creation of C.O.P. Educating users of LCMS.	To have less text and see an increase of geo-visual information, with supporting text in the map.	LCMS is not fully satisfying user's needs in how they want to work with the system.	Dissatisfaction is not documented and workarounds created when LCMS does not comply with the user's needs.	Create user groups in Safety Regions that can assess, document, and structure user requirements for future developments.
4 **Plotter Funct mngr.** *Experience: 5+ years*	Coordinating software optimisation within a Safety Region and geo-information functionality.	To see an increase in the pool of information sources for LCMS.	Lack of method for getting information into the system without needing a log-in account.	Log-in accounts create an "in or out" participation environment.	Create an information pool/database outside of LCMS that LCMS users can "dip into".
5 **SR director** *Experience: 10+ years*	Strategic design and management of a Safety Region	Convey less meetings during a crisis regarding the input of information into LCMS. Construct, design, and review IT systems internally.	Safety Regions do not act as a united construct. To act together there is currently no need, invitation, money, or national government presence to do so.	Fragmented organisational culture prevents systemic review of work processes. Lack of framework for Safety Regions to share and work together more cohesively, & IT development is a new concept for people within the Safety Regions.	Intelligent system design can alter behaviour. Win full support from top management at Safety Regions and initiate national movement towards internal LCMS review (with support from technical community), and conduct a STOP/GO assessment.
6 **Head of com. Info mngr.** *Experience: 10+ years*	Analysing data and processing information.	Improve system user interface so it is more logical and ergonomic towards decision making.	System is not flexible nor embedded enough with current work processes.	Currently high level of user needs assessed. Lack of usable guidelines and help reference for low level user.	Create User Groups with technical developers to understand each other's difficulties and challenges.

7 **Calamity coord.** *Experience: 3+ years*	Prepare organisation for all crises. Plan, train, and evaluate preparations and incidents.	All government bodies in a crisis can see what is happening in their territory. Every organisation can make an individual assessment if they need to do something or not.	Everybody has a wish for the same future regarding information sharing, but there is a lack of understanding in the right way to achieve it.	Cultural differences between government bodies hinders situational awareness and information sharing between us.	Combine LCMS and WCMS end-users in a network to understand how each one works with their information.

Amongst the most discernible patterns identifiable from interview participant's possible solutions, is to see an increase in how information platforms are governed to evaluate and resolve issues associated with the use and sharing of not just GI, but with the encompassing Information Infrastructure (II).

5.10 Summary

From the analysis, focus was set on the SDI resources and relationships between the actors required to support and implement information sharing in emergency response. LCMS is the primary tool used to coordinate information and uphold the net-centric way of working, it provides significant advantages to support sense and decision making in (GRIP level) incidents. Geo-information is regarded as a vital tool in these incidents, however when assessing the informational needs of the involved actors, none could fully determine which information formats were of optimal value, meaning that the availability of a large pool of information sources is required to cater for the ad-hoc method of obtaining information.

The assessment from the actor analysis highlighted that System 3 of the VSM for information system management (including GI) is not yet embedded or fully integrated with the basic operational processes of the emergency services. Thus, the "fragmented", "reactive" organisational culture is a significant factor hindering information flow and coordination. Regarding external partners (i.e. critical infrastructure partners) assessing situational awareness of information capabilities and defining baseline agreements for information sharing is viewed as the way forward to improve the information paradigm.

To identify problematic patterns in the emergency response network between the Safety Regions and their external partners, incorporating evaluative processes to understand existing gaps in information sharing can provide greater value to the emergency response SDI as a whole to improve efficiency. The net-centric method has allowed to increase situational awareness among partners, but there is a need to assess the performance of information systems involved by defining a governance structure that will allow the emergency response network to assess information gaps and requirements both internally and externally.

Chapter 6

Developmental stage

6.1 Introduction

The conducted methodology utilised qualitative analysis to investigate the socially constructed nature of reality regarding the use of geo-information in emergency response. The current infrastructure was studied from the perspective and reflection of different actors from 3 Safety Regions, thus different aspects of the infrastructure have been highlighted. By conducting such a study, absolute facts have not been generated but instead an insight into how information & GI sharing is routinely accomplished, and thus establishing a set of conventions on GI governance.

The GII is in a transition from a specialist user base to a general practitioner user base, and evidence of this transition was found in the two competing perspectives from the LCMS performance indicators. Therefore SDI governance must adapt to include and communicate with these users in order for the value of the SDI to remain relevant and meet their needs. This chapter will explore the concept of a SDI governance structure by taking the findings from Chapter 5 into consideration to explore the current governance strategy and thus a comparison will be made between the current and ideal situations.

6.2 Intelligent governance

The SDI model enables an organisation, or network of organisations, to create, share, and use geo-information in relation to its business or organisational requirements. Thus, the model is a governance structure that ensures that geo-information and standards are used to support the organisation's needs, and so policies are created as supporting entities (ESRI, 2010). As discussed in Chapter 2, the SDI is a sub-component of the I.T./Information Infrastructure, and the boundaries between the SDI and II are ill-defined, sometimes synonymous, and results in complex interactions between them. As such, SDIs are multi-faceted and have moving targets, requiring cross-disciplinary research and an understanding of the I.T. domain to grasp an appreciation of the associated complexities (Crompvoets et al., 2008).

Developments and trends in I.T. have significant influence over the SDI, an example being the movement from desktop GIS to cloud GIS in recent years, and thus, allowing the user to access and analyse data from multiple work environments. Figure 6.1. provides an overview of how an SDI is embedded within an organisation to meet the business requirements, and when GI can enhance an organisation's operational processes, a SDI is considered an important component in the design and development of to support organisational strategy (Rajabifard, 2008),. From this overview it can be considered that a well-defined SDI acts as the gatekeeper to efficient and effective sharing of GI to a network of individuals, or organisations. Thus assessment and SDI governance goes beyond measuring the performance of its composing individual parts, but to a higher level of measuring the value that GI brings to an organisation, or network, from the integration of the SDI components. Therefore, the organisational strategy and the II (I.T. + SDI) must be coherently understood to make sense of the value gained from a SDI. From here the relationship between SDI & I.T. governance will be explored, and the findings from Chapter 5 will be gauged to SDI governance.

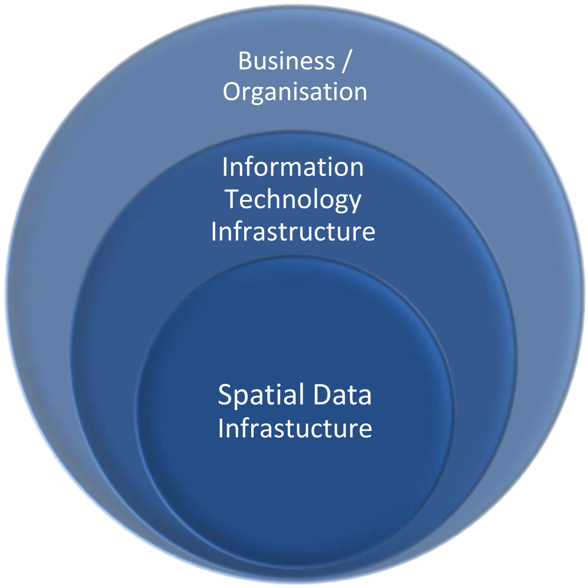


Figure 6.1. SDI in relation to the organisational environment

Defining governance

I.T. Governance can be defined as "the responsibility of the board of directors and executive management … consisting of the leadership and organisational structures and processes that ensure that the organisation's I.T. sustains and extends the organisation's strategies and objectives", (ITGI, 2003). This statement encompasses that I.T. governance is broader concept than I.T. management and is considered an integral part of an organisation and for its stakeholder network. Management can be regarded as the supply of I.T. products and services for an organisations I.T. processes, while governance encapsulates the evaluation of performance to meet future I.T. requirements (De Haes & Van Grembergen, 2004). Thus, effective governance can support management decisions to align organisational strategy with I.T. strategy.

I.T. has become crucial in supporting the growth and sustainability of organisational strategies, and how an information system is viewed within an organisation (if as a commodity service or strategic partner) can affect the overall value and performance of the organisation (De Haes & Van Grembergen, 2015). The Strategic Alignment Model (SAM) (Henderson & Venkatraman, 1993) is recognised as the dominant overview model to align organisational strategy with I.T as it is regarded important to achieve optimal use of information systems within an organisation to achieve full value of I.T., and therefore the system must be aligned and functional with the basic organisational operations (Goepp &

Avila, 2015: Avison et al. 2004). The SAM (Figure 6.2) advocates that by linking the three of the four components, a strategic fit between the organisational environment (i.e. emergency response) and I.T. (i.e. LCMS) can be aligned (Henderson & Venkatraman, 1993).

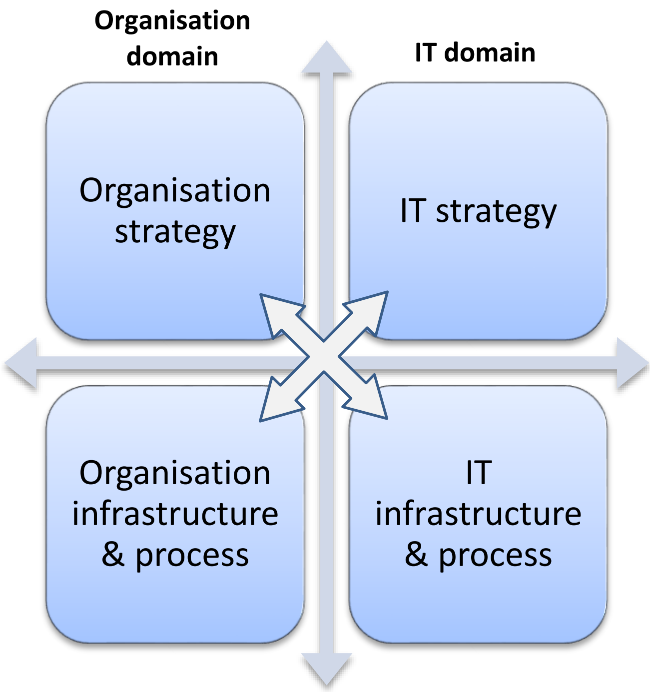


Figure 6.2. Strategic Alignment Model (Henderson & Venkatraman, 1993).

However, it must be highlighted that all governance models are an oversimplification of reality and of the necessary effort of required input to adhere to them, and organisational context, culture, and structure are significant variables that can impede or facilitate a governance structure (Müller et al., 2015). Chan & Reich (2007) argue that alignment research is "mechanistic" and fails to fully grasp the realistic difficulties behind the process of strategy alignment. They also discuss that alignment cannot be fully achieved if the organisational strategy is unknown, and that the I.T. infrastructure must adapt to the organisational infrastructure and not the other way around.

Nedović-Budić et al. (2008) utilised an approach to identify how useful GI within a supplied SDI meets a user's particular needs, thus SDI effectiveness is only as good as the perceived added value that the supplied GI brings to the user. With this in mind four components are deemed as vital assets to help generate and utilise internal data of user perception to advance the process of organisational strategy alignment with information systems (Larson & Matney, 2007):

Four components to intelligent governance:

- A governance committee.
- A framework for governance strategy.
- An end-user support structure.
- A process to review overall governance.

Governance committee

A governance committee can set the conditions and put in place the necessary processes to uncover and evaluate problems to achieve a more structured organisational/II alignment. The committee is an overview of the involved parties from top management to end-users, with the main goal to provide greater transparency for all involved and to ensure that organisational processes and information system processes are aligned. A committee can separate governance from management to enable a holistic approach to determine the way people within an organisation can and/or should work together. This means that the rights, roles, and responsibilities that support the framework structures, people, and work processes are determined from multiple inputs. Based on interview participants' remarks regarding their SDI network, the LCMS governance committee bodies (Figure 6.2) were pragmatically drafted based on the components of the Viable System Model.

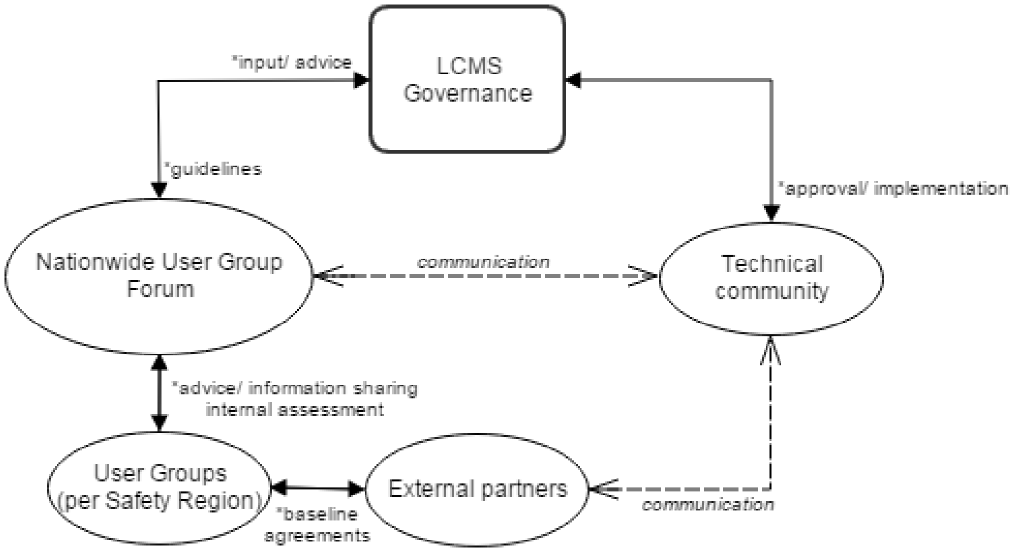


Figure 6.3. Pragmatic Governance committee.

Framework for governance strategy

The current geo-informational governance structure was investigated with the Viable System Model (Chapter 4), to understand how actions are controlled within the emergency response SDI network. An important limitation to highlight at his point is that the governance strategy was assessed from the perspective of LCMS end-users and therefore the entire governance strategy may not have permeated to their viewpoint. However, by analysing the governance strategy in this way it can be determined if the current strategy is transparent and if the VSM sub-systems are actively communicating amongst each other. The rights, roles and responsibilities that were assigned to the VSM sub systems, based on input from the interviews were identified as:

System 1 (operations): End-users of LCMS (information managers, plotters, emergency service officers at the operational level & tactical level, LCMS account holders from external partners). Basic processes to share information and representation of GI.

System 2 (coordination): The net-centric method allows all end-users to coordinate their own information and to share it with all users. But, a key actor identified for the coordination of information within LCMS was found to be the 'information coordinator', who works alongside the plotter. No baseline agreements between internal or external partners were identified.

System 3 (Management): Internal management within the Safety Regions for information management is an active domain, however it does not transcend fully to information management within LCMS. Active assessments were found to be lacking on the performance of the SDI and LCMS after the occurrence of an incident. Participants found this sub-system component to be absent for assessing user performance and user requirements within LCMS.

System 4 (Future/planning): IFV are the responsible organisation for the development of the net-centric way of working. They are responsible for the strategic planning and assessment of LCMS. Interview participants perceive a discernible gap between end-user requirements and the strategic planning of LCMS.

System 5 (System policy): System policy/guidelines was found to be a slow developing area, and also deemed absent by interview participants. A correlation between the absence of structured system 3 for II assessment, and the interaction between the strategic II planners (system 4) may explain the perception on the lack of system policy & guidelines for II & SDI development.

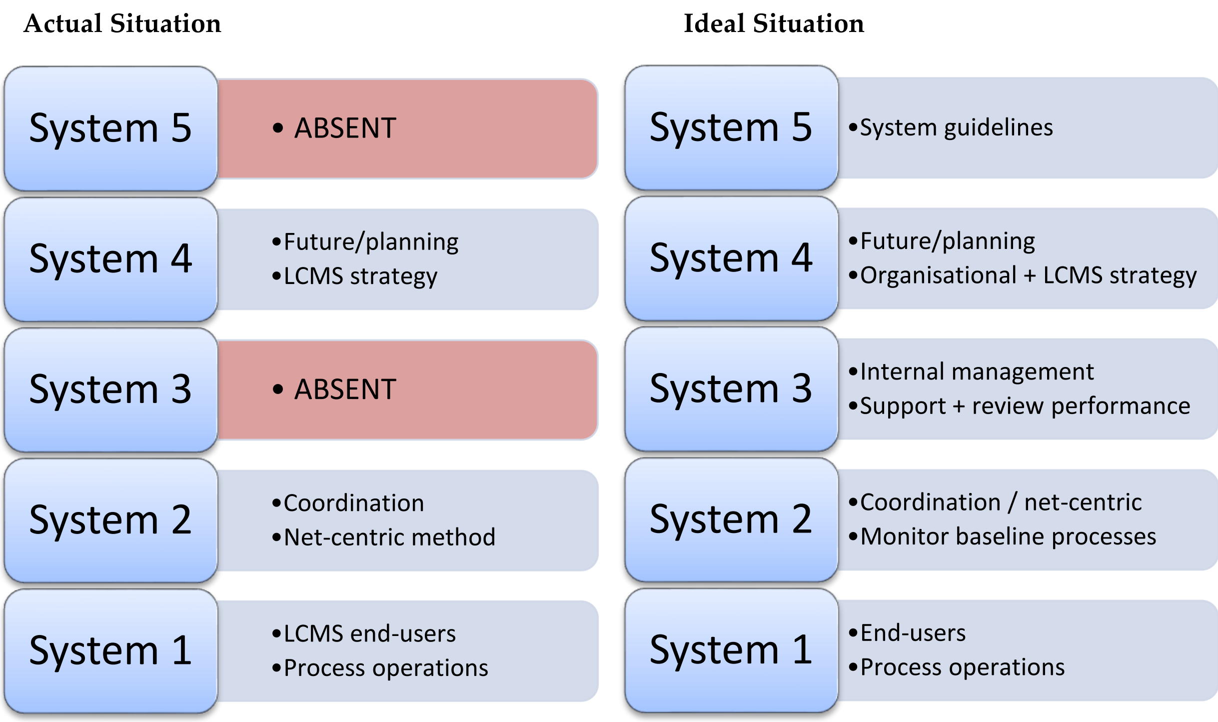


Figure 6.4. Actual & Ideal situational comparison

The current governance structure was found to be lacking in internal management function (System 3) for internal review, and because the future/planning function (System 4) guidelines (System 5). For the current situation, System 1 composes of the LCMS end-users (i.e. plotters, and information coordinator/manager). The users can access GI from the Geo4OOV server, but could not necessarily comment on the required GI processes needed to work with the data. Mapping of dynamic GI is possible but understanding the difference in semantics between the emergency services is a process that is in progress. The ideal situation would be to build out the GI related work processes and have clear semantics between all parties. Comprehending the GI delivery capabilities of all involved parties is the first step to align semantics.

System 2 is the coordination function. LCMS provides one reference point for all the involved parties, and as a result is a coordinating function in itself. It allows individuals to validate the information in real-time by discussing the presented information. The information coordinator at the tactical was identified as a key actor to retrieve information from external partners, however no baseline agreements exist for information retrieval and is an ad-hoc process. An ideal situation would move towards setting and documenting agreements for information response times, and building out agreements based on the understanding of System 1.

System 3 involves internal management. System 3 should be assessing the value of LCMS and reviewing performance after incidents and trainings. This systemic review was unknown to interview participants and thus deemed as an absent component. Review structures are in place within the Safety Regions but currently do not extend to the full paradigm of information management, and thus the potential for internal assessment of

LCMS can be easily structured. Assessment factors can potentially cover a whole range of topics including semantics, information delivery, usability, data quality, etc.

System 4 includes the technical development of LCMS and the strategic planning of the ER SDI, which is the responsibility of IFV. An interview participant conveyed that a gap exists between the high-end developers and non-specialist end-users. Issues stemming from this view-point can be engaged with the structuring of an independent and recursicve EDM structure within System 3, allowing System 4 to assess and be more in-tune with difficulties coming from System 1. As a result transparent guidelines can be generated for the system as a whole (System 5) with the ability for System 3 and 4 to communicate, find, and solve problems relating to the infrastructure.

6.3 The SDI Network Maturity Model (NMM)

The governance structure so far has been assessed on a qualitative basis from a small sample group, thus a more quantitative maturity review can validate the findings from Chapter 5. Based on the I.T. alignment maturity model (Luftman, 2000), and the SDI stages of development maturity model (van Loenen & van Rij, 2008), key aspects were adapted from both models to create a maturity model adjusted the VSM governance model (Figure 6.4.) to measure communication between the sub systems, and the strategic relationship between organisational requirements, I.T., and the SDI (Table 6).

A SDI network concept captures the dynamic and heterogeneous interactions between a large number of partners (Vancauwenberghe et al., 2011). The goal of the maturity model is to be able to assess current perspectives of the SDI network and the state of communication between the network components, while also providing an insight into the activities necessary to improve the interactions and communication within the governance of the SDI network.

The VSM unravels an organisation's structure to identify the resources and relationships necessary to support an organisations basic operational processes rather than on the formal structure of the organisation (Espejo et al., 1999). The I.T. alignment maturity model assesses the relationship between the function of I.T. and the basic organisational processes to achieve a road map to strategic alignment (Luftman, 2000). Six factors of communication; competency / value measurement; governance; partnership; architecture; and skills are assessed in the SDI Network Maturity Model.

	System 1: End-Users	Level 1	Level 2	Level 3	Level 4	Level 5
Comms	**Understanding of IT**	Not aware	Limited awareness	Emerging awareness	Aware of potential	Extensive
Comms	**Knowledge sharing**	Ad-hoc	Informal	Regular / clear	Unified	Strong & structured
Compet / value	**IT metrics**	Ad-hoc	Limited value	Emerging value	Aware of potential	Extensive
Compet / value	**Geo-ICT metrics**	Ad-hoc	Limited value	Emerging value	Aware of potential	Extensive
Gov	**Reporting of needs**	Not formal	Periodic	Regular comms	Effective committees	Partnership
Partner-shp	**Organisation perception of Geo-ICT value**	GI perceived as a cost	GI emerging as an asset	GI seen as an asset	GI is part of organisation strategy	GI & organisation co-adaptive
Architect	**GI data model integration**	No formal integration	Emerging integration	Standard enterprise architecture	Integrated with partners	Evolved with partners
Skills	**Education / training**	None	Minimum	Defined level	Across the organisation	Promoted & optimised
	System 2: Coordination	**Level 1**	**Level 2**	**Level 3**	**Level 4**	**Level 5**
Comms	**Information coordination breath/effectiveness**	Ad-hoc	Limited	Formalised	Bonded	Extra-organisation
Comms	**Knowledge sharing**	Ad-hoc	Informal	Regular / clear	Unified	Strong & structured
Compet / value	**Benchmarking**	Not practised	Informal	Focussed on specific processes	Routinely performed	Routinely performed with partners
Compet / value	**Service level agreements** (data delivery, response times, etc.)	Occasionally present	Technical	Emerging	Organisation -wide	Extended to external partners
Gov	**Reporting structure**	None	Some	Central	Decentral	Federated
Partner-ship	**Shared goals/risks/rewards**	Little reward & no risk	Little reward & some risk	Some reward & risk tolerated	Rewards shared & risk acceptance	Risks & rewards shared
Architect	**Standards articulation**	Ad-hoc	Standards defined	Emerging enterprise standards	Enterprise standards	Inter-enterprise standards
Skills	**Social environment**	Minimum IT – org. interaction	Strictly business relationship	Trust & confidence building	Trust & confidence achieved	Structured with all partners
	System 3: Management	**Level 1**	**Level 2**	**Level 3**	**Level 4**	**Level 5**
Comms	**Understanding of IT by org.**	Not aware	Limited awareness	Emerging awareness	Aware of potential	Extensive
Comms	**Inter/Intra organisational learning**	Ad-hoc	Informal	Regular / clear	Unified	Strong & structured
Compet / value	**Assessment / Reviews**	None	Some (informal)	Emerging formality	Formal	Routinely performed
Compet / value	**Continuous improvements**	None	Minimum	Emerging	Frequently	Routinely performed
Gov	**Committee involvement**	Not formal	Periodic	Regular communica-tion	Effective committees	Partnership
Partner-ship	**Role of organisation & Geo-ICT in strategic planning**	No seat at the table	Process enabler	Process driver	Strategy enabler/ driver	Geo-ICT & organisation co-adaptive
Architect	**Architectural transparency**	None	Limited	Focussed on communica-tion	Emerging technology management	Across the infra-structure
Skills	**Management style**	Command & control	Consensus-based	Results based	Value based	Relationship based

	System 4: Planning	Level 1	Level 2	Level 3	Level 4	Level 5
Comms	**Understanding of org. by IT**	Not aware	Limited awareness	Emerging awareness	Aware of potential	Extensive
Comms	**Inter/Intra organisational learning**	Ad-hoc	Informal	Regular / clear	Unified	extended to all
Compet / value	**Evaluation of infrastructure**	Ad-hoc	Periodic evaluation	Focussed on specific processes	Routinely performed	Strong & structured
Compet / value	**Providing solutions for user needs**	Not generally practiced	Informal	Focussed on specific processes	Routinely performed	Prioritised
Gov	**Organisation & IT cohesive strategic planning**	Ad-hoc	Functional	Some planning	Managed across organisation	Integrated with external partners
Partner-ship	**Relationship**	Conflict / minimum	Periodic interactions	Emerging value service provider	Valued service provider	Valued partnership
Architect	**Dataset integration**	No formal integration	Emerging integration	Standard dataset architecture	Integrated with partners	Evolved with partners
Skills	**Innovation**	Discouraged	Dependent on operations	Risk tolerant	Organisation & partners	The norm

Table 6: The SDI Network Maturity Model

6.4 Summary

The main pattern identified from Chapter 5 was for interview participants to see more communication between the various VSM components in the infrastructure. The governance of the SDI must adapt to include and communicate with all end-users in order for the value of the SDI to remain apparent and to meet future end-user requirements.

A maturity model was developed to assess communication and current perspectives of the SDI between the components of the network and governance structure. The end result of the maturity model is envisioned to provide an insight into the activities necessary to strengthen governance in relation to six factors of maturity.

Chapter 7

Evaluation

7.1 Introduction

The last stage of the research is devoted to the evaluation of the results (Chapter 5), and of the Actual/Ideal SDI governance structure comparison (Chapter 6) from the perspective of a relevant authority. The results from Chapter 5 and 6 were presented to LCMS suppliers, IFV, to reflect on the current infrastructure, the factors that they perceive to facilitate and hinder development, and to gather their ideal vison for GI sharing and information coordination in the future. This chapter will compose of the feedback and self-reflection from the suppliers of LCMS from their point of view to explore the factors that affect SDI development and strategic alignment.

7.2 Going back to the start

This section reflects on the SDI governance of LCMS from the perspective of IFV (Instituut Fysieke Veiligheid), the suppliers of LCMS and the link to the technical developers. An open group discussion took place where the results of the research were presented, discussed and reflected upon. This section asked why was LCMS needed, and how the developments have progressed since its initial conception.

The net-centric way of working and the use of LCMS was an evolutionary development that began in 2009. Around this time, several evaluations pointed out that information management was quite weak and a vulnerable aspect of crisis management. The main structure for working with information was with the generation of situation reports that were distributed amongst various teams and levels, and it was highlighted that this process hampered crisis management.

LCMS was developed to coordinate information more effectively between emergency teams with the use of a Common Operational Picture (COP) to support spatial orientation of the necessary information. This development distinguished four aspects of; organisation; work processes; human competence; and the technical components to develop LCMS to its current status. The main concept of the net-centric way of work was already developed, so the primary development questions related to how would LCMS access and distribute data.

Determining the driving forces

The net-centric method was the incentive to incorporate a system for sharing information between all of the emergency services. The technical aspect of building a system to coordinate information was considered the easier side to development, however the correct way to construct it in order to facilitate collaboration between organisations that hold different goals, objectives, and perspectives on a crisis was considered, and still is, a complex puzzle.

Processes for handling information have been changed with the introduction of LCMS, and with it comes a revolutionary change for people to think differently with information systems. The perceived difficulties involved with the information and GI, is the fact that emergency managers do not have a lot of time during an incident. Therefore, information must be interpretable, validated, and shared across a horizontal plain within seconds so that everybody has the same picture. Presenting this clear and concise picture within a number of seconds, and ensuring that the information remains multi-relevant for all emergency services is not easy. The semantic challenge associated with the COP is difficult to interpret, but work is on-going to define standards (VERA, 2015).

The need for such a tool to allow information to cross a horizontal plain between for inter-team coordination is the driving force for development. Factors of semantics, inter-human, and inter-team understanding are the elements that pose friction to slow down LCMS development. Current evaluation is conducted once a year on the net-centric way of work, and Safety Regions have their own evaluation cycles but there are no holistically established evaluations, and none that assess the value that GI brings to the operational processes. As one interview participate noted:

"GI plays an important role in what we do, but it does not have a seat at the table ... not yet at least."

Ideal vision for the future (Information warehouse)

The future of GI and information sharing in emergency response is linked to the discussion of what the future vision for LCMS usage will be. Will emergency managers use it only a few times a year for large incidents, or is the need there to use it on a daily basis for planning purposes? This is a discussion that still needs to be determined by stakeholders and end-users, as perceptions on this matter differ. The goal of LCMS is to be *the* crisis management infrastructure to support inter-team coordination within the Netherlands. Thus apart from the envisioned level of usage, there is an integral need to link LCMS to an information warehouse that is a part of daily operations.

An important question raised by IFV was, "does GI need a strategic role in operational planning?" A goal of SDI research is to assess the value GI brings to the basic operations of an organisation or network. By evaluating this component within LCMS, users and stakeholders have a clearer vision of which data fundamentally contributes to supporting organisational processes within in emergency response. The national geo-catalogue (Geo4OOV) is prioritised and managed separately from LCMS, but functional GI end-users from LCMS are currently campaigning to have more influence of what goes in and what does not go in to the geo-catalogue.

National data layer sources are used in the catalogue, from both open and private sources. It becomes problematic when icons that were initially developed, for example water management, have to cross over to other sectors who have their own set of defined geographical icons. There are reference architecture documents (VERA, 2015) that aim to align and comply with INSPIRE guidelines, but this is a slow process. Additionally, bordering Safety Regions with Belgium and Germany have to make agreements on which set of GI icons they use, but standards have not yet been defined on a national level. This semantic aspect is highlighted as the main reason way the standardisation process is slow, as separating the expertise needed to interpret a dataset is not an ideal solution.

It is predicted that LCMS end-users are going to have more say of what will be in the geo-catalogue and what will not, as they will be the prominent customers of the crisis management information warehouse. However, to increase and embed standardised use of LCMS, training, awareness, and education are considered by IFV as the fundamentals to allow Safety Regions become more aware of the GI possibilities that are currently available to them. There are currently separate tools that cater for "cold phase" planning maps, if LCMS can be used to make these maps then usage will increase. For detailed planning more functionality is needed and LCMS must have similar functionality with other emergency service applications.

Theoretically it is possible that the future information LCMS provides can contribute to planning functions, but if this is to occur then the GI capabilities must be extended. The end-user governance structure must also be adapted from rudimentary evaluations and to support continuous dynamic evaluation to better facilitate Emergency Manager's GI requirements. By incorporating continuous evaluations into internal management, yearly summative evaluations can be supported by identifying problematic patterns during specific incidents, and thus action can be taken to alleviate the same patterns from re-occurring.

7.3 Governance input

From Chapter 5, the main pattern from LCMS end-users was to see more communication to support and review understanding between them, the external partners, and the LCMS technical community (developers). The GII is gaining more prominence within the work processes of general practitioners of GI, therefore the infrastructure must adapt to accommodate and understand the requirements of these end-users. This group of "non GI specialists" accounts for the majority of LCMS end-users, and the perception that they hold of the information system holds significant influence of the trust that is built up around it.

Currently LCMS has two user networks, one composed of functional managers, and one for determining what net-centric coordination should look like. IFV fully understands that taking the perspective of end-users by definition is important, especially if LCMS is going to be the crisis management infrastructure then all end-users need to have their weight felt in developments. What makes structuring this input from end-users difficult is that, at present, there is a multi-layered governance structure and an increasing user base which increases the complexity year after year.

An issue raised by IFV is how to make governance manageable to involve each and every end-user without ending up in disarray? De Haes & Van Grembergen (2015a) discuss that evaluative efforts must be enforced by management, but evaluation must be conducted by the people responsible for the function of the specific focus to gain greater insights, resulting in evaluation efforts being removed from management and the movement towards more effective governance.

The current governance structure for LCMS composes of user groups and is connected by functional manager representatives in each Safety Region. There is on-going work on a mechanism to connect external partners on a higher level, who are currently regarded as "second-hand users". A holistic II evaluation that includes the assessment of the SDI, directed at the specific actor roles (including external partners) after the use of LCMS within an emergency incident can potentially contribute to identifying problematic patterns held within the crisis management infrastructure. Thus, allowing management to monitor and direct future actions based on evaluations weighted from end-users to aim for a more effective and efficient information sharing network.

IFV are the linking pin between end-users and the developers of LCMS, but there is no direct communication between System 1 (end-users) and System 4 (developers). The governance structure of the VSM underpins communication as a fundamental principle for empowerment within an integrated network, and is necessary for supporting the links between the individual parts. Espejo & Gill (1997) justify that communication ensures an organisation, and in this case the SDI network, can remain adaptable and in balance between internal and external perspectives. Communication from System 1 to the meta-system is a "prerequisite for viability", and effective evaluations and reporting structures between them can allow management to monitor communication and to place a degree of accountability to keep management in touch with the organisational processes.

IFV noted that Safety Regions should invest in more robust learning cycles that can contribute to LCMS development. This vindicates that a governance structure within the Safety Regions can be strengthened to ensure evaluations and reporting structures on network scenarios becomes an active operational process. Recursive VSM governance can ensure that the Safety Regions can manage and report on their own respective information networks, while remaining in balance with the national objectives for information sharing through effective communication & evaluative structures. In order for the Safety Regions to remain in balance with the national net-centric goal, the implementation of a holistic governance structure for evaluating the II after an emergency incident can ensure and better direct the SDI network to get the involved people to work together more cohesively.

Both the interview participants and IFV agree that System 3 (internal management) within the Safety Regions of the LCMS network can make improvements to reviewing and supporting information management. A transparent holistic governance structure to evaluate performance and identify problematic patterns must be clarified to all Safety Regions to fill this assessment gap, which is currently lacking from the conducted analysis. ISO/IEC 38500 proposes that governance processes to be organised by an EDM model (Evaluate – Direct – Monitor) which can ensure that II network objectives are achieved (De Haes & Van Grembergen, 2015a) by evaluating:

- Stakeholder requirements
- Rights, roles, & responsibilities
- Work processes
- Monitoring performance
- Compliance & progress against plans

7.4 Maturity Model

From Chapter 6 the infrastructure was explored in trying to align the SDI with I.T. governance, and a maturity model was developed to assess the level of communication between end-users and stakeholders. The maturity model was tested with IFV (System 4) to gather information on their perception of the infrastructure, but a significant limiting factor was the lack of input into the maturity model from actors within the other governance sub-systems (Systems 1-3). The maturity model was assessed qualitatively and therefore there is a lack of empirical testing on the model, and a lack of multi-perspective input from the different network components.

7.5 Summary

To summarise on governance, the components of the VSM allow an organisation to be flexible as the model is recursive. This can allow an organisation to remain in balance with monitoring and evaluating its own organisational processes, and with its overall SDI network performance.

To better facilitate Emergency Managers in the future, an increase of holistic EDM practices across all Safety Regions can provide better insights than any single observation from within one Safety Region on the value spatial data provides to emergency response. This can be facilitated by providing Safety Regions with evaluation and monitoring tools so that specific actors can produce information to the greater LCMS network on their specific organisational processes and compare practices on a national level. Such a framework will allow net-centric developers to better direct actions in the future from identifiable patterns occurring within the LCMS network.

Chapter 8

Results

8.1 Introduction

In the final chapter of this research, we will interpret the amalgamated information to answer the initial research questions set out at the start of the study. Limitations associated with the project will be discussed, as will future research possibilities.

8.2 Results on research questions

The structure of design science (Hevner et al., 2004) was used to decompose the socio-technical issue into manageable proportions. The decomposition of questions will be looked at before reflecting on the main research question.

Q1 What is the value of inter-organisation information exchange for emergency response and what mechanisms encourage the use of Geo-ICT? *(Chapter 2)*

Here it was identified that GI is the initial input to spatially orientate a coordinated response. The level of information necessary to assess the influence an incident may have on society has essentially no limits, and therefore no single organisation can effectively manage all of the required data to produce significant information. Therefore for critical infrastructure and organisations to tolerate risk, there is an incentive to coordinate networked information sharing.

Q2 How is GI currently used by Dutch authorities, and how does GI help support Emergency Managers in the accomplishment of their emergency response tasks? *(Chapter 3)*

The Netherlands has a contingency plan defined for emergency management known as the GRIP structure which is utilised when there is recognition for a greater level of coordination needed amongst the involved crisis partners. GI is a fundamental tool used to support spatial orientation of information and of decision making processes. There is a GI information warehouse known as the Geo4OOV server which is accessible with the use of LCMS. LCMS is the primary information platform used by emergency partners to coordinate, share, and access GI through the use of a COP.

Q3 How can we capture and identify factors that impede/facilitate GI sharing between multiple organisations and actors? What are the recommended theories? *(Chapter 4)*

The VSM and SDI model were used in conjunction with one another to focus on the particular SDI resources affecting an end-user from their own perspective. The resulting methodology was essentially a GI network analysis that assessed the factors that enable and obstruct GI sharing. The VSM was found to help alleviate the complexity associated with SDI analysis by focusing on the necessary sub-systems for the SDI to remain a viable system as a whole. The VSM proposes definitive boundaries for a SDI network by focussing on the sub-system functions for a SDI network to remain viable, irrespective of the organisational structure.

Q4 ***What are the informational needs of Emergency Managers, what are their tasks, and in what formats are data/information currently gathered, processed and shared between them and Emergency Responders?*** *(Chapter 5)*

From the interviewed actors within the emergency response infrastructure, the perceived level of how information sharing currently works has significantly improved since the introduction of the net-centric way of work. The infrastructure has moved from the generation of situational reports within specific teams, to being able to distribute information instantaneously across a horizontal plain to involved partners. With this new platform for information sharing, the use of GI has significantly increased which has seen the development of a Geo-Information warehouse (Geo4OOV) being utilised through LCMS to support the net-centric COP.

The majority of LCMS users are "general practitioners" of GI, and the infrastructure must be able to assess and review their requirements as they hold influence over the perception of value that LCMS brings to the operational processes. GI users of LCMS are campaigning to have more influence of what is available to them within the geo-catalogue, and "general practitioner users" are also requiring for improved and extended usability of Geo-ICT capabilities.

Q5 ***How does the current infrastructure compare to the ideal situation (from the perspective of interview participants), and does it facilitate the identified informational requirements?*** *(Chapter 6)*

The current infrastructure for sharing and coordinating GI was analysed from the basic laws of the VSM. Systems 1 (operations) and 2 (coordination) of the VSM are currently functioning to allow users within the LCMS system to use and share GI. System 3 (internal management), responsible for reviewing and supporting SDI operational performance within the individual Safety Regions, was determined absent from the conducted analysis due to the lack of evaluative efforts after an emergency incident had occurred. Simultaneously, System 5 (system policy/guidelines) was found to be slowly developing as the communication between System 1 and 3 was determined absent, and this has a knock-on effect to the quality of communication between System 3 & 4 (future planning), which results in the constraint development of System 5.

The Ideal situation would see System 3 promoting evaluative efforts targeted towards the all actors within the infrastructure, and for evaluations to be conducted by actors responsible for their specific roles. This process would see the level communication on user needs and performance to greatly increase, as with System 3 & 4's ability to determine measurement criteria and identify patterns that impede and facilitate II and SDI development. Overall the end result of the Ideal situation would see an increase in the viability of the LCMS network as a whole according to the laws of the VSM, and facilitate the LCMS network to identify their informational requirements more effectively.

Q6 How can we better facilitate the informational needs of Emergency Managers? *(Chapter 7)*

Factors of GI semantics, inter-human, and inter-team differences in working with GI were factors found to slow down SDI development within the LCMS infrastructure. What is needed is not only to be able to capture the difficulties that the infrastructure possesses, but to also be able to identify difficulties as patterns so that holistic systemic measures can be taken to alleviate problems from re-occurring in other parts of the infrastructure in the future.

Current evaluative measures are practiced once a year to reflect on the crisis management infrastructure. By enabling internal management within all Safety Regions (with a defined systemic evaluation structure) to support and review the operational processes relating to their II and SDI, can provide an increase in the capacity for Safety Regions to not only manage their own LCMS network, but to report and identify problematic patterns that may be occurring within other Safety Regions. This process involves moving from summative evaluation to continuous and developmental evaluation to facilitate an adaptive and growing infrastructure. It was recommended that a holistic EDM model across all Safety Regions can evaluate and monitor the value that GI brings to the operational processes after the occurrence of an emergency incident, to aid the direction of future policy and guidelines for the system. Thus, the infrastructure is better facilitated in the understanding of user requirements from multiple end-user perspectives.

8.3 Conclusions

GI in ER needs to be managed by a conglomerate of organisations in an organised network for effective coordination. The SDI model is a governance structure relating to GI but comes under criticism due to ill-defined boundaries when being placed within an organisational structure. The VSM can be used as an effective tool to focus on the required resources needed for the particular functions a system or network needs to accomplish in order to remain viable. Thus, the VSM is able to propose definitive boundaries of a SDI network based on the VSM sub-systems. Such an approach was utilised in order to capture the GII for emergency response. The main research question set out to answer:

"To what extent do the current procedures to collect, organise, disseminate and analyse geo-information during the response phase of an emergency match the needs of Emergency Managers in the Netherlands, and how may a mismatch be overcome to facilitate these informational requirements?"

GI is primary utilised during an emergency once the incident has been defined as a GRIP level, to support coordination and sense making through the use of COP for all the involved crisis partners. On-scene GI mapping of an incident is achieved through verbally sourced information passed onto the COPI from the operational level. The tactical level relies on its SDI network to assess the greater extent an incident may have on society and critical infrastructure, while also collecting dynamic information on the progression of an incident from the operational level, and other dynamic sources such as social media.

GI is an important component to the emergency response infrastructure in the Netherlands, yet it was found to be an absent constituent of internal review within the Safety Regions. The inclusion of a holistic review structure can provide insights into identifying problematic patterns, and acknowledge the value that GI brings to the operational processes to allow the future planning of the infrastructure to better facilitate Emergency Manager's informational requirements.

8.4 Limitations & future possibilities

The main body of information for this research was obtained from qualitative actor analysis, and was reliant on participant's perceptions, experience, and objectives. Therefore such an analysis only provides a snapshot into the problem perception as findings are only relevant for a short period of time, or when the next significant change is influenced on the infrastructure.

There was a lack of empirical testing and lack of multiple perspective input from all sub-systems within the maturity model, so it cannot yet be claimed that it covers the full spectrum of SDI governance alignment. There may have existed bias within the researcher when examining the participants, and although much attention was giving to this area in order to limit research bias, it cannot be excluded from the limitations of the study.

For SDI research, the VSM works rather well to place SDI resources in context within a network, and thus brings more structured clarity to the resources necessary for the functioning of a SDI network. The research conducted in this study only begins to touch upon the field of cybernetics, as the VSM has its own language, laws, and rules of system structure. Further research may look at SDI network governance and delve deeper into the necessary GI related resources to better align SDI with the II.

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Appendix 1.

Interview structure

The objective of this research is to evaluate the use, communication and exchange of geo-information between multiple organisations (tactical level) and emergency responders (operational level) within the Netherlands. The type of crises will be correlated to the GRIP structure to assess when spatial technology becomes useful and where difficulties with information sharing begin. The methodology will be conducted through a User-Needs Analysis to assess the flow of geo-information in order to highlight the informational needs of emergency managers.

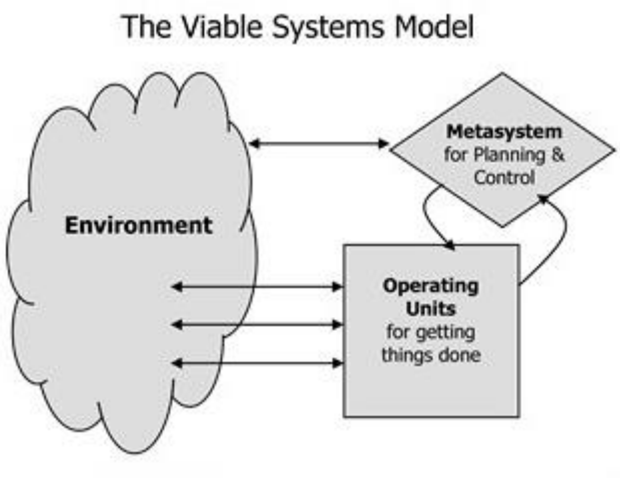
Part of data collection will be undertaken through semi-structured interviews and will be carried out in compliance with the Charter of Fundamental Rights in the European Union, Article 8 (concerning the protection of personal data). All data collected is to be made anonymous, and a consent form will be issued to all participants before an interview to outline:

- Participation is voluntary.
- Participants can ask questions & will receive answers before deciding on their participation.
- Interviews will last ~60 mins.
- There is no degree of risk & burden involved in participation.
- Participants have the opportunity to express and discuss their needs for information sharing, and provide feedback as experienced professionals in the venture to tailor and improve their respective work processes.
- Data will be collected, protected during the project and either destroyed or re-used at the end of the research.
- Participants can withdraw themselves & their provided data at any time during the research.
- Participants have the option to review how their data is used before the final submission of the thesis.

The main focus of the interviews will be to assess: What are the informational needs of Emergency Managers (tactical level), what are their tasks, and in what formats are data/information currently gathered, processed and shared between them and Emergency Responders (operational level)?

Interview part 1

The first part of the interview will be to get the participant to map out their role within the disaster management infrastructure and to use the diagram as a heuristic tool for the rest of the interview. Such a diagram can be visualised in its basic elements as:



To help the participant to identify their surrounding infrastructure with respect to geo-information and to map out the infrastructure from their perspective, the following questions will be asked in relation to the Spatial Data Infrastructure (SDI) product-based model**:**

- What information, from a disaster event in GRIP level (x), do you need and use to perform your job responsibilities?
- What information do you use when making decisions in GRIP level (x)?
- Where does this information come from and how do you get it?
- Where is this information stored once you have it?
- Who looks at the information with you?
- Who needs/requests information from you?
- Is the information you gather, information you would routinely share within your organisation?
- How does the information sharing currently happen?
- Do you keep a record of how the information guides your decision-making processes?

Interview part 2

Once the infrastructure is mapped out, and the participant is satisfied, additional questions will be directed at the work processes in creating and moving geo-information across the identified communication channels from the heuristic diagram. Depending on the participant's role and in which level of the operations identified problems may vary. Questions to identify work processes between a communication channel, from **part 1,** follow as:

Q1. How is the communication of geo-information maintained?

- What are you trying to achieve?
- How is it being achieved?
- Which activities have to be done to create/move geo-information?
- Can you describe the process from start to finish?

Q2. Are there self-improving or self-assessing processes (measurable KPI's or CTQ's) in place to monitor/manage work processes?

- **If yes**: Do they work?
- Do these processes require an evaluation themselves?
- Are improvements that are recommended by evaluations monitored?
- How often are agreed upon standards reviewed, and by whom?

Q3. Where do you spend most of your time?

- Where do you repeat work within the process, an how often?
- What parts of the process would you like to eliminate, and why?
- When time is crucial, what parts of the process do you skip or work around?

Interview part 3

The interview will finish with **part 2**, and the participant will be asked to commit to filling in an on-line questionnaire which will analyse the use of spatial data for disaster management. The participant can fill out this questionnaire in their own time but a deadline will be set for December 18th.

Interviews are being targeted for and between: **November 9th –December 18th 2015**.

By identifying the bottlenecks in current work processes and by understanding the way geo-information is used in collaborative efforts, between the Safety Regions (e.g. ROT) and emergency responders (e.g. COPI), the identified work processes can ultimately increase the efficiency of the entire operational effort. The intended outcome of the project is to provide information to emergency managers, researchers, and system developers on how geo-information is used and shared in practice. By understanding how data and technologies are used within the crisis management infrastructure can provide an insight in how to improve the efficiency of data usage, thus leading to better data governance.