**NATIONAL TECHNICAL UNIVERSITY OF ATHENS**

**SCHOOL OF RURAL AND SURVEYING ENGINEERING**

**DEPARTMENT OF GEOGRAPHY AND REGIONAL PLANNING**

# Decision Support Systems for Participatory Flood Risk and Disaster Management

**Panayiotis Sophronides**

A dissertation submitted in fulfillment of the requirements for the degree of
Doctor of Philosophy of the National Technical University of Athens.

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# Decision Support Systems for Participatory Flood Risk and Disaster Management

by

Panayiotis Sophronides

who holds

a Diploma in Rural and Surveying Engineering of
the National Technical University of Athens, 2010

and

a Master of Science and a Diploma of Imperial College in
Hydrology and Water Resources Management, Imperial College London, 2011.

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Advisory Committee in charge:
Professor Maria Giaoutzi (Supervisor), National Technical University of Athens
Professor Henk Scholten, Vrije Universiteit Amsterdam
Professor Demetris Koutsoyiannis, National Technical University of Athens

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Decision Support Systems for Participatory Flood Risk and Disaster Management

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Multi-layered water safety, geodesign, flood risk communication and management, virtual 3D city models, open data standards, 3D information system, flood emergency response, shared situational awareness, common operational picture, network-enabled capabilities, network-centric information systems, information quality, system quality.

«*Πάντα πάντα περνάς τη φωτιά για να φτάσεις τη λάμψη.*
*Πάντα πάντα τη λάμψη περνάς*
*για να φτάσεις ψηλά τα βουνά τα χιονόδοξα*».
Οδυσσέας Ελύτης, Το Άξιον Εστί, Τα Πάθη, Ε’ (1959).

«*Always you pass through fire to reach the glow.*
*Always you pass through the glow*
*to reach the high snow-resplendent mountains*».
Odysseas Elytis, The Axion Esti - It is worthy, The Passion, Psalm V (1959).
Translated by Jeffrey Carson and Nikos Sarris (1997).

## Preface and acknowledgements.

This PhD thesis entitled “Decision Support Systems for Participatory Flood Risk and Disaster Management” purports to critically review the existing knowledge and to identify and propose innovative solutions towards improving situational awareness for better supporting decisions for flood risk and disaster management. The thesis is consisted of two theoretical and two empirical studies. The first theoretical study (chapter 2) includes a literature review on multi-layered water safety and a theoretical systematization of this integrated flood risk management approach in a thorough, multidisciplinary and collaborative methodology for complex problems solving inspired by geodesign towards improving situational awareness, cooperation and decision making. The second theoretical study (chapter 4) through an extensive literature survey across disciplines explores the contribution of a common operational picture in improving situational awareness for emergency response operations. The first empirical study (chapter 3) investigates the information potential of virtual 3D city models and it exploits their capabilities by developing a virtual 3D city model for Heerhugowaard case study area in the Netherlands. Furthermore, it conceptualizes a 3D information system based on virtual 3D city models and extended by open international data standards towards defining a system framework capable to support situational awareness for effective flood risk management and emergency preparedness. Finally, the second empirical study (chapter 5) organizes a field exercise with realistic flood scenarios and the participation of professionals for measuring the added value service of network centric support tools in achieving shared situational awareness based on a common operational picture for  flood emergency response.

This PhD thesis has been a long research journey full of knowledge, full of experiences, “full of adventure, full of discovery” to recall Ithaka (1911) of the eminent Greek poet Constantine P. Cavafy. Furthermore, it has been a remarkable opportunity to unwrap my potential and spearhead innovation in a creative endeavor. An endeavor inspired by my personal vision to serve and promote the science of engineering and research towards contributing to the protection of human life. This thesis through its findings aspires to reinforce society in its battle against floods which are the most common and dominant natural hazards causing a lot of human fatalities, enormous social disruption, environmental and economic impacts worldwide.

At this point, I would like to express my deepest gratitude to all those who believed, supported and encouraged me during the course of this PhD thesis. First and foremost, I would like to thank my PhD thesis advisor and mentor Prof. Dr. Maria Giaoutzi whose prominent academic quality, talent and enthusiasm, scientific value and human status strengthened substantially my personality in academic and personal level. I am indebted to Prof. Giaoutzi who has been for me an inexhaustible source of knowledge and wisdom during this long research journey. I thank her for teaching me how to look at the essence of the things, I thank her for believing in my potential, I thank her for giving me the opportunity to become a doctor of engineering under her supervision but above all I thank her for being a spiritual motivator and good friend.

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## 5. AN EMPIRICAL APPROACH TO THE ASSESSMENT OF THE EFFECTIVENESS OF NETWORK-CENTRIC SUPPORT TOOLS FOR FLOOD EMERGENCY RESPONSE: RESULTS OF A FIELD EXERCISE……………………………………………………………..…… 105

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## Introduction.

This PhD thesis aims to identify, explore and propose innovative solutions towards improving Situational Awareness (SA) for better supporting decisions for flood risk and disaster management. Firstly, the thesis concentrates on identifying how geodesign can contribute to the improvement of SA and decision making in regards to optimal water safety in a particular area of interest. Secondly, the thesis focuses on exploring how 3D information concepts through their information and communication potential can improve SA which in turn can support better decisions for efficient flood risk management and emergency preparedness. Thirdly, the thesis focuses on the investigation of the added value service of introducing network centric information systems to the safety agencies for better supporting the achievement of SA based on a common operational picture, that can lead to better decisions with better effects in the flood emergency response domain.

The thesis is consisted of both theoretical and empirical studies. A presentation of the six chapters of this thesis follows:

*Chapter 1*: It offers a literature review on the disaster management cycle along with its different stages and it briefly introduces and discusses novel information concepts towards achieving SA in support of decision making for flood risk and flood disaster management. Motivated mainly by these, it presents the research aim, objectives and structure of the PhD thesis, proceeding with previewing the subsequent chapters and results of this dissertation.

*Chapter 2*: It provides a literature survey on the Dutch multi-layered water safety concept and it theoretically systematises the latter in a geodesign framework towards improving situational awareness, collaboration and decision making.

*Chapter 3*: It employs a case study area in the Netherlands for exploring the usefulness of virtual 3D city models in flood risk communication and management. Furthermore, it conceptualizes a 3D information system based on virtual 3D city models as a step towards defining a system framework for flood risk management and emergency preparedness.

*Chapter 4*: It delivers a literature survey on the contribution of a common operational picture in improving SA and it investigates how this can be employed by the emergency services in their response operations.

*Chapter 5*: It organizes a field exercise with realistic flood scenarios and the participation of real emergency response professionals. In addition, based on constructs about information quality and system quality identified through an extensive literature survey, it reports the results of an empirical analysis regarding the effectiveness of network centric information systems in flood emergency response operations.

*Chapter 6*: It concludes by summarizing the main results of this dissertation along with their implications, proceeding to recommendations for public safety policy makers, professionals and researchers.

In the appendices of this thesis, the questionnaires (in Dutch) about information and system quality that have been answered by the participants (real emergency response professionals) of the field exercise of this dissertation are provided.

# 1. SETTING THE SCENE.

Although flood risks and flood disasters are related to each other, they are not the same. In this context, the chapter purports to shed light on these concepts presenting a widely acceptable perspective of the disaster management cycle along with its different stages. Thereafter, it briefly introduces novel information concepts towards achieving situational awareness for supporting decision making at different stages of the disaster management cycle. In view of this, the thesis is motivated to research how situational awareness can be improved towards better supporting decisions for flood risk and disaster management. The remaining of this chapter presents the research aim and objectives of the thesis. Finally, it delineates the structure of this dissertation, providing a preview of its chapters and results.

## 1.1 The flood disaster management cycle.

Flood hazards are the most common and catastrophic of all the natural disasters which cause each year devastating socioeconomic and environmental impacts as well as many casualties around the world (Leskens *et al*., 2014; Mayomi *et al*., 2013; Espada *et al*., 2012; Tingsanchali, 2012; Vanneuville *et al*., 2011). Furthermore, floods have the highest occurrence frequency among all the natural disasters (Leskens *et al*., 2014; Chang *et al*., 2007). Population growth, urban expansion and increase in wealth are among the major causes for increasing economic losses in flood-prone areas (Koks *et al*., 2014; Bouwer, 2011; Nicholls *et al*., 2008). In order to deal with floods, it is important to review the main concepts of the disaster management cycle.

In general, the disaster management cycle (see figure 1.1) accepted by several agencies worldwide is consisted of four phases: mitigation, preparation, response and recovery (Vanneuville *et al*., 2011; Zlatanova and Fabbri, 2009; Lumbroso, 2007). The concept of flood disasters has been approached from various disciplines such as hydrologists and geographers among others (Oruonye, 2012). Furthermore, denotation of terms in the context of flood disaster management often varies depending on the sector in which is applied (Coste, 2001). For example, the terms risk management, hazard management, disaster management, crisis management are found interchangeably (Zlatanova and Fabbri, 2009). This thesis considers the first phase of the disaster management cycle as the risk management process while the last three as the pillars of the disaster management.

Although flood risk and flood disaster are related to each other, they are no synonyms. Lumbroso (2007) distinguishes between risks and disasters in terms of impact. In particular, while risk is associated with any measurable consequence, a disaster signifies a large or catastrophic event. Vanneuville *et al*. (2011) consider that flood risk management applies to a wide range of events while flood disaster (emergency) response attempts to minimize the impacts from a particular flood disaster. The following example is characteristic of the difference between flood risk and flood disaster management. When flood risk drops below a certain threshold, additional measures can be considered superfluous in the risk management process. During a flood disaster every plausible measure and action is justifiable towards minimizing its adverse consequences. Nevertheless, the picture is not black and white as flood risks and flood disasters are interconnected. In particular, flood emergency response and preparation phases are supported by the outcomes of flood risk management. Furthermore, risks are inevitable in the sense that even optimizing the results of risk management towards achieving better safety situations, there will always be a residual risk (Grothe *et al*., 2005). Nature cannot be controlled and since one can hardly predict when and where the next emergency situation will strike (Borkulo *et al*., 2005), the subsequent phases of the disaster management cycle, i.e. preparation and effective response, they are of utmost importance for minimizing the consequences of a potential flood.

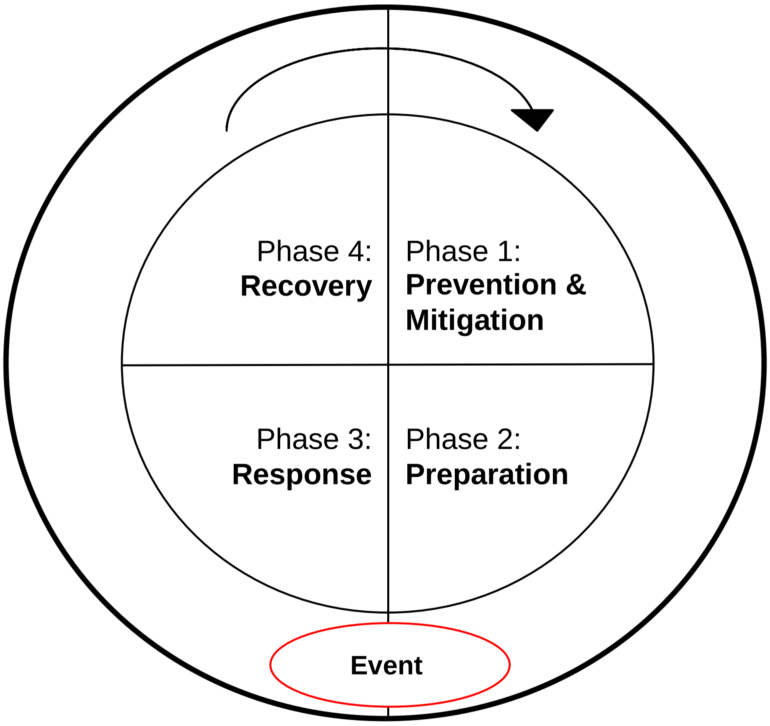

Figure 1.1: Disaster management cycle.

(Adapted from Lumbroso, 2007)

In short, the four phases of disaster management cycle are interrelated, but simultaneously, they have their own distinct characteristics. Zlatanova and Fabbri (2009) describe them as following: *Prevention and mitigation* concentrates on measures in the long-term horizon capable to reduce vulnerability and/or exposure to flood hazards towards minimizing flood risks; *Preparation* is about framing the institutional and organizational arrangements which underpin the emergency response operations. Furthermore, this phase deals with preparation activities which include evacuation plans, early warning systems, temporary physical measures, training sessions, preparatory field exercises. *Response* operations take place after the occurrence of a flood event and it is the most challenging phase of the cycle due to the complex, unpredictable and dynamic nature of emergencies; *Recovery* is the phase after the response operations and in particular after the normalization of an emergency situation. It includes all the required measures for removing damages as well as the long term supply of irreversible detriments.

For successful flood risk and disaster management, spatial information is of critical importance. Flood risks require static and model information for statistics (Vanneuville *et al*., 2011) while flood emergencies need semi-static, model and most importantly real time information for the response operations (ACIR, 2005). In particular, emergency response operations are defined by the actual situation. For instance, the actual number of the inhabitants during an emergency defines the number of evacuations in a particular area of interest. On the contrary, in risk management, what matters is the average number of inhabitants over a year.

Risk management can be considered to be explicitly spatial discipline while disaster management is even more implicitly spatially-oriented (Zlatanova and Fabbri, 2009). Typical applications in both risk and disaster management are tied to a possible large geographical area (Björkbom *et al.*, 2013) and thus awareness of the importance of spatial information is crucial (location awareness). Furthermore, the entire disaster management cycle depends on large volumes of information of high-quality that various safety agencies create and maintain (Oosterom *et al*., 2005). Therefore, information should be effectively shared and exchanged via geo-information and communication systems within the entire disaster management cycle.

## 1.2 Novel information concepts towards achieving situational awareness in support of decision making.

Situation Awareness (SA) is a complex concept and therefore it is hard to define the term (Sandom, 2012; Charness, 1995; Hopkin, 1995). However, Endsley (1995) proposed a definition of SA which is widely applicable across different domains and disciplines and it has been highly cited and highly influential in cognitive science research (Steenbruggen, 2013; Sandom, 2012; Yin *et al*., 2012; Roy, 2007). Based on the role of SA in human decision making in dynamic systems, Endsley's definition suggests that this is "the perception of elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future" (Endsley, 1995). Although SA is rooted in the military domain, it has been recognized as a critical part of making effective decisions in emergency response (Madey *et al*., 2006; Blandford and Wong, 2004) and risk management (McLucas, 2003). For achieving SA, an appropriate set of perception elements have to be identified and coupled with higher level comprehension patterns and forecast operators (Yin *et al*., 2012).

### 1.2.1 3D information concepts to support situational awareness.

Risk management is one of the key foundations of disaster management cycle. It provides inputs for decision making and simultaneously it purports to increase risk awareness among stakeholders (US Department of Health and Human Services, 2002). Risk communication is at least as important as the risk assessment (Kemec *et al*., 2010a). In this context, the three dimensional visualization of natural disasters in an area of interest, it has seen significant growth in the last few years (Bandrova *et al*., 2012). Although stakeholders formulate risk management measures that often have a 3D component (e.g. elevation of constructions) without realizing it, it is much more effective when their decisions are aided by 3D visualizations. According to the experiment of Treichler (1967), most of the information received by humans is by the sense of sight which indicates that information visualization is important for communication and information distribution (Wu and Hsieh, 2012; Lu *et al*., 2012). Effective visualization support people to efficiently obtain the required information (Lu *et al*., 2012). Furthermore, increase of realism and dimensionality can increase awareness of a particular situation (Kibria *et al*., 2009).

An increasing number of applications is based on 3D geo-information (Stadler and Kolbe, 2007). Availability, management and presentation of geospatial information, play a pivotal role in the management of risks. However, information has to be represented within a consistent framework such as a virtual 3D city model (Döllner and Hagedorn, 2008). In this context, virtual 3D city models are applied for risk management (Stadler and Kolbe, 2007; Shiode, 2001; Döllner *et al*., 2006a) forming a firm ground for 3D decision support systems (Döllner *et al*., 2006a). They represent spatial and geo-referenced data, allowing up-to-date and flexible access to 3D city models which is of critical importance for risk management (Zlatanova and Holweg, 2004). Furthermore, 3D city models can serve as a medium to manage, integrate and distribute complex geo-information based on a uniform communication metaphor, the virtual 3D city model. In particular, virtual 3D city models enable visual integration of heterogeneous geo-information within a single framework and thus they can create and maintain complex information spaces (Döllner *et al*., 2006a). In short, virtual 3D city models are key components of geo-information infrastructures providing important information of different aspects of the disaster management cycle (Kolbe *et al*., 2005).

In risk management, the required data is derived from distributed sources which are often thematically and spatially fragmented (Stadler and Kolbe, 2007). Furthermore, in risk management, only 3D geometry and appearance information is not sufficient, as for querying and analysis applications complex semantic data is required. Data standards can provide a high degree of interoperability (Döllner *et al*., 2006a) and also they can facilitate seamless data integration and explicit determination of semantics. In this way, massive, heterogeneous and distributed risk related data from different domains such as GIS and BIM can be integrated into virtual 3D city models towards supporting awareness of flood risks situations. 3D information systems based on 3D models can act as effective tools for decision support during the risk management process by enabling dynamic adaptations of the focused aspects of a discussion; by allowing variations in the visualizations as well as by supporting investigations at different scales. Therefore, 3D information systems have the potential to stimulate awareness of a particular flood risk situation towards supporting stakeholders to obtain a clearer perception of the characteristics of hazards, potential pathways and receptors which their linkage imposes risk.

### 1.2.2 A common operational picture to support situational awareness.

One of the main causes of organizational failure in emergency response is the lack of shared SA (Sapateiro and Antunes, 2009; McManus *et al*., 2007). Therefore, constructing and maintaining SA is instrumental in the success of decision making during the different phases of the disaster management cycle and most especially in the response operations. In this context, a Common Operational Picture (COP) has the potential to facilitate the development of SA through depicting all acquired and shared data derived from several sources in a single presentation to the user (Björkbom *et al*., 2013; Hager, 1997). More simply, a COP can provide information and knowledge about what is going on around its user. Major hurdles for efficient and effective multi-agency disaster management and simultaneously key antecedents for information systems success are Information Quality (IQ) and System Quality (SQ) (Lee *et al*., 2011; Steenbruggen *et al*., 2015). Both IQ and SQ are important requisites for achieving SA.

Disasters' treatment requires information sharing and coordination between several autonomous safety agencies (Bharosa *et al*., 2009a; Bharosa *et al*., 2009b; Bharosa *et al*., 2009c). Network centric systems have the potential to enable efficient information sharing for supporting SA, through the deployment of a COP. In particular, a COP is widely utilized to support SA during network centric operations (Steenbruggen, 2013; Wark *et al*., 2009). The added value service of the network enabled capabilities is reflected in their value chain (see Steenbruggen *et al*., 2012; UK Ministry of Defense, 2005). According to this, in the information domain, better networks can enable better information sharing through constructing a COP which in turn can support better shared awareness of a particular situation that can lead to better decisions in the cognitive domain. Effective decisions are related to better actions with better effects in the physical domain. Nowadays, a growing interest in the introduction and utilization of network centric information concepts has been observed towards improving cooperation between the different safety agencies. The basic idea that underpins such concepts is sharing information once with all via a peer-to-peer network rather than once with each that is the logic behind hierarchical information coordination structures. Nevertheless, information coordination architectures in public safety networks are traditionally based on hierarchy (Bharosa *et al*., 2011; Mackenzie *et al*., 2007; Bigley and Roberts, 2001; Hale, 1997). This can hinder efficient information sharing, communication and cooperation among the several safety agencies and stakeholders.

SA goes far beyond than just reading “dots” on maps (Lambert and Scholz, 2005). SA is related to the psychological, mental and cognitive status of the end user of a system and it is about comprehending the significance of the distributed information in an operational context during the decision making process. There are many factors that can influence SA. According to Harrald and Jefferson (2007), the introduction of concepts such as SA, COP and network centric working from its safety and combat origins to the complex and heterogeneous structure of the safety organizations is extremely difficult and short term strategies based on the assumption that shared SA will be easily achieved are doomed to fail. Therefore the introduction and use of novel information concepts should be done carefully and in different stages with consideration of the human factor and strong involvement of the management of the different safety organizations.

### 1.3 Research aim and objectives of the PhD thesis.

This PhD thesis through its theoretical and empirical foundation aims to identify and explore how situational awareness can be improved towards better supporting decisions for flood risk and disaster management. The associated research questions are listed below:

1. How can geodesign frame the multi-layered water safety towards improving situational awareness and better supporting decisions in regards to achieving optimal flood security measures (Chapter 2)?

2. How can 3D information concepts support information dissemination and visualization towards improving flood risk communication, awareness and management (Chapter 3)?

3. How can novel concepts in information technology contribute to the improvement of information sharing, communication, awareness and co-operation between safety agencies (Chapter 4)?

4. What is the effect of employing network centric information systems in terms of information and system quality towards improving situational awareness and flood emergency response operations (Chapter 5)?

## 1.4 Structure and outline of the PhD thesis.

The PhD thesis is consisted of six chapters and it includes two empirical studies. In figure 1.2, the relationship between the different chapters of this dissertation is delineated.

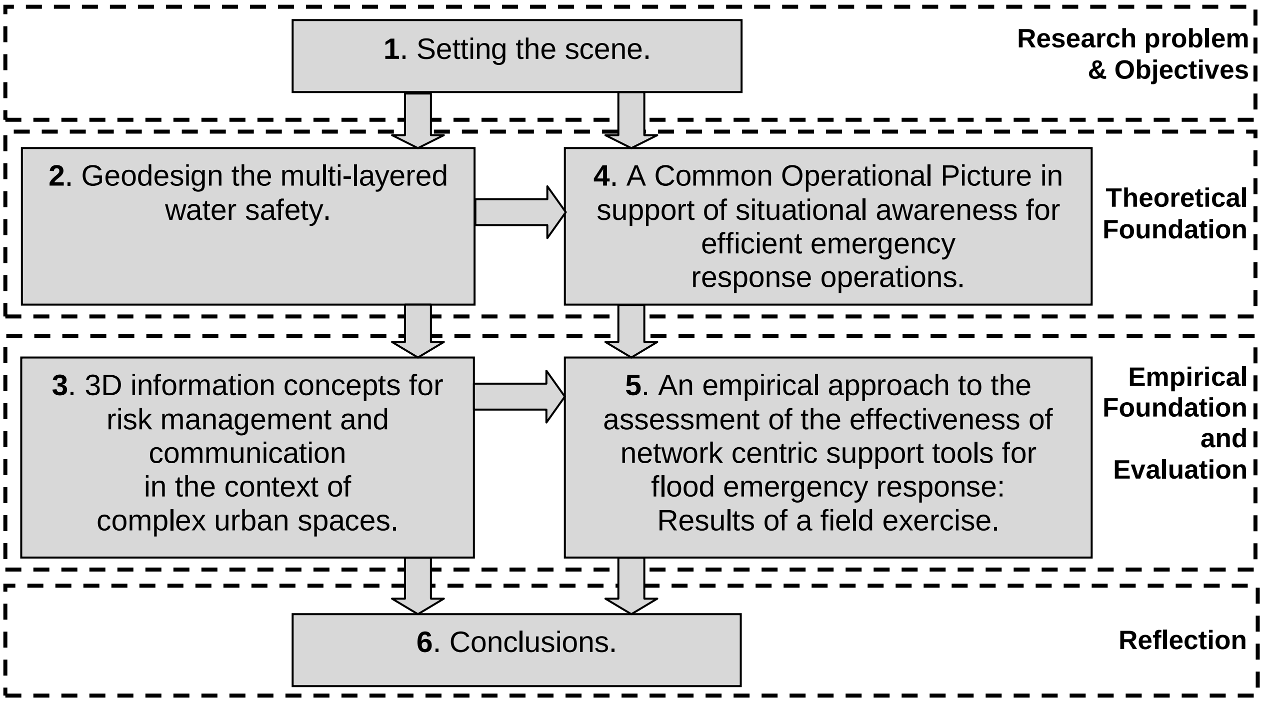

Figure 1.2: Structure of the PhD thesis.

The chapters of this PhD thesis carry out an in-depth research towards improving situational awareness during the different phases of risk and disaster management. Effective decision making relies on access to and interpretation of static and model information in the prevention and mitigation and also in the preparation phase of the disaster management cycle depicted in figure 1.1; while in the response phase, semi-static, model and dynamic information is required. In this context, a common operational picture that can piece together all the required information has the potential to improve awareness of a situation at a particular point of the disaster management cycle which can lead to better actions with better effects in the real world. The subsequent four interrelated chapters which are shown in figure 1.3, expand on how decisions can better be supported for flood risk and disaster management.

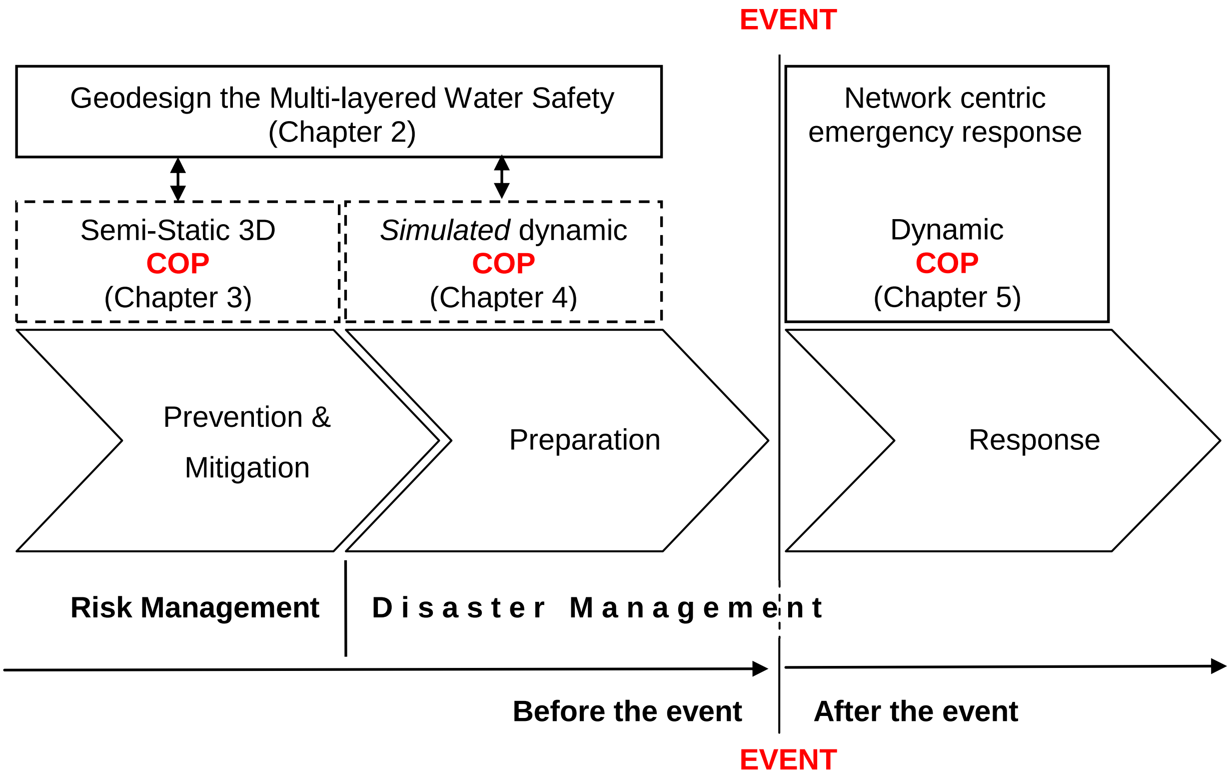

Figure 1.3: Contribution of the PhD chapters to the different phases of risk and disaster management.

***Chapter 2** frames the Dutch multi-layered water safety concept in the context of a systematic, thorough, multidisciplinary and collaborative methodology for complex problems solving i.e. geodesign*. Initially, the chapter describes the main recommendations for flood safety and practices in Europe. In this context, the multi-layered water safety concept which the Netherlands has introduced as a response to the European Flood Risk Directive (2007/60/EC) is delineated and analyzed. In short, this multi-layered water safety is an integrated flood risk management concept which does not base only on flood probability minimization through preventive measures (layer 1) but also on consequences' reduction in the case of a flood event via spatial solutions (layer 2) and emergency response (layer 3). The chapter proceeds with qualitative assessment of the multi-layered water safety concept and it demonstrates the need of a methodological framework that urges stakeholders' participation and active citizenship, experimentation and impact assessment towards reaching optimal combination of safety measures, tailored to the specific characteristics and conditions of an area of interest. Optimal safety measures should not only be based on their economic efficiency but also on their social acceptability. In view of these, the chapter introduces geodesign and outlines geodesign framework and models. Furthermore, it theoretically systematizes the multi-layered water safety concept in a geodesign framework.

The implementation of geodesign indicates that it has the potential to provide awareness of the current situation of a particular area of interest which in turn it may support the allocation of weights regarding the three layers of the multi-tier safety concept. Furthermore, it indicates that participation and interaction of the safety policy makers as well as iterations for achieving maximum consensus between them concerning the more balanced safety measures, taking into account their economic efficiency, their impact on the environment, the local circumstances and the values of the people at place are methodologically enabled.

***Chapter 3*** *provides an overview of novel information concepts through an extensive literature review, organization of a case study and system conceptualization which can contribute to the improvement of risk communication and management*. Firstly, the chapter presents a conceptual model for risk identification and it discusses the needs on risk communication that support stakeholders to become risk aware and participate in the risk management decision making process. Thereafter, 3D virtual city models which reveal high information potential are introduced and their contribution in integrating, managing and communicating complex geo-information for risk management in the urban suburbs is investigated and qualitatively assessed. In this context, a virtual 3D city model for Heerhugowaard area of interest in the Netherlands has been developed. This model can enable stakeholders to obtain dynamic 3D renderings of the flood risk components and their relations and thus it contributes to the achievement of shared awareness regarding a particular flood risk situation. Afterwards, the chapter explores open data standards from GIS (CityGML) and BIM domains (IFC) and it identifies their role in risk management. Building upon the virtual 3D city models, an interoperable 3D information system which utilizes these existing open international standards from GIS and BIM domains is conceptualized and its functionalities are explored in the context of risk communication and management. Such an information system can support both information and communication processes, building capacity for participatory risk minimization, preparedness and response. In particular, it can provide up-to-date information on demand regarding the physical and functional characteristics and relations of the city objects and components at both the city and the facility scale. Furthermore, it has the potential to provide information about the external environment and also about the buildings' interior structures which are important in the management of risks and residual risks as well as in the preparation of evacuation plans for emergency response. Through the employed data standards, the system can enable not only navigation functionalities but also easy-to-use querying and analysis capabilities.

***Chapter 4*** *through an extensive literature survey, it provides an overview of novel information concepts and it investigates how these can be employed in emergency* *response*. Initially, the chapter gives a literature review on natural disasters. Thereafter, it differentiates between incidents and disasters; and it describes in details the different phases of an emergency. Also, characteristic types of delays during the response operations are identified and presented. Afterwards, the design premises for an efficient emergency response system are delineated based on literature. The chapter continues by discussing the network enabled capabilities for information sharing and it demonstrates their added value service in response operations. In essence, this is reflected in their value chain according to which better networks can lead to better information sharing in the information domain which in turn can drive to better awareness regarding a particular situation and better decisions in the cognitive domain. Such decisions can have better actions and effects in the physical domain. Next, situational awareness is reviewed exploring how individual, shared and team situational awareness can be achieved. Then, a background to a common operation picture is provided and challenges in developing such a picture are explored in the context of emergency response operations. The real benefit of creating a common operational picture is theoretically explored and a basis for its quantitative and qualitative measurement is delineated based on literature. In order to cope with the complexity, uncertainty and dynamic nature of an emergency, information, communication, multi-disciplinary collaboration and coordination among the safety agencies aided by flexible information and communication systems is required. A common operational picture achieved through network centric systems is a promising emergency response tool which can contribute to the achievement of shared situational awareness towards faster normalization of an emergency situation.

***Chapter 5*** *reports the results of an empirical analysis regarding the effectiveness of network centric information systems in emergency response operations*. Firstly, the chapter provides the theoretical foundation of the field exercise organized for acquiring the experts' judgment. In this context, a number of constructs suitable for measuring information quality and system quality in emergency response operations are identified and described. The constructs utilized for the field experiment of the chapter are shortlisted and tabulated. Through extensive literature review, it has been identified that information quality and system quality are major hurdles for efficient and effective multi-agency response, simultaneously being key components for the success of information systems. In addition, information quality and system quality are important requisites for achieving situational awareness which in turn is essential for decision making and effective response actions. However, despite the wealth of literature on information quality and system quality in the profit-oriented business environment; research on the quality of information sharing among the various emergency services and the systems used for information distribution in public safety domain where ensuring the public good is of crucial importance is very limited and empirical support is almost non-existent. The chapter proceeds by discussing the hierarchical (traditional) vs. the network centric information coordination structures, identifying pros and cons. Thereafter, the chapter describes the design of the case study. In particular, it delineates the set-up of the exercise; the demographics of the professionals participated in the field experiment; the network centric technology used; the flood scenarios utilized; the experimental protocol and the limitations and assumptions of the case study. Afterwards, the chapter tabulates and qualitatively discusses the results of the exercise i.e. the experts' judgment on selected information quality and system quality dimensions. The main empirical findings of this chapter indicate that the network centric tools seem that they tend to improve situational awareness by enabling better information sharing and by achieving a common operational picture. Nevertheless, the introduction of such concepts to safety agencies should be done carefully and in different stages with strong involvement of the management of the emergency response organizations taking into account organizational structures, institutional rules, norms and most especially the human factor.

***Chapter 6*** *concludes* by summarizing the main findings of this PhD research along with their implications, proceeding to recommendations for public safety policy makers, professionals and researchers that can be drawn from this thesis.

## 2. GEODESIGN THE MULTI-LAYERED WATER SAFETY.

This chapter aims to frame the multi-layered water safety concept in the context of a systematic, thorough, multidisciplinary and collaborative methodology for complex problems solving i.e. geodesign. Multi-layered safety is an integrated flood risk management concept based not only on flood probability reduction through prevention (layer 1) but also on consequences' minimization in the case of a flood through spatial solutions (layer 2) and crisis management (layer 3). It has been introduced in the Netherlands in 2009 following the European Flood Risk Directive adopted in 2007. In this study, the multi-layered safety is qualitatively assessed, demonstrating that it resembles more a parallel system and that collaboration is required for deciding the most desirable safety measures which should not only be based on their economic efficiency but also on their social acceptability. In light of these, the multi-layered safety concept is attempted to methodologically be systematized following the geodesign framework. The latter indicates that through its implementation, understanding of the current situation of a particular area of interest which in turn it may support the allocation of weights regarding the three layers of the multi-tier safety concept is facilitated. Furthermore, the geodesign of the multi-layered safety shows that participation and interaction of the safety policy makers as well as iterations for achieving maximum consensus between them concerning the more balanced safety measures, taking into account their economic efficiency, their impact on the environment, the local circumstances and the values of the people at place are methodologically enabled.

### 2.1 Introduction.

Flood risk management in the Netherlands currently focuses on technical flood prevention measures such as levees and dykes (Moel *et al*., 2013). However, in Europe, flood management is moving towards an integrated risk management approach where measures about exposure and adverse consequences are considered (Büchele *et al*., 2006). This movement is motivated by the European Flood Directive (2007/60/EC) which urges EU member states to adopt a risk-based approach that takes into account potential consequences of floods next to their probability (Kellens *et al*., 2013). In the Netherlands, the multi-layered safety concept which is consisted of three layers i.e. (1) prevention; (2) damage reduction via sustainable spatial solutions and (3) preparation for emergency response has been introduced as a reaction to the European Flood Directive in order to support a flood risk-based management approach (Ministry I & E, 2009). Nevertheless, the application of this concept is still in its infancy and a focus on preventive measures (layer 1) is obvious (Moel *et al*., 2013).

The implementation of the multi-layered safety concept needs the combination of objectives and funding from various policy domains at different spatial scales and for several temporal horizons, the involvement of various disciplines and the collaboration between stakeholders with several interests and means (e.g. Potter *et al*., 2011). Required protection levels may vary between different areas which may have different flood regimes. The optimal solution for Dutch flood safety can be a combination of measures from the three layers that jointly can minimize the overall flood risk (Ministry I & E, 2009). Without discussion and visualization of the impact of alternative water safety measures, their context cannot be understood so that they reflect local conditions and specificities. Furthermore, different stakeholders have different expectations regarding water safety. For instance, residents of a study area may aim to maintain high level of flood security irrespective of economic and environmental costs, technocrats may seek to preserve a significant level of water safety but considering the economic efficiency of the different measures while the public officials may see the same area as a vehicle to implement programs to achieve their political goals.

In the context of multi-layered water safety, a single methodological framework which determines the roles of different stakeholders, promotes dynamic visualization and communication of the current situation, enables the comprehension and evaluation of proposals and permits feedback in the necessary phases does not exist. In order to overcome the lack of methodology, the main goal of this study is to orchestrate the multi-layered safety concept in a geodesign framework-oriented decision-making process (Steinitz, 2012).

This study commences its mission by describing the main recommendations for flood safety and practices in Europe (section 2) followed by the Dutch perspective (section 3). In this context, the multi-layered safety concept is analyzed attempting to demonstrate the need for a methodological framework which stimulates stakeholders’ participation and active citizenship, experimentation and impact assessment in order to reach optimal combination of safety measures tailored to the specific characteristics and conditions of an area of interest. The remainder of this chapter is organized as follows: Section 4 provides definitions of geodesign and outlines geodesign framework and models. Section 5, firstly describes data underlying the multi-layered water safety concept and secondly it attempts to theoretically systematize this concept in a geodesign framework. Finally, section 6 presents the conclusions of this chapter.

## 2.2 Flood safety in Europe.

Floods are the most dominant natural hazards in Europe (Bakker *et al*., 2013). According to European Environmental Agency (2010), only between 1998 and 2009, Europe suffered over 213 major damaging floods, which have caused some 1126 deaths, the displacement of about 500 000 people and at least €52 billion in insured economic losses. However, by taking the right measures their likelihood can be reduced and their impacts can be limited. The need for developing comprehensive European water legislation was initially identified by the council in 1988 which has resulted to bilateral meetings of officials from France and the Netherlands to discuss the integration of European Water policy legislation (Bakker *et al*., 2013). Following an informal meeting in April 1995 between the Netherlands, France, Germany, the United Kingdom and Spain, a joint position paper was drafted which formed the basis for a wider consultation between water directors of all European Union (EU) member states. This process led to the adoption of Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy known as the Water Framework Directive (WFD). Although Europe has already adopted in 2000 WFD which deals with integrated water management, water quality and ecology (EU, 2000), the flood protection is not explicitly faced in it. Thus, a European approach to flood protection was put on the agenda resulting firstly in a Flood Action Programme in 2004 and later in the adoption of the Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks known as the Floods Risk Directive (FRD) (Bakker *et al*., 2013). FRD along with the Hyogo Framework for Action (HFA) which form two key recommendations for the protection of those at risk are introduced and the main safety practices in Europe are explored.

### 2.2.1 The main recommendations for flood safety.

Floods cannot be completely eradicated (Mostert and Junier, 2009) and for this, in the European level attention has been moved from protection against floods to managing flood risks (e.g. Klijn *et al*., 2008; Twigger-Ross *et al*., 2009; Hecker *et al*., 2009; Vinet, 2008; Manojlovic and Pasche, 2008), fact which is reflected in FRD entered into force on 26 November 2007. FRD is the first directive of the EU (Mostert and Junier, 2009) that deals with floods, requiring from the member states to perform a preliminary assessment of flood risks mapping the flood extent, assets and humans at risk, prepare flood risk management plans for the regions under significant flood risk and take adequate and coordinated measures to reduce this risk (EU, 2007). According to the directive, EU member states have to facilitate public participation, reinforcing public rights to access information and related measures about flood risks and to influence the planning process (ICPDR, 2012). In addition, EU member states have to coordinate the implementation of the FRD with the WFD. The driving force for this coordination is that physical flood protection infrastructures are some of the key drivers for determining ecological status of waters with regards to hydro-morphological quality elements (Santato *et al*., 2013). In addition, a number of measures which focus on flood risk reduction can have multiple benefits for water quality, nature and biodiversity as well as in terms of regulating water flows and groundwater restoration in water scarce areas (Brättemark, 2010). In brief, preparation of river basin management plans under WFD and flood risk management plans under FRD are elements of integrated river basin management and thus their mutual potential for common synergies and benefits must be used.

FRM purports to reduce the likelihood and/or the impact of floods on human health, environment, cultural heritage and economic activity (Santato *et al*., 2013). In this context, EU member states should develop, periodically review and if necessary update plans for flood risk management with focus on prevention, protection and preparedness (EU, 2007). Prevention will be feasible via a suitable land use practice which prevents floods' damage by avoiding construction of houses and industries in present and future flood prone areas and by adapting future developments to the risk of flooding (EC, 2004). Furthermore, according to the European Spatial Development Perspective (1999), flood prevention in the major European river catchment areas can only be made effective through the imposition of explicitly defined conditions and intervention in land uses.

HFA along with FRD are two key policies for the protection of communities at risk (Bakker *et al*., 2013). "HFA for Action 2005-2015: Building the resilience of nations and communities to disasters" has been adopted in January 2005 by 168 governments during the World Conference on Disaster Reduction, held in Kobe, Hyogo, Japan and is about building resilience of nations and communities to disasters targeting to make the world safer from natural hazards substantially reducing the disaster losses, in lives and in the social, economic and environmental assets of communities and countries (UNISDR, 2007). HFA is essentially a global blueprint for disaster risk reduction which provides guiding principles, priorities for action and practical means for achieving disaster resilience for vulnerable communities. It focuses on the development and strengthening of institutions, mechanisms and capacities to build resilience to hazards and it encourages the adoption of disaster risk reduction logic in sustainable development policies and planning as well as in emergency preparedness, response and recovery programmes (UNISDR, 2007). For the monitoring of the implementation of HFA, responsibilities are allocated to governments and also to regional and international organizations and partners in the United Nations International Strategy for Disaster Risk Reduction (UNISDR[1]) secretariat. HFA is related to flood risk management, since floods are one of the main hazards which annually affect millions of people all over the world (Bakker *et al*., 2013).

### 2.2.2 Flood maps and safety practices in Europe.

Flood maps are developed by several institutions for a variety of purposes mostly used by the governments for emergency planning (e.g. evacuation) and spatial planning (Moel *et al*., 2009). At the European level, some countries use spatial planning for advisory purposes and some other have binding legislation to employ flood hazard or risk information. The full potential of regulating land use in flood prone areas is often not reached as in many countries flood zones only serve as guidelines or there are practical problems associated with the implementation of binding rules (Santato *et al*., 2013; Moel *et al*., 2009). Except from the planning purposes, flood maps are also utilized in raising awareness, in water management purposes, in flood assessments as well as in the insurance industry. The focus of different European countries in respect to flood safety for which flood maps are utilized is tabulated below (see table 2.1).

Table 2.1: Flood maps and their uses for flood safety in European countries (where information is available).

| **Use by government** | Belgium (Flanders) | France | Switzerland | Netherlands | Great Britain | Romania | Slovakia | Hungary | Ireland | Lithuania | Czech Republic | Slovenia | Germany | Spain | Italy | Finland | Austria | Luxembourg | Poland | Norway | Portugal | Sweden | Latvia |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Emergency Planning | | | ■ | ■ | | ■ | ■ | ■ | | ■ | ■ | ■ | | ■ | | ■ | | | ■ | ■ | ■ | ■ | ■ |
| Spatial Planning (Advisory) | | | | | ■ | | | ■ | ■ | | | | | | | ■ | ■ | ■ | | ■ | ■ | ■ | ■ |
| Spatial Planning (Binding) | | ■ | ■ | | | ■ | | | | ■ | | | ■ | ■ | ■ | | | | ■ | | | | |
| Construction | | ■ | ■ | | | | | | | | | | ■ | | | ■ | | | | | | | |
| Awareness | | ■ | | ■ | ■ | ■ | | ■ | ■ | | ■ | | ■ | | | ■ | | ■ | | | ■ | | |
| Insurance | ■ | | | | ■ | | | | | | | | | | | | | | | | | | |
| Flood assessment/management | ■ | | | ■ | | | ■ | | ■ | | | | | | | ■ | | | | | ■ | ■ | |

(Moel *et al*., 2009)

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[1] The United Nations (UN) General Assembly adopted the International Strategy for Disaster Reduction (ISDR) in December 1999 and established UNISDR, the secretariat to ensure its implementation. The focal point in the UN system for the coordination of disaster risk reduction and the implementation of HFA is the UNISDR office.

## 2.3 The Dutch perspective to flood safety.

For over a millennium, people in the Netherlands have been both fighting against and enjoying the benefits of water from the sea, the major rivers Rhine and Meuse, precipitation and seepage of groundwater (De Lange *et al*., 2014; Ven, 1993). The Netherlands is considered as one of the safest deltas in the world largely focusing on the flood prevention through its defense system. However, an evaluation of the water safety policy demonstrated that the country is not prepared for extreme flooding (Kolen *et al*., 2012). In addition, risk analysis for the Netherlands in 2008 (BZK, 2008) and 2009 (BZK, 2009) demonstrated that although a flood disaster is “highly unlikely”; it is the disaster type with the most catastrophic consequences in case of occurrence. For this, the multi-layered safety concept which is currently the Dutch perspective to flood safety is introduced and analyzed.

### 2.3.1 The multi-layered safety concept for flood risk management.

As a response to the EU FRD, the Netherlands in its National Water Plan 2009-2015[2] has introduced the multi-layered safety concept which bases on the widely adopted recommendations of both the FRD and the UNISDR’s HFA. In essence, the multi-layered safety concept is a three-tier approach to flood risk management (Gersonius *et al*., 2011) which integrates measures for reduction of probability and mitigation of loss in a flood protection system (Tsimopoulou *et al*., 2013). Multi-layered safety reinforces flood protection and operationalizes flood resilience by distinguishing three safety layers: (1) prevention; (2) spatial solutions and (3) emergency response (Hoss, 2010; Tsimopoulou *et al*., 2013; Gersonius *et al*., 2011; Herk *et al*., 2014). It is both a risk-based and a resilience-based approach as it focuses not only on the reduction of the probability of flooding via preventive measures such as dykes’ reinforcement but also on the reduction of the consequences of flooding (e.g. human fatalities and economic losses) through spatial measures and preparedness for emergency response (e.g. emergency management plans) (Rijke *et al*., 2014; Hoss, 2010). Such a framework has been developed in Belgium’s Flanders (Cauwenberghs, 2013). In USA and Canada [see for instance (Lopez, 2009; Lopez, 2006) and (Fraser Basin Council, 2008) respectively] similar approaches are used but called “multiple lines of defense” (Kolen *et al*., 2012).

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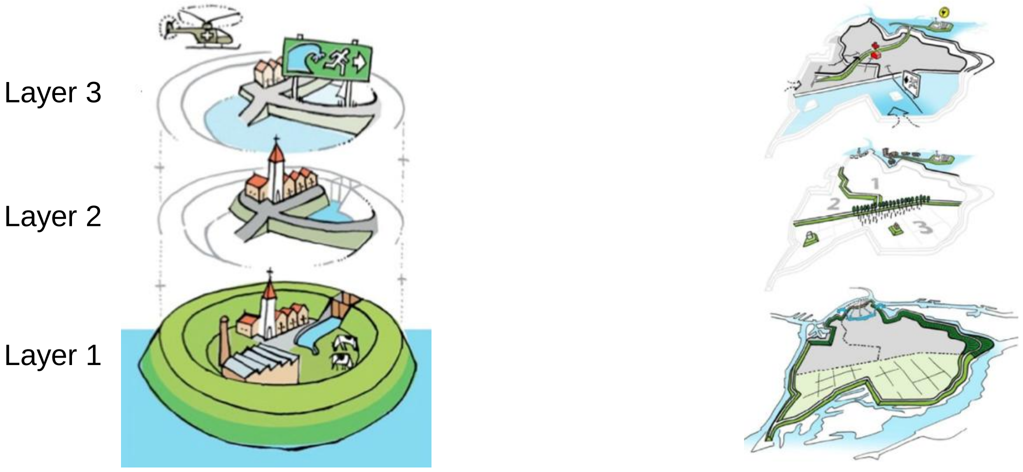
[2] “The National Water Plan: The Netherlands, a safe and livable delta, now and in the future” describes all water-related measures which have to be taken during the period 2009-2015 in order the Netherlands to stay safe and prospering for the future generations exploiting the opportunities of water (Hoss, 2010; Deltacommissie, 2008).

The three layers of the multi-layered safety (see figure 2.1) which forms an integrated flood risk approach are presented below (Hoss, 2010; Tsimopoulou *et al*., 2013). The first two layers are physical measures while emergency response focuses on institutional (organizational) measures taken before the event (Hoss *et al*., 2011).

- Layer 1: *Prevention.*
  This is about preventing rivers and seawater from inundating areas that are usually dry by constructing flood defenses or preventing high river discharges.
- Layer 2: *Spatial Solutions.*
  These are pro-active measures which focus on the decrease of loss in the case of flood occurrence by spatial planning, adaptation of buildings and protection of vital infrastructure. Solutions include location of urban and industrial land uses in areas with lower flood risk; raise of the constructions' ground levels etc.
- Layer 3: *Emergency Response.*
  This focuses on flood emergency preparedness by setting the organizational framework of the emergency response as well as by developing evacuation plans, early warning systems, temporary physical measures such as sand bags and medical treatment.



Application of the multi-layered safety in the case of Dordrecht island.

Figure 2.1: The three layers of the Dutch multi-layered safety concept which reduce the probability of floods (layer 1) and their consequences in case of occurrence (layers 2 and 3). (Rijke *et al*., 2014)

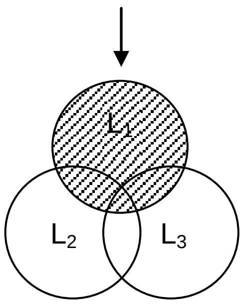
In the Netherlands, multi-layered safety is considered a shift from the past where attention was traditionally paid on the first layer of flood prevention, to the exploration of the potential of sustainable spatial planning and emergency preparedness whose measures are intended to be tailored to local areas for minimizing the magnitude of the flood damage in case of such an event. However, multi-layered safety makes the task of water security more complex, as it is broader in scope and it requires multi-actor based work across multiple locations (Gersonius *et al*., 2011). While only Rijkswaterstaat (Directorate-General for Public Works and Water management) and local waterboards are responsible for the first layer of dyke rings, the second and third layer involve several parties including provinces, municipalities, safety regions and private parties which call for much higher level of coordination. Furthermore, the complexity of multi-layered safety lies on the need to account for future changes such as population increase or decrease, changes in economic and spatial developments.

### 2.3.2 Analysis of the multi-layered safety system.

The Dutch shift from a predominantly prevention policy to multi-layered safety implies alteration of the flood risk management from a serial to a parallel system (Hoss, 2010). Furthermore, Jongelan *et al*. (2012) mention that the multi-layered safety represents the relationship between the different phases or strategies as a parallel system rather than a serial system which means that the different layers are not as weak as the weakest link fact which is falsely described by the safety chain concept. In this context, multi-layered safety requires interventions across its three layers to effectively reinforce the overall system's resilience to floods (Rijke *et al*., 2014; Gersonius et al., 2011). Hoss (2010) concluding that there will never be absolute safety, suggests implementation of multi-layered safety with respect to optimal allocation of resources instead of attempting to achieve maximum security at any price. Rijke *et al*. (2014) state that it is more efficient to invest in the layer(s) with the highest return on investment and to skip or minimize the use of the other(s).

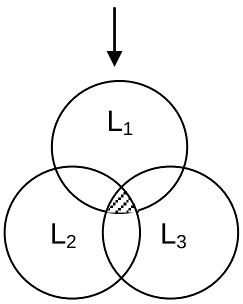
For the description of how the multi-layered safety system will function as a serial vs. a parallel system in case of a flooding, equations (1) and (2) are used and the respective Venn diagrams are employed for visualization purposes (see figure 2.2). As layer 1 is about reducing the probability of occurrence of flooding through preventive measures, in the case of flooding, layer 1 de facto fails. In a serial system, if one of its components fails, means that the whole system immediately fails. In a parallel system this fails only if all its three layers fail. In case that one or two out of its three layers fail, the entire system does not fail. However, for multi-layered safety, neither the one nor the other system definition can be valid, while currently a definition regarding this has not been indicated (Tsimopoulou *et al*., 2013). Jongejan *et al*. (2012) justify the latter by the following paradigm: If a levee system were to fail, less or more humans could be saved through emergency response, but the immediate damages could not be undone, nor could crisis response bring the immediate flood victims back to life.

$$MLS_{serial} = L_1 \cup L_{2|1} \cup L_{3|1} \quad (1)$$



Venn diagram for a serial system

$$MLS_{parallel} = L_1 \cap L_{2|1} \cap L_{3|1} \quad (2)$$



Venn diagram for a parallel system

where:

$L_1$: Failure of Layer 1 (prevention);

$L_{2|1}$: Failure of Layer 2 (spatial solutions) given the failure of Layer 1 (prevention);

$L_{3|1}$: Failure of Layer 3 (emergency response) given the failure of Layer 1 (prevention).

Figure 2.2: Failure of the multi-layered safety concept as a serial vs. a parallel system. (Adapted from Tsimopoulou *et al*., 2013)

In multi-layered safety, if Layer 1 fails leading to a flooding, Layers 2 and 3 can minimize the consequences of this flood event. However, the measures taken in multi-layered safety should not only focus on the reduction of either the flood probability or the damage in case of flooding, but on both parameters simultaneously. The explicit definition of failure in each safety layer in the form of exceedance of certain thresholds can significantly contribute to the management of multi-layered safety systems, as it introduces safety classification added in a system by means of decrease of flooding probability; reduction of environmental and economic damage and minimization of human fatalities (Tsimopoulou *et al*., 2013).

### 2.3.3 The need to methodologically frame the multi-layered safety concept.

The multi-layered water safety concept more closely resembles a parallel system in which Jongejan *et al*. (2012) mention that it is more cost-effective to invest in one component rather than dispersing the available budget over all of them. From an economic perspective, attention should be paid on how the different investment strategies affect the probability of adverse consequences, based on the rational assumption that smaller losses are desirable over greater ones. However, local conditions could lead to different optimal balances between measures corresponding to the three layers of this multi-tier safety concept i.e. between measures for flood probability reduction and damage minimization in case of flooding.

Economically speaking, beyond low cost investments in damage mitigation measures, how effective could heavy investments in this direction be? In 2007, Taskforce was established to improve disaster preparedness (TMO, 2009) considering strong investments in emergency planning, evacuation routes and equipment. The purchasing and maintenance costs of a fleet of aerial rescue means (helicopters) is enormous taking into account that they will be rarely used on average to save some people from their rooftops. But even in this case the huge economic impact of a flood disaster and the inevitable injuries and human fatalities are unavoidable. In this situation, the minimization of the probability of flooding would be the more efficient strategy. Another example is the case of a flooding in a densely populated area, where an additional investment in prevention is likely to yield a far greater return compared to an additional investment in loss mitigation measures (Jongejan *et al*., 2012). However, in the case of Dordrecht city in which historic buildings line the existing flood defenses, Hoss (2010) in a comprehensive assessment of the multi-layered safety concept where he has explored how the flood risks can be reduced, he identified that the improvement of emergency response preparedness or the flood proofing of buildings could yield better compared to the strengthening of the flood defenses (flood probability reduction). This happens due to the relatively high costs of reinforcing the flood defenses, considering the relatively small size of the area protected by them (Jongejan *et al*., 2012).

Cost-benefit analysis can be applied for structuring complex decision problems (Arrow *et al*., 1996) including safety regulations. However, the ability of cost-benefit analysis to produce morally relevant outcomes has been challenged, particularly for matters related to health and safety, where factors other than costs and benefits influence humans' moral judgments (e.g. Slovic *et al*., 2004; Slovic *et al*., 1984; Fischhoff *et al*., 1981). Hence, the results of a strict cost-benefit analysis should not be binding for the agency heads (Arrow *et al*., 1996). In this context, the multi-layered safety should not be driven only by economic factors focusing on the estimation of some efficient balance between safety and return.

Since there is no one single multi-layered safety policy, a framework such as geodesign which takes into account the roles and values of the people at place and the principles of sustainability in a collaborative and interactive process for making balanced decisions is required. In this context, this paper purports to geodesign the multi-layered safety having in mind that collaboration and maximum consensus between the involved stakeholders has to be achieved for deciding the most desirable, balanced and sustainable safety measures. In the following sections geodesign is introduced and applied in order to methodologically systematize the multi-layered water safety concept following a characteristic script of geodesign.

## 2.4 Methodological framework: Geodesign.

Geodesign needs collaboration which In turn requires organization that asks for a framework around which tasks can be identified and linked (Steinitz, 2012). In this context, the methodology of this study i.e. geodesign is introduced and framed.

### 2.4.1 Geodesign: Definitions.

The design of land uses in the context of geographic space and natural environment is not a recent concept (Paradis *et al*., 2013). The latterly dubbed geodesign has its roots thousands of years ago, being an interdisciplinary process of place making, where design has been variably affected by surrounding geographies and natural conditions (McElvaney, 2012). Goodchild (2010b) supporting that geodesign is not new; he states that it represents a re-examination and probably a repurposing of a number of established fields. However, Miller (2012) argues that unlike the activity of geodesign, the term is relatively new and only a small number of geo-related businesses have utilized geodesign as part of their name.

Dangermond (2009a, b) sees geodesign as a systematic methodology for geographic planning and decision making which employs all the geographic knowledge (layers of information, measurements and analytic models) that users collectively build, maintain and import into a new interactive process where one can design alternatives and acquire geography-based feedback on the consequences of these designs in a timely manner. Flaxman (2010a, b) defines geodesign as “a design and planning method which tightly couples the creation of a design proposal with impact simulations informed by geographic context”. Steinitz (2012) simply specifies geodesign as changing geography by design where design related processes are developed and applied towards changing the geographical study areas in which they are utilized and realized. The desire to change geography goes beyond individual buildings, looking at the broader scale plans towards better understanding the effect on the landscape (Artz 2010[2], 21). For the practice of geodesign, interdisciplinary collaboration between the design professions, geographical sciences, information technologies and the people at place is a must (Steinitz, 2012).

Paradis *et al*. (2013), by exploring the various definitions of geodesign, they identify that the integration of geographic sciences and geospatial technologies with design which facilitates digital geographic analysis to inform the design processes is the fundamental characteristic of geodesign. Fully leveraging geography during the design process can result in designs that emulate the best features and functions of natural systems, where humans and nature are mutually benefited via a more peaceful and synergistic coexistence (Artz 2010[2], 16). In this regard, Dangermond (2010) sees geodesign as “designing with nature in mind” (Artz 2010[2], 6). Furthermore, Ervin (2011) mentions that “geodesign enhances the traditional environmental planning and design activities with the power of modern computing, communications and collaboration technologies, providing on-demand simulations and impact analysis to provide more effective and more responsible integration of scientific knowledge and societal values into the design of alternative futures”.

### 2.4.2 Geodesign framework and models.

Steinitz framework for geodesign illustrated in figure 2.3 (Steinitz, 2012) and previously known as framework for landscape planning (Steinitz, 1995), it employs *six questions* that can be answered by *six models* for the description of the overall geodesign process (Steinitz, 2012).

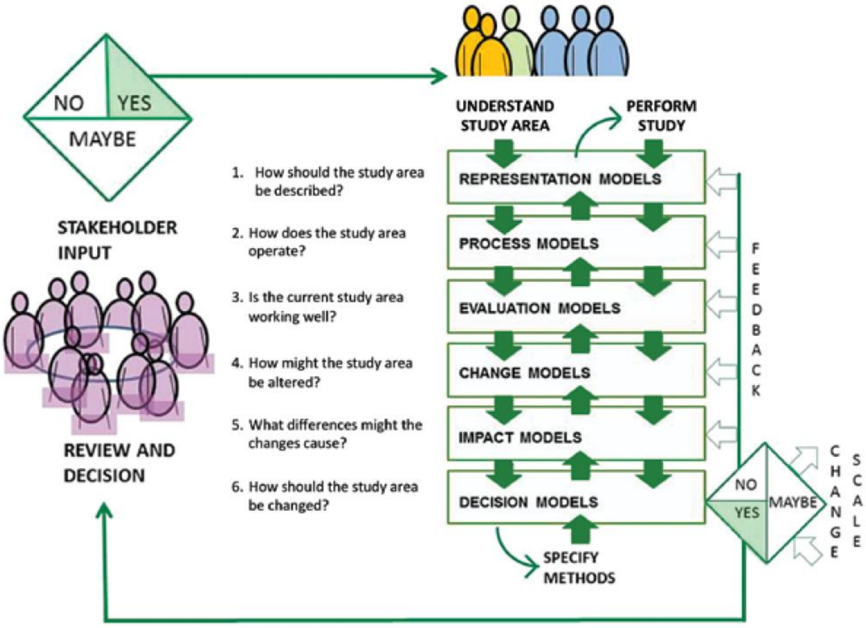


Figure 2.3: The geodesign framework.
(Steinitz, 2012)

The first three questions refer to the past and the existing conditions of the study area within a geographic context, while the last three are about the future more than the past and the present. The first three models used for answering the first three questions comprise the assessment process, while the last three models used comprise the intervention process respectively (Miller, 2012). Geodesign concept through its six questions, provide a rapid, holistic, participatory, interactive and adaptive process for developing a more sustainable future (Dangermond, 2010). Furthermore, it enables the design of various alternatives, their evaluation in terms of impact on the natural environment as well as their utility to the human population; and selection and implementation of the alternative that is projected to achieve the best balance, thus supporting the development of the most educated and informed decisions about the future (Dangermond, 2009a).

During a geodesign study, three iterations of the six questions of the geodesign framework (see figure 2.3) are explicitly or implicitly performed at least once before a decision towards implementation can ever be reached (Steinitz, 2012). In the first iteration where the questions are asked in a sequence from 1 to 6, the geographic study area as well as the context and the scope of the study are intended to be identified answering *why* the study should take place. In the second iteration, where the questions are asked in a reverse sequence i.e. from 6 to 1, thus making geodesign decision-driven rather than data-driven, the methods of the study are intended to be selected and defined, simultaneously answering to the *how* questions. In the third iteration, the methodology designed by the geodesign team during the second iteration is carried out and having data as a central concern, the study is implemented and results are provided. At this stage, the questions are asked from top to bottom i.e. from 1 to 6, attempting to identify *what, where* and *when*.

Dangermond (2010) sees this iterative design/evaluation process as the way in which the human brain operates i.e. try something, evaluate the results and move on. In order the stakeholders to come to decisions, questions must be asked and answered and options for selection must be framed and deliberated. In short, the geodesign framework can be seen as collaboration facilitator as well as a valuable supporter in the organization and solving of large and complex design problems, often at geographic scales ranging from a neighborhood to a city, from the local to the national and even international level.

## 2.5 Geodesign the multi-layered safety concept: The case of the Netherlands.

Firstly, the information needs for the multi-layered safety concept in the Netherlands are explored. Afterwards, geodesign is theoretically implemented to present a framework for developing shared understanding of the current situation of an area of interest in terms of flood safety as well as for achieving collaborative selection of the optimal multi-layered safety measures. The latter is accomplished by taking into account the values of the people at place, economic efficiency and environmental impacts of alternative safety measures in an attempt to achieve maximum consensus between the stakeholders.

### 2.5.1 Information needs.

In order a study area to be described, information is needed. Adapting the information requirements as described by ACIR (2005) for the multi-layered safety, these can be determined as semi-static and model information. Furthermore, these information components are clustered into 6 different categories (see figure 2.4). However, when measures such as preventive organized evacuations are decided in the context of the emergency response layer, their implementation needs dynamic information. This is related to the (simulated) escalating flood and its effect on the incident location and the surrounding environment (geographical awareness); the capacity and the activities of the emergency response organizations to tackle it and normalize the situation.

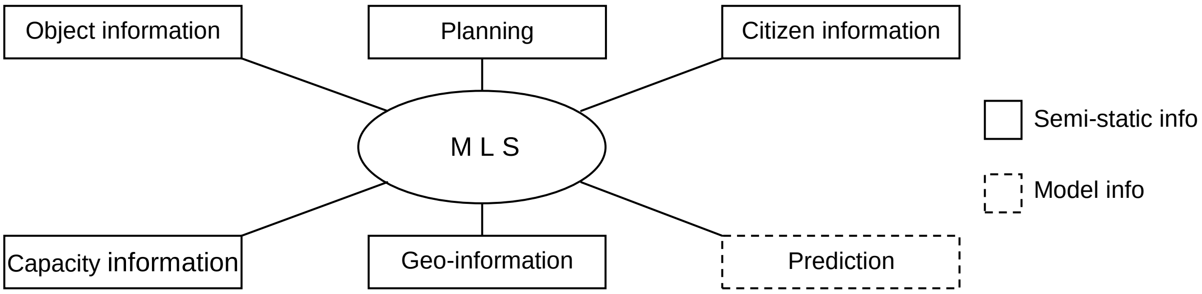


Figure 2.4: Overview of the information categories needed for the multi-layered safety concept.
(Adapted from ACIR, 2005)

In table 2.2, an overview of data required for the multi-layered safety concept in the case of the Netherlands is provided. Almost all of these data have a spatial (geographical) component.

### 2.5.2 Implementing geodesign on the multi-layered safety concept.

In this study, geodesign is used as a theoretical framework in its conceptual form (see table 2.3) to shed light on involving stakeholders in the identification of the most desirable water safety measures taking into account their socioeconomic and environmental impacts. The utilization of geodesign framework purports to increase the effectiveness of the multi-layered safety concept, even though effectiveness is a broad concept which can include many aspects. In addition, through its models and iterations it intends to enable communication of stakeholders’ values. In theory, by geo-designing the multi-layered safety concept, integration and exploration of ideas with direct evaluation at the same time is intended to be enabled. Furthermore, as geodesign is underpinned by trial and error logic, it increases the opportunity for experimentation and learning by doing (Steinitz, 2012).

The results of framing the multi-layered safety in the context of a geodesign study are tabulated (see table 2.3). At the end of the process, the stakeholders can say no, maybe or yes to the alternative safety measures. *No*, implies that the proposed safety measures do not meet their requirements, *maybe* can treated as feedback and calls for changes possibly in the allocation of the weights regarding the three safety layers and a *yes* means implementation of the proposed safety measures. The latter will be used as data in the updates and future reviews of the multi-layered safety measures through the proposed framework. The route for coming into an agreement regarding the most suitable, desirable and balanced safety measures is not straight forward and normally non-linear, as many entries of different types and of different sources may be received leading to revisit and revision of the decisions.

Moura (2015) based on her empirical study, she mentions that the use of geodesign framework has proven to be a system in an open box that establishes steps, presents partial results, composes potential changes and choices, simulates alternative scenarios and possibilities, determines responsibilities and limits of what is acceptable based on societal values and urge people to decide about their common future employing a shared way of communication and ideas exchanging. In this line, it can be said that geodesign is not a linear process as it contains feedback loops for model adjustments towards identifying optimal solutions. Stakeholders' involvement in the identification of the most favourable measures regarding the three layers of the multi-tier safety concept is needed to foster credibility in decisions making. In literature, some authors including Batty (2013), Steinitz (2012) and Goodchild (2007) discuss how geotechnologies can support stakeholders' participation in geodesign. In particular, the potential of interactive geodesign tools in decision making is increasingly acknowledged. (Steinitz, 2012; Dias *et al*., 2013). For example, an interactive mapping device called "touch table" can be used as stakeholders' communication platform in the implementation of geodesign on the multi-layered safety concept, similar to previous studies (see Eikelboom and Janssen, 2015; Janssen *et al*., 2014; Arciniegas *et al*., 2013; Alexander *et al*., 2012). The added value service of a touch table which includes for instance learning by experimenting, intuitive control, geospatial database availability has been discussed in several articles (e.g. Pelzer *et al*., 2014; Pelzer *et al*., 2013; Eikelboom and Janssen, 2013; Arciniegas *et al*., 2011).

Table 2.2: Data inventory for the multi-layered safety concept in the Netherlands.

| TEMPORAL NATURE | **Data** | **Details** | |
|---|---|---|---|
| SEMI - STATIC | Topographic data | Top10NL: Open topographic data [Street networks; Railroad networks (Rail, metro and tram lines); Water bodies (rivers, sea, lakes, etc.); Building footprints; Terrain (grassland, arable land, etc.); Design elements (noise barriers, trees, pylons, etc.); Relief elements (land contour lines, sea depth lines, etc.); Geographical and functional areas (neighborhoods, campgrounds, etc.)] that can be used at scales between 1: 5000 and 1:25000 throughout the Netherlands. | |
| | | BAG - Basic registration of Addresses and Buildings (*In Dutch: Basisregistraties Adressen en Gebouwen*): Open geodata about building footprints and addresses. | |
| | Elevation data | AHN2 - Actual Height Data (*In Dutch: Actueel Hoogtebestand Nederland*): Open, detailed and precise elevation data (terrain, building and vegetation information) of 0.5 m x 0.5 m resolution. Digital Terrain Model (DTM) and Digital Surface Model (DSM) can be extracted from AHN2 providing terrain and objects' height information respectively. | |
| | Flood defenses' specifications | Location, technical characteristics (e.g. capacity, cross-sections) of primary and regional flood defenses protecting from open (North sea, Wadden sea, rivers, Ijsselmeer and Markermeer) and inland water (lakes, streams, canals) respectively. These include weirs, barrages, sluices, dams which regulate water levels by water intake or releasing water when needed as well as dykes (floodgates or levees), natural sand dunes and storm surge barriers which manage or prevent water flow into specific land regions. Topographic information about the flood defenses at scale 1:1000 can be retrieved from DTB – Digital Topographic Database (*In Dutch: Digitaal Topografisch Bestand*). | |
| | Soil composition | GeoTOP from TNO – Dutch Organization of Applied Scientific Research (*In Dutch: Nederlandse Organisatie voor Toegepast-Natuurwetenschappelijk Onderzoek*): Detailed three dimensional (3D) model of the subsurface of the Netherlands which is divided into voxels of 100m x 100m resolution. Information regarding stratigraphy, lithology and uncertainty of the voxel appearance is included. It is currently available for the provinces of Zeeland and South Holland. For the multi-layered safety concept, emphasis is placed on the composition of the primary and regional flood defenses. | |
| | Water bodies data | Water depths at different locations from the New Amsterdam Level [*In Dutch: Normaal Amsterdam Peil* (NAP)]. NAP is also the Dutch point for altitude measurements (m). | |
| | | Flow rates ($m^3$/s) of water in natural and manmade open channels. Flow rate ($m^3$/s) of the sea water. | The water services (*In Dutch: Waterdienst*) of the Rijkswaterstaat and the regional waterboards can provide such information. |
| | | Cross-sectional characteristics of the water-bodies. | |
| | Precipitation and evapotranspiration data | Time series of rainfall (mm) during a day, rainfall intensity (mm/h), evaporation (mm/day), transpiration (mm/day) and evapotranspiration (mm/day) for areas (ha) at different locations. This information can be derived from STOWA Meteobase, the foundation of applied water research (*In Dutch: Stichting Toegepast Onderzoek WaterBeheer*). | |
| | Sewerage system specifications | Technical and geographical specifications of the system and its components (e.g. drains, manholes, pumping stations, screening chambers, storm overflows). Emphasis is placed on the collection of the storm water runoff. Regional waterboards and Rijkswaterstaat water services can provide such information. | |
| | Flood risk data | Risk map (*In Dutch: Risicokaart*): Vulnerable objects exposed to flood hazards and guidelines for emergency preparedness in case of different inundation depths. | |
| | Population | Numbers for every postcode district. (Derived from CBS - Central Bureau of Statistics (*In Dutch: Centraal Bureau voor de Statistiek*). | Inhabitants, density, growth, age, sex, disabled. |
| | Land Uses | LGN6 - Nationwide Land Uses (*In Dutch: Landelijk Grondgebruik Netherland*). | A grid file which distinguishes 39 land uses with a spatial resolution of 25m x 25m). Its main classes are urban, forest, water, nature and agricultural crops. |
| | | Derived from CBS. | Land uses per municipality for different chronologies with their coverage in hectares (ha). |
| | Emergency capacity | Number and capacity of rescue means (ground and aerial) and emergency responders classified per emergency organization [e.g. Fire brigade operational staff (professional and voluntary) provided by CBS]. Location, number and capacity of emergency relief centers categorized by their function (e.g. medical aid, sheltering, catering, animal welfare) as well as by municipal area. | |
| | Financial indicators | Flood defenses. | Unit (construction, improvement and maintenance) cost per type and function. |
| | | Security care. | Material costs per emergency response organization. |
| | | | Personnel costs (per capita spending) per emergency response organization. |
| MODEL | Prognosis data | Land-use forecasts.<br>Flood forecasts based on different inputs and model parameters. | |

Table 2.3: Theoretical implementation of geodesign on the Multi-Layered water Safety concept (MLS).

<table>
<tr><th><b>GEODESIGN THE MLS</b></th><th>FIRST ITERATION<br>(WHY?)</th><th>SECOND ITERATION<br>(HOW?)</th><th>THIRD ITERATION<br>(WHAT, WHERE, WHEN?)</th></tr>
<tr><td>1. How should the study area be described?<br>➢ <i>Representation models</i>.</td><td>• What is the location of the Area of Interest (AoI)? How the hydrologic system functions in this AoI?<br>• What are the physical, economic and social activities in the AoI?</td><td>• Where exactly is the study area and how is it bounded in hydrologic terms?<br>• Which data are needed? At what scale, classification, and times? From what sources? At which cost? How to be represented?</td><td>• Acquire the required data (An overview is provided in table 2).<br>• Analyze and visualize them over time and space using appropriate technology [multi-scale Geographic Information Systems (2D, 3D, 4D)].<br>• Organize them according to the needs of the three safety layers. Communicate them to the interested MLS parties using relevant (geo-) technology instruments (e.g. touch table).</td></tr>
<tr><td>2. How does the study area operate?<br>➢ <i>Process models</i>.</td><td>• What are the major hydrological processes in the AoI? How these processes are affected by precipitation and evapotranspiration, infiltration and percolation?<br>• How the surface and the sub-surface systems are linked in the AoI?<br>• How the flood defenses are functioning in the AoI? What is their capacity?</td><td>• Which hydrological processes should be considered in determining MLS policies and measures?<br>• At what scale and for which time horizon should the safety measures operate?<br>• What should be the level of complexity of the process models (for describing the AoI) that fit the purpose of the MLS study?</td><td>• Implement, calibrate and test the selected hydrologic models (stochastic; process-based models) for the AoI. Change the model parameters and run them several times.<br>• Explain how the model outputs pinpoint the need to focus on one or more safety layer(s).</td></tr>
<tr><td>3. Is the current study area working well in terms of flood safety?<br>➢ <i>Evaluation models.</i></td><td>• Have they been recorded high water depths in the AoI? Why?<br>• Are there currently problems with the functioning of the flood defenses? Why? Where?<br>• Are there developments in zones of high flood risks? How will it be tackled in the future spatial plans?<br>• Are the people at place aware about these problems? Are they prepared? Are the emergency agencies prepared to respond?</td><td>• What are the evaluation criteria for the alternative safety measures corresponding to the three MLS layers? Economic? Legal? Societal? Environmental?<br>• What are the measures for evaluation of the success in terms of prevention (flood probability reduction), loss minimization through spatial solutions and emergency preparedness in the case of flooding?</td><td>• Evaluate the flood safety condition of the AoI based on defined thresholds. Visualize and communicate the results.<br>• Explain how the local socioeconomic activities as well as environmental factors affect the flood safety in the AoI.<br>• Evaluate the current safety measures taken in the AoI, identify their effectiveness and classify them according to the three safety layers. Identify whether a reinforcement of the current measures or a shift is needed in the context of the MLS.</td></tr>
<tr><td>4. How might the study area be altered in order to meet the flood safety requirements?<br>➢ <i>Change models.</i></td><td>• In which of the three safety layers will the weights be placed? What are the alternative scenarios? Need visualization?<br>• How the AoI will meet the flood safety requirements in the future? Will it be a shift from the current practice? How?</td><td>• What is the time horizon and scale(s) for the alternative safety measures? Are there any assumptions and requirements for them?<br>• What change model(s) will they be used to describe the future alternatives in terms of flood safety? Will the outcomes be simulated and/or visualized?</td><td><b>Example of alternative measures that can be visualized</b>. Participants can propose more.
<table>
<tr><th>MLS<br>RISK</th><th>Layer 1: Prevention</th><th>Layer 2: Spatial solutions</th><th>Layer 3: Crisis management</th></tr>
<tr><td>Source (hazard/ water overload)</td><td>Redistribute discharge over river arms, retain runoff; Give waterways more space.</td><td></td><td></td></tr>
<tr><td>Pathway (Exposure)</td><td>Large scale flood defenses (e.g. reinforcing or building new dykes); Flood defenses enabling controlled overflow.</td><td>Reconsider settlements location; Compartmentalization; Alleviation (e.g. elevation) of constructions</td><td>Preventive organized evacuation; Temporary flood defenses.</td></tr>
<tr><td>Vulnerability (Receptor)</td><td></td><td>Flood proofing of buildings.</td><td>Self-reliance/temporary flood proofing of buildings; Emergency relief, rescuing.</td></tr>
</table>
(Hoss <i>et al</i>., 2011)</td></tr>
<tr><td>5. What differences might the changes cause in terms of cost-efficiency?<br>➢ <i>Impact models.</i></td><td>• What is the impact of the alternatives in terms of cost-efficiency?<br>• Are measures related to the reduction of flood probability more beneficial compared to measures related to consequences reduction in case of flooding? Why?</td><td>• Are the economic impacts of the possible safety measures related to the three MLS layers regulated by legislation or regulations? How?<br>• Which impacts even if they are cost-effective should be assessed from a legal and/or environmental perspective?</td><td>• Perform a cost-benefit analysis for the alternative measures corresponding to the different safety layers of the AoI. Identify and rank the most cost-effective. Visualize and communicate the results.<br>• Compare and explain the impacts of the measures corresponding to the different safety layers in terms of cost-effectiveness.</td></tr>
<tr><td>6. How should the study area be changed in order to meet the flood safety requirements taking into account moral factors and values of the local society, cost-efficiency of the safety measures and the impact of the measures on the environment (principles of sustainability)?<br>➢ <i>Decision models.</i></td><td>• What is the main purpose of the study? Is it more efficient to invest only in the layer with the highest return in economic terms? Is it socially acceptable?<br>• Who are the major stakeholders and what are their positions, if known?<br>• Are there any binding technical and/or legal limitations for the AoI that must guide the MLS study? Are there any identified implementation difficulties for any of the measures related to the three layers of the MLS?</td><td>• Who will make the decisions and how? What do they need to know? What will be the basis for their evaluation? Scientific? Cultural? Legal? Ethical? Combination of the previous?<br>• What should the decision makers consider as failure of the safety layers?<br>• Are there issues related to the implementation of the safety measures in terms of cost and technology?</td><td>• Check whether the more cost-effective alternative measures corresponding to the three safety layers of the MLS are morally relevant and thus more likely to be socially acceptable.<br>• Check whether these measures have any side effects on the environment.<br>• Select a number of safety measures in a multi-disciplinary driven context, taking into account their economic efficiency, the values of the people at place and their environmental impacts and decide upon their suitability:<br>○ <i>No</i>, which implies more feedback;<br>○ <i>Maybe</i>, which means that further study at different temporal and spatial scales is required;<br>○ <i>Yes</i>, which drives to the presentation of the most suitable safety measures to the stakeholders for their decision and possible implementation.</td></tr>
</table>

## 2.6 Final remarks on the geo-design of the multi-layered water safety.

In recent years there has been considerable attention in improving the flood protection in Europe and beyond. As a consequence, it has been a growing need to share information and best practices in the field of flood risk management. In this context, the Netherlands has introduced the multi-layered safety concept for flood risk management which is based on recommendations for flood protection such as the EU flood risk directive and the UNISDR Hyogo framework.

The multi-layered safety concept includes structural and non-structural measures representative of its three layers which target to reduce the flood risk probability through prevention (layer 1) as well as the consequences in case of flooding via spatial solutions and emergency response (layers 2 and 3). By analyzing a multi-layered safety system, it can be deduced that such a system resembles more a parallel than a serial one, as failure of the safety measures in one layer does not mean failure of the whole system. However, it is not exactly a parallel system because when the preventive measures fail, the immediate consequences cannot be undone. The measures corresponding to layers 2 and 3 are able to reduce the damage, but not to completely eradicate it. Failure of the preventive measures is obvious when a flood occurs. But what is considered failure in layers 2 and 3 has to explicitly be defined which will support the allocation of weights between the three layers of the multi-layered safety concept.

The goal to promote stakeholders' participation and collaboration towards supporting decision making in regards to the most desirable and balanced water safety measures across different spatial and temporal scales, it has been achieved by theoretically orchestrating the multi-layer safety concept in a geodesign structure. A primary concern for the multi-layered safety concept is the inventory of the required data. Decisions especially for matters related to flood safety should rest on the firm ground of relevant and of high quality data. In this context, this contribution attempts to provide a first comprehensive overview of the data required for the multi-layered safety concept. However, questionnaire surveys with the participation of the involved to this multi-tier safety concept can shed more light regarding the information requirements of each safety layer. In this way, overlaps in terms of information needs between the three safety layers can be identified as well.

In order to develop and select optimal flood safety measures, all the stakeholders involved in the multi-layered safety concept have to develop awareness regarding the current water safety status in an area of interest. In particular, they have to comprehend the current functioning of an area of interest and also the way(s) in which flood safety is presently addressed. Furthermore, the stakeholders have to work together respecting each other values, considering local circumstances and searching for the most balanced and sustainable solutions. Cost-benefit analysis can extract the measures which can yield better from an economic perspective. However, in matters related to health and safety, the human judgments are influenced not only by economic factors but also by their ethical values. In this context, the systematization of the multi-layered safety concept following the geodesign framework creates surplus value for the local society, economy and environment through its different and iterative feedback driven processes. The geodesign of the multi-layered safety concept motivates collaboration between the involved to the multi-layered safety parties without losing their identities. It underpins trial and error logic so that all stakeholders can assess the impact of the safety measures resulting from their own points of view. In this way, the stakeholders can identify overlaps in terms of the proposed measures which in turn can create maximum consensus between them leading to the selection of the most desirable future water safety measures that consider their cost efficiency, their impact on the environment and the values of the people at place. But in order the geodesign of the multi-layered safety concept to be successful, it should be seen useful by those working with it. If intentionally deviate from the principles of this framework, the decisions i.e. the safety measures can leave the stakeholders unsatisfied who in turn will reject them.

Further research is needed towards transferring the implementation of geodesign on multi-layered safety from theory to practice. In particular, the geodesigned multi-layered safety concept should be experimented, tested and experienced in workshop settings and in different contexts for identifying optimal safety measures. Furthermore, during such workshops, technology driven tools which empower society by enabling their participation in the decision making should be employed and assessed in the context of practicing geodesign for arriving at sustainable arrangements regarding water safety.

# 3. 3D INFORMATION CONCEPTS FOR FLOOD RISK COMMUNICATION AND MANAGEMENT IN THE CONTEXT OF COMPLEX URBAN SPACES.

Nowadays, an increasing number of applications are utilizing 3D city models for their purposes as they reveal high information potential. In the context of the rapidly urbanizing world, the contribution of the virtual 3D city models in integrating, managing and communicating complex geo-information for risk management in the urban suburbs is explored and qualitatively assessed in this article. For this, a virtual 3D city model for Heerhugowaard case study area in the Netherlands which is situated below mean sea level has been developed, using open data. This model provides the stakeholders with dynamic 3D renderings of the flood risk components and their relations, facilitating the development of shared awareness regarding a particular urban flood risk situation. Furthermore, building upon the virtual 3D city models, an interoperable 3D information system which utilizes existing open international standards from the GIS and BIM domains is conceptualized. Such a concept additionally provides up-to-date information on demand regarding the physical and functional characteristics and relations of the city objects and components at both the city and the facility scale. It supplies information not only about the external environment but also about the buildings' interior structures which are important in the management of risks as well as in the preparation of evacuation plans for managing the residual risks.

## 3.1 Introduction.

According to the United Nations (2014), the world has urbanized rapidly since 1950 and projections indicate that it will continue to urbanize in the coming decades. In 2014, just over the half of the global population was residing in urban cities while this distribution is expected to shift further over the next 35 years (UN, 2014). Cities are centers of economic activity and growth and as more population move to the cities and businesses invest locally, more lives and assets accumulate in disaster prone areas (Swiss Re, 2013). The thread to city population and local economies is real and is relentlessly increasing as cities continue to expand and risk management practices fail to keep up with the pace of change. Therefore, strengthening the resilience of cities becomes a matter of utmost importance.

Geospatial researchers have learned that the availability, management and presentation of geospatial information, play a pivotal role in the management of potential disasters especially in the urban spaces (Lee and Zlatanova, 2008). Treicher (1967), an experimental psychologist, through his famous psychological experiment about determining how human beings obtain information, he proved that 83% of the information received by humans is by the sense of sight. This indicates that the information visualization is necessary for communication and information distribution (Wu and Hsieh, 2012; Lu *et al*., 2012). Effective visualization assists people in effectively and efficiently obtaining the required information (Lu *et al*., 2012). Kibria *et al*. (2009) have experimentally demonstrated that the increase of realism and dimensionality, increase the user perception of understanding of a particular situation. 3D maps are probably more understandable to users, especially those with limited map reading skills as they allow thematic data to be presented in a format that more closely resembles natural conditions and offer visualization advantages not available in traditional 2D mapping (Patterson, 1999; Basic *et al*., 2003). However, both classical 2D and 3D maps do not provide sufficient support for decision making because they can only offer views prepared in advance (Döllner *et al*., 2006a).

Nowadays, a high interest exists in the use of 3D models for interaction (Kibria *et al*., 2009) as interactive 3D models are valuable tools in improving awareness regarding incidents such as floods (Duzgan *et al.,* 2011; Mioc *et al.,* 2011; Stanchev *et al.,* 2009; Basic *et al.,* 2003). Virtual 3D city models which are applied for an increasing number of applications (Mao, 2011; Stadler and Kolbe, 2007; Döllner *et al*., 2006a; Shiode, 2001) can be utilized for managing risks in the urban context. Kolbe *et al*. (2005) report that virtual 3D city models memorize the shape and configuration of a city and they enable 3D visualizations. Sadek *et al*. (2002) state that if a picture worth a thousand words, a virtual 3D city model is worth a thousand pictures. Mao (2011) mentions that 3D city models make easier the understanding of the spatial properties of urban objects by the stakeholders, since the real world is in 3D and it is natural for the human brain to interpret 3D scenes.

In the context of risk management, only 3D geometry and appearance information is frequently not sufficient, as complex semantic information is required for querying and analysis purposes. However, the needed data are typically derived from distributed sources and often are thematically and spatially fragmented (Stadler and Kolbe, 2007). Therefore, standards are required to be employed for seamless data integration and explicit determination of semantics. In this way, massive, heterogeneous and distributed risk related data from different domains such as GIS and BIM can be integrated into virtual 3D city models in the context of a 3D information system. This 3D system should act as an effective tool for decision support during the risk management process permitting dynamic adaptations of the focused aspects of a discussion, enabling variations in the visualizations and supporting investigations at different scales. For such virtual 3D city models-based information systems for risk communication and management, little information exists.

The main purpose of this study is to present and explore different information concepts which can contribute to the improvement of risk communication and management. The paper, commences its mission by presenting in section 2 a conceptual model for risk identification, discussing the requirements on risk communication that support the stakeholders to become risk aware and participate in the risk management decision making process. In section 3, the data underlying a virtual 3D city model developed for Heerhugowaard case study area are described and the role of this model in risk communication and management is qualitatively assessed. In section 4, the CityGML open data standard from GIS domain is delineated and its role in the context of virtual 3D city models for risk management is demonstrated. In addition, BIM domain and standards are introduced and the role of BIM fields in risk management is discussed. In section 5, a conceptual 3D information system based on virtual 3D city models and extended by open international standards i.e. IFC from BIM domain and CityGML from BIM domain is presented and its functionalities are explored in the context of risk communication and management. Finally, section 6 summarizes the most important findings of this contribution.

### 3.2 Flood risk communication and management.

United Nations International Strategy for Disaster Risk Reduction (UNISDR) (2009) defines risk management as the systematic approach and practice of managing uncertainty to minimize potential harm and loss which is comprised of assessment and analysis of risks and the implementation of strategies and specific actions to control, reduce and transfer them. The assessment and analysis of a particular risk, requires a thorough understanding of the components of a risk system which are described by the Source-Pathway-Receptor (S-P-R) model; where sources are the origins of the hazards; receptors are the entities that potentially can be harmed by a hazard including people, the manmade and the natural environment and pathways are the routes by which a hazard can reach those receptors (McGahey, 2009). According to the Office of Public Works (OPW) of the Government of Ireland (2009), the S-P-R model has been widely adopted for the assessment, communication and management of environmental risks. In addition, the S-P-R model is closely related to the framework utilized by the Organization for Economic Cooperation and

Development, the European Union and the UK for the State of the Environment reporting (Evans *et al*., 2003). This S-P-R model which is conceptually illustrated below including interactions between its components in the case of flooding, is adopted and used in this study as the basis for risk visualization and communication (see figure 3.1).

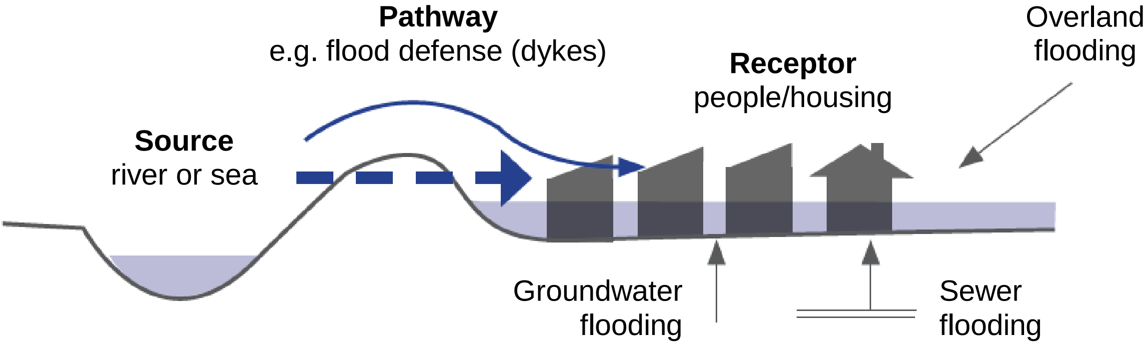


Figure 3.1: Risk (S-P-R) model for assessing and informing the environmental risk management.

(OPW of the Government of Ireland, 2009)

Risk assessment requires identification of all the three components of the S-P-R model including their relation. Therefore, probability and magnitude of the source(s), the performance and response of pathways as well as barriers to pathways and the consequences to the receptors including people, properties and the environment must be explored. There can be no risk unless a connectivity between S-P-R is identified (Kandilioti and Makropoulos, 2011; Sayers *et al*., 2003). The OPW of the Government of Ireland (2009) states that flood risk assessment ultimately aims to combine the S-P-R components through visualization and description of risks on a spatial scale which allow the analysis of their consequences.

Lang *et al*. (2001) mention that the transition of risk management from a traditionally depicted linear process to a cyclic process with risk communication at its heart is not a coincidence (figure 3.2). Reynolds and Seeger (2012) state that the importance of risk communication, it has been signified by the field of environmental health.

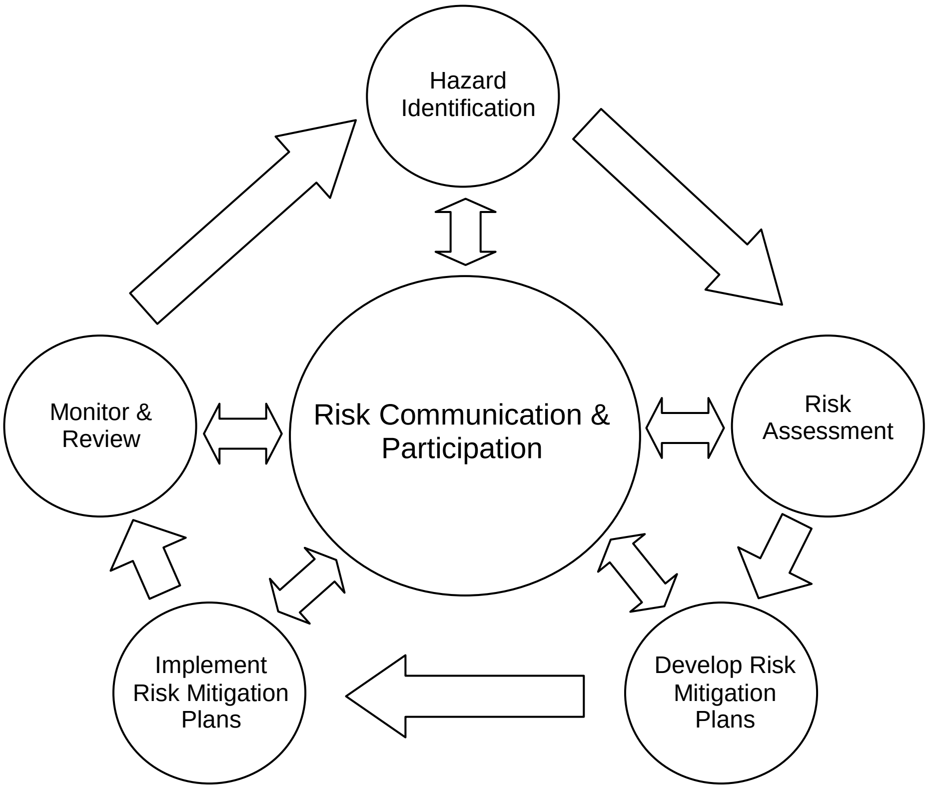


Figure 3.2: The risk management cycle.
(Adapted from Chorus and Bartram, 1999)

Risk communication as defined by Glik (2007) is “the exchange of information about health risks caused by environmental, natural, technological, agricultural or industrial processes, products or policies”. Lang *et al*. (2001) determine risk communication as “any purposeful exchange of information about risks between interested parties”. In this context, the communicator of risks should convey or transmit information to interested parties about hazards as well as about the magnitude of the consequences either weak or strong resulting from a behavior or exposure. Interested parties include public or private institutions, industry groups, scientists and individual citizens (Covello, 1991).

Bennett and Calman (1999), mention that risk management inherently incorporates reciprocal (two-way) risk communication among all the interested parties. In addition, they point out that risk communication is not just about dissemination of information, as its key component is the process through which the necessary information and opinion for effective risk management are incorporated in the decision. Covello (1998) notes that risk communication should target to produce informed, involved, interested, cautious, rational, solution-oriented and collaborative stakeholders.

Based on Lang *et al*. (2001), it can be said that strong relationships between stakeholders is an advantage during a crisis situation. Marra (1998) identifies six characteristics which appear consistently in management and communication literature as a measure of a relationship. These are trust, understanding, credibility, satisfaction, co-operation and agreement. Therefore, risk communication tools should target to fulfill all these characteristics that contribute in building relations between the involved stakeholders during the risk management process.

Finally, a number of goals that a risk communication program should aim to fulfil have been identified through literature (Lang *et al*., 2001; Renn and Levine, 1991; Kasperson and Palmlund, 1989; Covello *et al*., 1986; Zimmermann, 1987; Renn, 1987) and they are presented:

- *Enlightenment role* focusing on the improvement of risk understanding among target groups;
- *Right-to-know* aiming to the provision of information about the source of a hazard to those who may be exposed;
- *Attitude modification role* in order to legitimize risk-relevant decisions, improving the acceptance of a specific risk source or challenging such decision simultaneously rejecting specific risk sources;
- *Legitimate function* explaining and justifying risk management practices targeting to the enhancement of trust in the competence and fairness of the risk management process;
- *Risk reduction role* in order to reinforce public protection through information about risk mitigation measures;
- *Behavioral alteration role* in order to facilitate protective behavior or supportive actions towards the communicating agency;
- *Emergency preparedness role* supplying the target groups with guidelines or behavioral advices for emergency situations;
- *Stakeholders involvement role* focusing on the education of decision makers about public concerns and perceptions;
- *Participation role* in order to support the reconciliation of conflicts regarding risk related controversies.

In brief, effective risk communication should enable the stakeholders to identify, comprehend and be aware of risks and residual risks[3] during the risk management process. In addition, open channels of communication must be incorporated, allowing them to exert their influence and actively participate providing their own inputs and insights in the decision making for mitigation of risks to socially tolerable levels. However, most of the times, risks are communicated to a variety of audiences. Hence, risk communication should facilitate timely provision of factual information, via authoritative and accessible sources with clear, precise and understandable messages tailored to the needs of the different audiences-stakeholders that are likely to have different education, knowledge and level of intelligence, interests, values and understanding. In the following section, the contribution of virtual 3D city models in effectively communicating risks in a realistic, understandable and comprehensive fashion, simultaneously enabling stakeholders' participation, it will be qualitatively assessed.

## 3.3 Virtual 3D city models for flood risk communication and management: The case of Heerhugowaard.

In this section, the virtual 3D city models are introduced. In addition, a virtual 3D city model prototype developed for Heerhugowaard case study area is presented and its role in risk communication and management is explored.

### 3.3.1 Virtual 3D city models in the context of managing and communicating complex urban information.

Virtual 3D city models are increasingly utilized in different sectors of economy, enterprises and public administration which call for visualization of geographic information. Döllner *et al*., (2006b) state that the virtual 3D city models represent spatial and geo-referenced urban data by means of 3D GeoVirtual Environments (GeoVEs) that basically include terrain, building and vegetation models as well as models of roads and transportation systems. The virtual 3D city models have capabilities for storing and referencing of both classical georeferenced

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[3] UNISDR (2009) defines residual risk as the risk that remains in unmanaged form, even when effective disaster risk reduction measures are in place, and for which emergency response and recovery capacities must be maintained. The presence of residual risk implies disaster management preparedness and development of evacuation plans for emergency response.

*raster* and *vector* data. These data can be visualized for instance as an image layer over a DTM layer.

In essence, virtual 3D city models depict urban spatial geo-referenced data via a common platform known as the virtual city. Furthermore, as the city models can be classified in the 3D GeoVirtual Environments (GeoVEs), they act as interactive interfaces between city model and users (Döllner *et al*., 2006b). Generally, GeoVEs serve as mediums for dissemination of geo-information to users, facilitating exploration, analysis and management of storage for geo-information. In this context, virtual 3D city models enable the presentation, exploration, analysis and management of urban data allowing the visual integration of heterogeneous geo-information within a single framework, thus developing and maintaining complex urban information spaces. These spaces contain integrated thematic and application oriented geo-referenced data which can jointly be presented and related to the geometric entities stored, maintained and managed by the virtual 3D city models (Döllner *et al*., 2006a; Döllner *et al*., 2006b). Therefore, virtual 3D city models form a significant concept in 3D geoinformation systems.

Analysis of the thematic spatially correlated objects and the associated information is widespread in applications related to 2D Geographic Information Systems (GIS) while the potential of virtual 3D city models to serve as the mean for conveyance of complex urban information has not been extensively investigated in the context of risk management. The 3D representation of a city can communicate spatially correlated thematic information in a comprehensive way which may prove useful in fields directly and indirectly related to risk management and crisis response. The requirements on virtual 3D city models depend on the context of each application. On the one hand, if a high degree of photorealism is desired in order to give a realistic overview of a landscape with the associated S-P-R components which their connectivity forms a risk, the 3D visualization quality is directly related to the proximity between the virtual and the actual city model. On the other hand, if analytical and exploratory functionalities are attempted to be provided, the visual details of the landscape objects are not of primary importance (Döllner *et al*., 2006a). In the following figure 3.3, photorealistic 3D visualization provides a concrete overview of existing or planned environments while in the figure 3.4, abstract 3D visualization encodes thematic information in a selected urban area.

Different requirements on 3D visualization based on the context of each application

Figure 3.3: Photorealistic Visualization.
Developed using CityEngine

Figure 3.4: Abstract Visualization.
Developed by the Berlin's Senate Department of Urban Development (Döllner *et al.*, 2006a)

### 3.3.2 A virtual 3D city model for flood risk communication and management: The case of Heerhugowaard.

The role of a simple virtual 3D city model in risk communication and management will be qualitatively investigated. For this, a case study area in Heehugowaard city which is located in the west of the Netherlands has been selected for 3D modelling. This city and municipality which is part of the province of North Holland and the region of West Frisia is situated on average around 3 meters below Mean Sea Level (MSL). In addition, the land of Heerhugowaard is flat, as it is constituted of polders. Therefore, it is crucial to ensure identification and communication of risks by delineating the S-P-R model in the context of a virtual 3D city model.

#### *Data underlying the virtual city model of Heerhugowaard.*

The 3D modelling process of Heerhugowaard case study area starts from a comprehensive inventory of all the required geographical data. The data acquisition process for the particular area of interest has been carried out in collaboration with the regional water board *Hoogheemraadschap Hollands Noorderkwartier (HHNK)*[4]*.* The 2D and 3D information used in this project are derived from various open sources. In particular, the 2D TOP10NL, Basisregistraties Adressen en Gebouwen (BAG) and Open Street Map (OSM) as well as the elevation Actueel Hoogtebestand Nederland (AHN)2 data which are described in details in table 3.1, they have been utilized for the modelling of selected part of Heerhugowaard case study area.

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[4] *HHNK is a* governmental body charged with the responsibility of carrying out a number of functional tasks such as water management, water control, water quality assurance and roads management in the region of North Holland, above the North Sea Canal.

Table 3.1: Data sources used for the development of 3D models of Heerhugowaard.

| **2D spatial information extracted from open geo-data.** | |
|---|---|
| TOP10NL | TOP10NL is a detailed digital topographic database provided by the Dutch cadastre. TOP10NL are open geodata that can be used at scales between 1: 5000 and 1:25000 throughout the Netherlands. They are considered suitable for viewing and editing of geographic information. Also, they can be used as substrate for data visualization and as geometrical reference in GIS applications.<br>TOP10NL data are originated from aerial photographs, field measurements and other external sources of information. They include different topographical features and in particular the following object classes:<br>• Street networks;<br>• Railroad networks (Rail, metro and tram lines);<br>• Water bodies (rivers, sea, lakes, etc.);<br>• Building footprints;<br>• Terrain (grassland, arable land, etc.);<br>• Design elements (noise barriers, trees, pylons, etc.);<br>• Relief elements (land contour lines, sea depth lines, etc.);<br>• Geographical and functional areas (neighborhoods, campgrounds, etc.). |
| BAG | BAG are open geo-data which include information regarding buildings and addresses. The Dutch municipalities are responsible for both the recording and the quality of these data which are centrally available through the national BAG data infrastructure. The management of this data infrastructure is charged to the Dutch cadastre which also has to ensure BAG data availability to the various customers. |
| OSM | OSM are by definition open data providing information about street and rail networks, rail stations, rivers, borders etc. These data are collected and stored in a freely accessible database. It is worth mentioning that anyone can voluntarily contribute to the Implementation and modification of the OSM's geographic information. |
| **3D spatial information extracted from open geo-data.** | |
| AHN2 | AHN is a multiannual cooperation program between Rijkswaterstaat and the water boards which aims to produce height information for the water system and the flood management needs of the whole Netherlands (Zon, 2013). Since 6 March 2014, AHN are open data. In essence, AHN provide detailed and precise elevation information. In particular, AHN2 data contain terrain, building and vegetation information of 0.5 m x 0.5 m resolution. Laser altimetry from an airplane or helicopter is used for the determination of the heights. The height measurements can be described by 3D point clouds and grids. In general, the grids downsize the larger 3D point cloud datasets from which they can be exported by employing filters and different interpolation techniques. These grids are linked with the DTM and Digital Surface Model (DSM) which provide terrain and objects' height information respectively. For the texturing of both the DTM and DSM, aerial photographs can be projected on top of them. |

***The architecture of the virtual 3D city model of Heerhugowaard.***

In this section, the virtual 3D city model of Heerhugowaard which integrates 2D and 3D geo-information, developing and maintaining 3D models from 2D footprints (features) using procedures (rules) for risk communication is presented. The data requirements for 3D modelling of selected part of Heerhugowaard case study area are summarized in the following table 3.2:

Table 3.2: Data used for the development of 3D models of Heerhugowaard.

| **Data source** | **Used to extract** |
|---|---|
| Top10NL | Street and railroad networks, water bodies |
| BAG | Building footprints |
| OSM | Street and railroad networks |
| AHN2 | Elevation information for the development of DTM and DSM |
| Aerial Photograph | Landscape (terrain and building roofs) texture |

The virtual 3D city model of Heerhugowaard which is outlined in figure 3.5, it is formed by the following components:

- *3D Authoring and Editing System*: It is responsible for developing and editing the virtual 3D city models and their components towards fulfilling the needs of applications and users. Also, it is charged with the geometric modelling of 3D objects such as architectural building models, transportation networks, water masses, trees. The system's 3D modelling software is the Environmental Systems Research Institute's (ESRI's) CityEngine which relies on feature geometry, feature attributes and procedurally defined rules towards automation. In essence, CityEngine through the procedural approach applies procedures in the form of rules and python scripting for the interactive generation of 3D models in a time-efficient way compared to the handcrafted (manual) modelling. Roumpani (2013) suggests that the procedural modelling which is directly related to complexity theories enables models' development that can be disaggregated to a very fine Level of Detail (LoD). Furthermore, CityEngine allows the mathematical models' visualization in a 3D manner by incorporating interactive controls and simulating modifications in real time. The CityEngine's capabilities of interaction enable models testing on existing environments as well as their communication at large, providing a powerful tool for improved understanding of risks in the context of the natural and manmade environment.

- *3D Geodatabase System*: It serves as the database for the storing and managing of the virtual 3D city model. Its principal objects which are the city objects represent geo-referenced geometric entities. This is a simple database which does not follow the logic of any data standards.
- *3D Presentation System*: It provides real time visualization and interaction with the virtual 3D city model and it targets to communicate the risk to the stakeholders. The 3D city models can be viewed as web scenes at the web browser via the CityEngine WebViewer which is based on WebGL technology. In addition, the 3D city models can also been exported and viewed at earth browsers such as ArcGlobe or Google Earth.

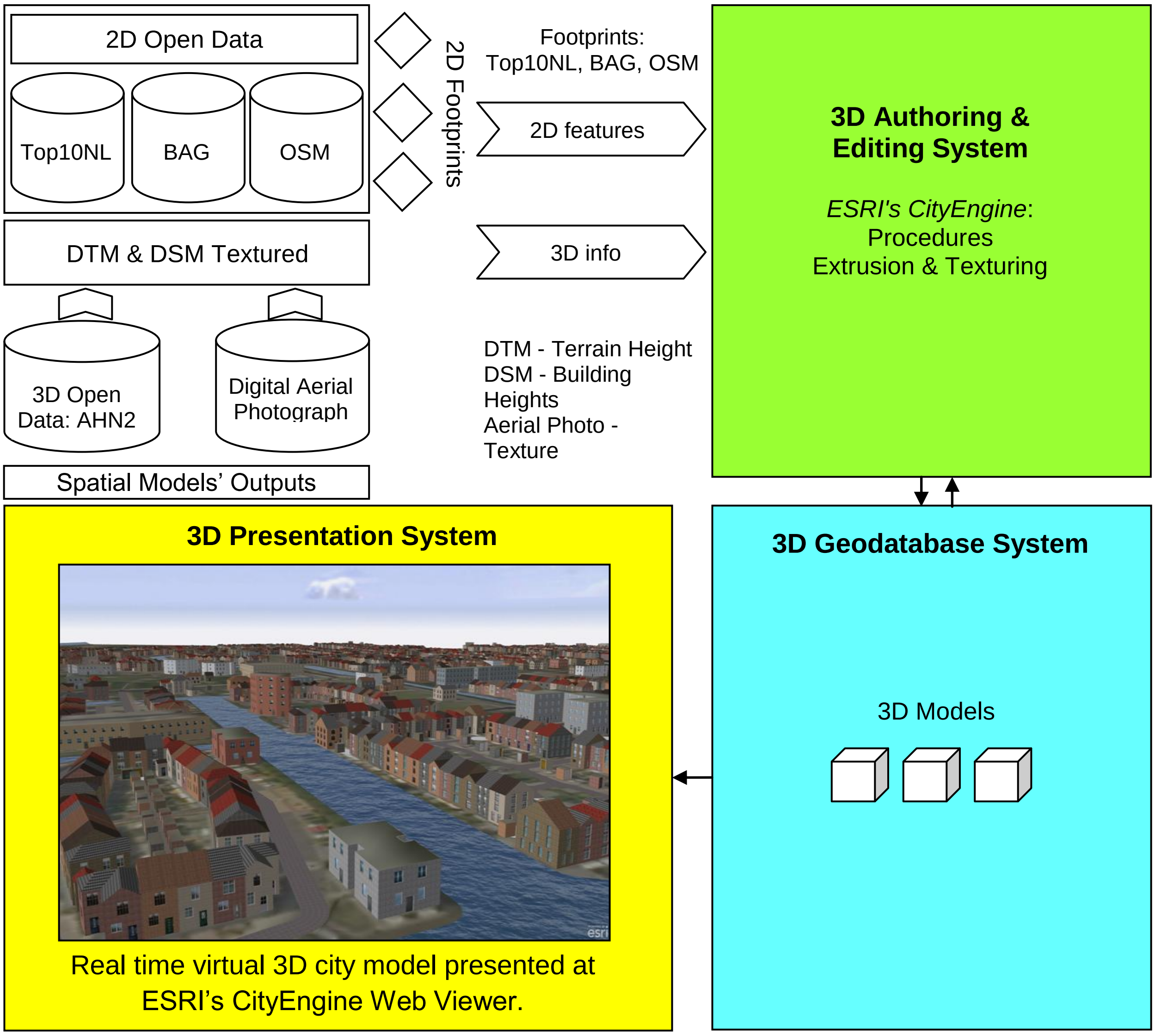

Figure 3.5: The virtual 3D city model of Heerhugowaard case study area.

### ***Qualitative assessment of the role of Heerhugowaard's virtual 3D model in flood risk communication and management.***

Kemec *et al*. (2010b) mention that useful 3D geovisualization tools contain suitable presentation of information and appropriate tools for interaction. In addition, through literature (Duzgan *et al*., 2011, Mioc *et al*., 2011, Stanchev *et al*., 2009 and Basic *et al*., 2003) it has been identified that interactive 3D models are useful and valuable tools for improving awareness regarding a particular risk e.g. flooding.  The virtual 3D city model of Heerhugowaard allows interactive visualization, attempting to provide a realistic depiction of risks (S-P-R components and linkage) to the stakeholders. The quality of the 3D visualization which is associated with the proximity between the modelled city objects and the reality, it is strongly considered by the virtual city model of Heerhugowaard as it aims to produce informed, involved, collaborative, and rational solution oriented stakeholders. In figure 3.5, the 3D city model of Heerhugowaard which is presented at CityEngine Web Viewer, it provides a concrete overview of the potential flood risk in a photorealistic way taking into account the geometries as well as the attributes of the components of the risk (S-P-R) model. In this case, *Source* is considered the canal, as *Pathway* the polder while Receptors include the natural and manmade environment (e.g. urban land, buildings and transportation networks) and consequently the society and the local economy.

For visual data mining purposes, the city objects are geometrically described while the attribute tables maintain related information in the context of the virtual 3D city model of Heerhugowaard. These tables contain sets of key value pairs and are developed by filtering, merging and importing data sets into the 3D city model's authoring and editing component supported by CityEngine. Therefore, non-graphic information such as year of construction becomes visible in the CityEngine's inspector. In addition, the stakeholders can explicitly select one or more individual city objects, spatially select one or more city objects by drawing a polygon into the CityEngine's viewport or select city objects of a category (e.g. buildings) and components (facades) in a rule-driven context by defining a filter condition based on the attribute table of the objects. Afterwards, rules can be assigned to the selected city objects which are generated according to the procedures of the rules' files. In the context of risk management, rules can contain for example colorization of the buildings' facades which their height is below a certain threshold and are affected by the evolution of a flood event according to their alternative simulated scenarios. For such buildings, the stakeholders can decide that temporal barriers are not sufficient and that either vertical or horizontal (following predefined suitability criteria for each case) evacuation plans must be developed in the context of formulating flood preparedness measures. In addition, rules can apply colorization of the roofs of buildings which their height is above a certain threshold, their roof type is flat and their roof area is above a defined limit which makes them suitable for deployment of horizontal evacuation plans. However, such procedures alter the actual appearance of the buildings. Furthermore, queries in the context of rule-based modelling have a level of complexity as in the case of Heerhugowaard's virtual 3D model, they require knowledge of scripting usage of the CityEngine's Computer Generated Architecture (CGA) shape grammar which is a unique programming language specified to generate architectural 3D content (ESRI R & D Center, 2014).

Steenbruggen (2013) states that the "communication processes can be divided in three related domains: information, cognition and physical". In the context of risk management, the information domain is about risk related data while the cognitive domain focuses on human mental processes. Finally, the physical domain includes activities in the real world. In the information domain, better communication of information can lead to better awareness of a particular situation. In the cognitive domain, this better understanding of the situation can drive to better decisions which in turn can lead to better actions and effects in the physical domain. In the context of the virtual 3D city model of Heerhugowaard, the information domain provides the raw material, the basis for risk communication contributing to the development of shared understanding of a particular risk situation by the stakeholders. In addition, as the virtual 3D city model of Heerhugowaard which is a prototype that enables interactive stakeholders' participation and real time modifications through its procedures during the management of a particular risk, it purports to drive to better decisions in the cognitive domain and better outputs in the physical domain.

Nevertheless, in the context of virtual 3D city models, not only effective and interactive communication of risks must be facilitated, but also a high degree of interoperability as well as easy-to-use querying and analysis functionalities which will satisfy the needs of the safety agencies involved in risk management and crisis response. For risk management applications, only geometry and appearance of 3D city models is not sufficient. Semantic and thematic information in regards to 3D city objects (e.g. buildings) and components (e.g. walls, roof, columns, beams) with their functions and use (e.g. residential, commercial, industrial) as well as topological relations for validating that city objects are correctly aligned to each other are also required. In this context as well as for validity, reliability and usability of the virtual 3D city models, international standards from GIS and BIM domains which can integrate massive, heterogeneous and distributed information towards supporting the cognition of risk-based spatial situations and functional relations, they will be explored in the following sections.

## 3.4 GIS, BIM domains and existing international standards for risk communication and management in the context of virtual 3D city models.

Nowadays, a growing number of applications and systems employ virtual 3D city models (Döllner *et al*., 2006a). In the context of risk management and communication, accurate representations of 3D city objects and information regarding their geometry, semantic, thematic and topological context are required. In addition, 3D city models should support the identification and understanding of spatial patterns and processes either visually observed or not, thus creating knowledge and raising awareness for the stakeholders involved in risk management.

In Spatial Data Infrastructures (SDIs), distributed risk-related data come from different sources. Often, these data are varying in terms of spatial, geometrical and thematic context. For the complete exploitation of the capabilities of virtual 3D city models, widely accepted data models which facilitate interoperability, storage, visualization and distribution of geometry, semantics and relations of the modelled characteristics are required. Kolbe *et al*. (2005) mention that with the GIS domain's standard, CityGML, which bases on XML, an open data model for the storage and interoperable access to 3D city models that covers all their aspects maintaining different Levels of Detail (LoDs), becomes available. In addition, with Building Information Modelling (BIM) domain's technology and standards (e.g. IFC) the digital construction of accurate and detailed virtual models of buildings (Azhar *et al*., 2012; Azhar, 2011) which cover all their properties in a simulated environment becomes feasible. Furthermore, through BIM process, collaboration is enabled and integration of the roles of the stakeholders is encouraged. In this context, GIS' CityGML and BIM will be explored in the following sections focusing on the utilization of their concepts in risk communication and management.

### 3.4.1 GIS domain: The CityGML concept in support of risk communication and management.

An emerging standard from the GIS domain for the representation and exchange of 3D city models at multiple scales, called CityGML is presented and extensively analyzed, paying attention to the benefits that are resulting from its employment in the risk management process.

### *CityGML: The background.*

The City Geography Markup Language (CityGML) is an OGC[5] encoding data standard released as version 1.0 in 2008 (Gröger *et al*., 2008) and as version 2.0 in 2012 (Gröger *et al*., 2012). It is an open and application independent profile of GML3 initially specified by the graphical Unified Modelling Language (UML) as described by Booch *et al*. (1997). GML3 is an OpenGIS standard, driven by International Standardization Organization's (ISO) standards which bases on XML abstract format for the determination of application specific spatial data formats that provide support to either simple or complex 3D geometries and topologies (Kolbe *et al*., 2005). The data model behind CityGML, it bases on ISO 191xx standard family while its implementation is an application schema for GML3 (Kolbe, 2009). The XML figures of CityGML result from the UML diagrams by applying transformation rules provided by Cox *et al*. (2004), towards making them processable to standard GML3 readers. As it is based on GML 3.1.1 (Cox *et al*., 2004) which in turn is based on XML, the exchange of CityGML take advantages from all the techniques compatible with GML for data access, exchange, analysis, processing, cataloguing and storing provided by OGC, including the Web Feature Service (WFS)[6], the Web Processing Service (WPS) and the OGC Catalogue Service.

CityGML has been developed by the Special Interest Group on 3D of the initiative GeoData Infrastructure North-Rhine Westphalia (GDI NRW). The idea behind CityGML is the development of a common definition regarding the basic feature classes, attributes and relations in the context of a 3D city models' ontology with respect to geometric, topological, semantic and appearance properties (Gröger *et al*., 2006). This is crucial for the efficient and cost-effective maintenance of 3D models as well as for their reuse in various application domains (Stadler and Kolbe, 2007).

Representation, storage end exchange of 3D city models for a variety of purposes and applications including risk management and crisis response is feasible in the framework of the open and application - independent CityGML (Löwner *et al*., 2013). Beyond the geometric representations of 3D objects, CityGML enables storage of both their semantics and their interrelations. Furthermore, it supports the generalization and aggregation of

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[5] OGC is besides the official International Standards Organization (ISO) the most notable standardization organization in the field of geospatial information technologies (Löwner *et al*., 2013).

[6] WFS is a standarized web service that applies and integrates methods for access and management of geodata in the context of SDIs. The native data format of WFS is GML (Vretanos, 2002).

semantically determined features. Hence, CityGML not only supports 3D content visualization, but also manifold analytical capacity (Löwner *et al*., 2013).

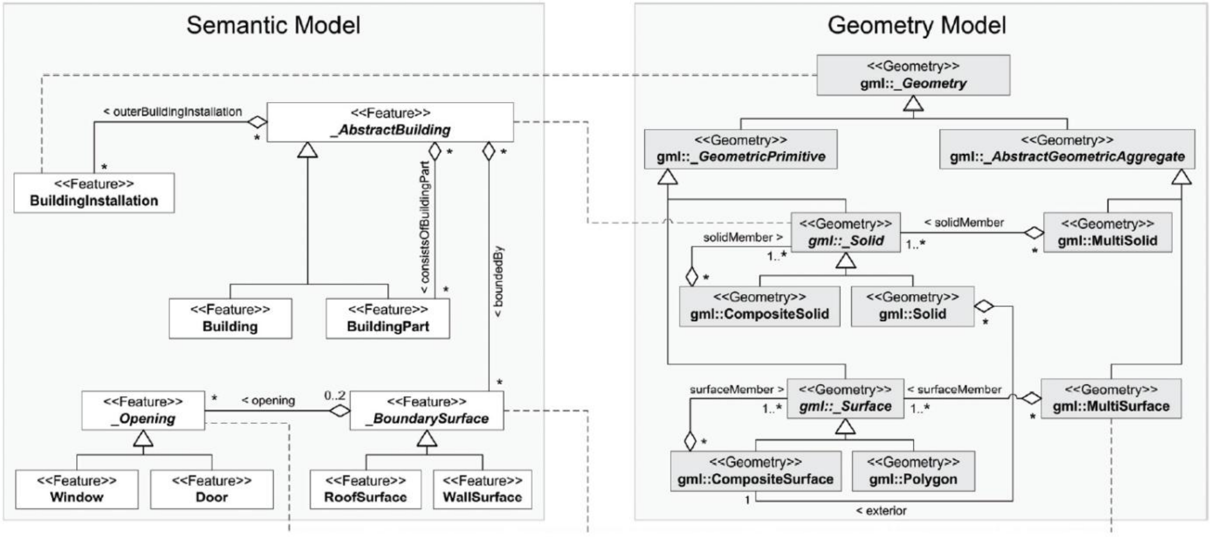
In the context of CityGML, topology can also have explicit representation. Each space component can be modelled once and thereafter it can be referenced by all those features characterized by equal geometry. Therefore, pleonasm is eliminated and explicit topological relations between components are preserved (Stadler and Kolbe, 2007).

The *modelling principle* of CityGML bases on class taxonomy of features as well as on disintegration in both semantic and spatial parts. CityGML distinguishes real world features providing 98 classes with or without geometric properties. These classes account for totally 372 well defined attributes (Löwner *et al*., 2013). Regarding disintegration, this for instance can start from the whole city over the city objects such as buildings, down to minor components like balconies. The outcomes of these decompositions are basically two hierarchical structures (see Kolbe and Gröger, 2003).

The *semantic model* of CityGML includes class definitions for the most significant features of 3D city models. These features contain DTMs, buildings, water masses, transportation networks, different vegetation types and even furniture. An illustration of a selected part of a semantic model employed for buildings' representation is shown in the following figure 3.6. The model class’s result from "Feature" (class) determined in ISO 19109 and GML3 for the delineation of spatial objects and their associated aggregations. Features contain spatial and non-spatial attributes specified in GML3 feature properties with related data types (ISO, 2005). From figure 3.6 the following can be extracted (Stadler and Kolbe, 2007):

- A building may recursively be constructed by building parts;
- A building may be confined by several types of surfaces including walls and roofs which in turn they may contain openings such as windows and doors;
- A building may have exterior building installations;
- The semantic as well as the geometry models, enable aggregations on different levels.

The *geometry model* of GML3 represents via its objects the spatial attributes of CityGML. This model rests on the standard ISO 19107 "Spatial Schema" (Herring, 2001), which represents 3D geometry in accordance with the Boundary Representation (Foley *et al*., 1995). Figure 3.7 displays a small part of this ISO 19107 "Spatial Schema". The GML3's geometry model comprises of primitives which depending on different connectivity requirements; they can be combined to form aggregate or composite geometries for every dimension. It is noted that while aggregate geometries are considered as arbitrary collection of primitives, composite geometries solely represent primitives which are topologically connected along their borders (Stadler and Kolbe, 2007). Generally, CityGML uses just a subset of the whole GML3 geometry package.



UML class diagram of part of both the semantic and geometry model of CityGML.

Figure 3.6: Part from the Building Model.

Figure 3.7: Part from ISO 19107 "Spatial Schema".

(Stadler and Kolbe, 2007; Booch *et al*., 1997)

CityGML is highly scalable and the datasets can include several urban entities supporting modelling at varying scales, from the smaller which correspond to individual buildings to the larger which include sites, districts, cities, provinces and even countries. CityGML is organized in 13 thematic modules which allow vertical scaling of a city model. This vertical modularization into independent and interchangeable modules which is achieved by various XML-Schemas with different name spaces, it enables the development of thin CityGML instance models without requiring the execution of the whole standard. Löwner *et al*. (2013) suggest that the most significant thematic modules of CityGML are both the fundamental *Core* and the *Building* modules. *Bridge* and *Tunnel* modules are modelled as the Building one while the remaining modules are modelled in less detail (see Gröger *et al*., 2012).

Löwner *et al*. (2013) state that CityGML can be either confined by using only selective modules and the LoD concept (see section 5.2) or can be expanded, given that specific applications typically have additional information requirements to be modelled and exchanged. In order this to be achieved, the Application Domain Extension (ADE) concept has emerged. In essence, the ADE enables the user firstly to add attributes or relations to

CityGML classes and secondly to determine new classes by generalization from CityGML classes. It is pointed out that all attributes and classes must be defined in a discrete and individual ADE namespace.

In short, CityGML is a multi-functional, multi-scale, interoperable and semantic information model which has capabilities for storage, exchange and representation of 3D city models at varying degrees of complexity with respect to geometry, topology semantics and appearance. This contributes to the flexible and sustainable utilization of CityGML as an exchange format in terms of data and applications (Stadler and Kolbe, 2007).

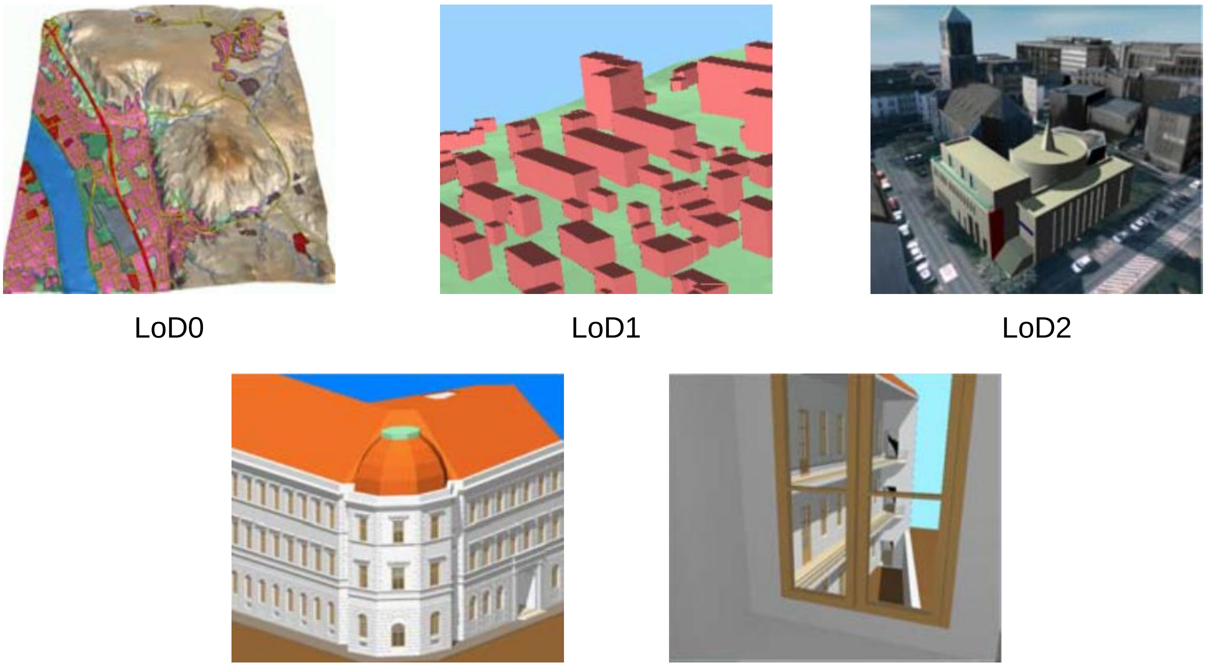
### *CityGML and Multi-Scale Modelling.*

CityGML open standard supports the LoDs concept in order to meet the requirements of different application fields including risk management and crisis response. In particular, it employs five consecutive LoDs to structure both the spatial and the semantic properties of the city models (Gröger *et al*., 2012). Consequently, every single object can be simultaneously represented in up to five different, clearly defined and discrete LoDs within a dataset, enabling the analysis and visualization of this object in multiple degrees of resolution. Gröger *et al*. (2007) note that two CityGML data sets which include the same object in different LoDs can be combined and integrated. While an object can have different representation for every LoD, different objects from the same LoD can be generalized in order to be represented by an aggregate object in a lower LoD. This can be achieved due to the fact that CityGML enables the decomposition and aggregation by supplying generalization connection between any CityObjects (Gröger *et al*., 2007).

Kolbe (2009) indicates that the LoDs of CityGML are progressively expanding from LoD0 which is basically a coarse regional model to LoD4 which represents indoor features i.e. building interiors. This expansion from a simple DTM to the more complicated structural model with interior details becomes feasible through the utilization of feature classes valid just for a particular range of LoDs. For instance, Stadler and Kolbe (2007) note that the building feature class is applicable for LoDs 1 to 4, while the boundary surface feature class is valid for LoDs 2 to 4.

In figure 3.8, the five different LoDs of CityGML are illustrated. LoD0 which is basically the coarsest in terms of details in the range from LoD0 to LoD4, it is a two and a half dimensional DTM which may be overlaid by an aerial photo or a map. LoD1 is essentially a blocks’ model which contains prismatic buildings without textures and roof structures, while

LoD2 has recognizable varying roof structures and thematically distinguishable and differentiated surfaces with representations of potential vegetation objects. LoD3 indicates architectural models with comprehensive representations of wall and roof structures with high resolution textures, balconies, bays and projections. In addition, LoD3 is consisted of vegetation and transportation objects. Finally, LoD4 builds over the LoD3 model by adding interior structures and features for 3D objects such as rooms, interior doors, stairs and furniture (Gröger *et al*., 2007).



LoD0 LoD1 LoD2

LoD3 LoD4

Figure 3.8: The five LoDs of the CityGML open standard.
(Gröger *et al*., 2007)

Gröger *et al*. (2007) indicate that LoDs are described by different accuracies and minimum objects' dimensions where accuracy is the standard deviation (σ) of the absolute coordinates of the 3D points in the space. In LoD1, the positional and height accuracy of 3D points is equal to 5 m or less, while all the objects with a footprint of at least 6m by 6m have to be taken into account. In LoD2, the positional accuracy should be 2 m while the height accuracy should be 1 m. Moreover, the objects that should be considered in this LoD, they must have a footprint of at least 4 m by 4 m. In LoD3 both the positional and the height accuracies are the same and equal to 0.5m while an object in order to be considered may have a footprint of 2 m by 2 m. Finally, in LoD4, both the accuracies should be 0.2 m or less. This data categorization in five LoDs contributes to the evaluation of the 3D city model data sets quality. This quality is critical when a spatial approximation of the extent of a particular risk is attempted in the framework of improving the awareness of the stakeholders regarding certain risks. In addition, the data classification enables data comparability which in turn it assists the integration processes of these data sets (Kolbe *et al*., 2005; Kolbe, 2009).

### ***CityGML in the context of virtual 3D city models for risk management.***

Risk management process incorporates geo-information during its different stages. Basic *et al*. (2003) argue that the dominance of GIS in risk management and in particular to risk analysis procedures is evident. The various aspects of geographical information can be either distinct such as maps or hidden like tables. Virtual 3D city models enable the direct communication of the participants of the risk management decision making process with the geo-information space through an easily understandable and comprehensive representation of a particular area of interest. For the multilateral and multifunctional exploitation of the advantages of 3D city and landscape models, the CityGML international open and interoperable data semantic model and exchange standard can be employed. The coherent semantic modelling of the spatial and thematic attributes of the 3D objects with their associated aggregations can be seen as a meaningful capability of CityGML. Also, the thematically rich properties of object classes can provide a firm ground for certain queries during the risk management process. In the preparation phase of horizontal evacuation plans as part of the implementation of risk mitigation measures, such queries can explore either the number of the buildings' floors or the different types of buildings and roofs. For example, buildings with flat roofs and roof area above a specified threshold can serve as landing base for aerial rescue means such as helicopters.

In the framework of risk management, 3D city models via CityGML data standard can facilitate incorporation of high resolution DTMs corresponding to specific areas of interest such as most vulnerable areas to natural disasters e.g. floods, into large area DTMs of low resolution, as a terrain model can be consisted of different parts with varied resolutions. In addition, 3D models enable the estimation of volumes and masses as their geometry is represented leastwise by a closed solid. Thereby, when for instance flood risk is assessed, the capacity of the installed drainage systems (e.g. ditches, drainage channels, culverts or sewers) and the inlets (e.g. gullies) can be computed.

In the context of CityGML, 3D objects can be correlated with data sets of external references like the cadastral database. Such a database can provide significant information regarding the details of the owners of buildings which for instance are prone to flooding. In addition, the properties of the objects such as buildings’ installations can be related to databases with associated technical information that is important in the planning of risk mitigation measures.

During the implementation of risk mitigation measures which can include preparation of evacuation plans by the fire services or other aid providers and rescue organizations, information regarding the building storeys with their corresponding height information above as well as beneath the ground level can prove useful. For example, this information can support the development of alternative evacuation plans for addressing different extents of building affection during an incident.

Kwan and Lee (2005) have experimentally demonstrated that emergency response delay within multi-level structures due to indoor route uncertainty can be much longer than delays in ground transportation in terms of the street network uncertainty. In addition, Gröger *et al*. (2006), have stressed that the modelling of passages between the neighboring rooms in buildings is of critical importance. Hence, the representation of the internal structures of the buildings particularly of the high-rise, can significantly improve the speed of crisis operations. In the paradigm of the building model of CityGML, the interior free spaces are modelled by rooms (see figure 3.9) which are considered semantic objects. The room solids are topologically connected by those surfaces which are used for the representation of doors or other closure surfaces that seal the doorways. In order the rooms to be determined as adjacent, common openings or closure surfaces must be identified. Kolbe *et al*. (2005), mention that this adjacency is accompanied by a graph of accessibility which can be used for instance either for the determination of the potential spread of a fire or for the calculation of escape paths incorporating algorithms regarding the shortest route during the preparation of the evacuation plans (see figure 3.10). Furthermore, the edges of the accessibility graph can be labelled by the associated distances and types of connection.

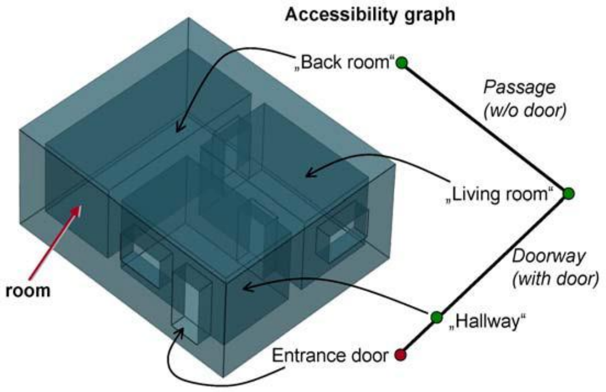


Figure 3.9: Building interior.

Figure 3.10: Accessibility graph deduced by the topological adjacencies of a room for the estimation of escape routes.

(Gröger *et al*., 2006)

In brief, virtual 3D city models through CityGML, deliver substantial information during the risk management process. More precisely, CityGML in the context of virtual 3D city models not only supports the identification, analysis and assessment of risks but also it can enable the implementation of risk mitigation measures such as preparation of alternative evacuation plans in an anticipated emergency. In addition, CityGML provides five LoDs with varying degrees of sophistication which can potentially contribute to the communication and management of risks.

### 3.4.2 BIM domain and standards in support of risk communication and management.

Building Information Modelling (BIM) is a growing knowledge domain in the Architecture, Engineering, Construction and Operations (AECO) industry (Succar, 2009) which through Building Information Models (BIMs) enables interoperability and facilitates data sharing and exchange between software applications (Isikdag *et al*., 2008). In addition, BIM enables generation of 3D visualizations (Azhar, 2011; Azhar *et al*., 2008; Howard and Björk*,* 2008). In this context, BIM is introduced and its applicability to risk management is explored.

#### *Introduction to BIM.*

The construction industry is highly fragmented and several information systems are utilized within each organization (Isikdag and Underwood, 2010). These information systems store and maintain buildings-related information that can be used in the risk management process for identification, assessment and communication of risks as well as for the preparation of risk mitigation plans including the development of alternative evacuation routes based on the construction characteristics (e.g. resistance, height, external passages, roof types) and the interior structures of the premises. Therefore, constant and consistent transfer of information between the different systems is and continues to be an apparent necessity (Isikdag and Underwood, 2010). In this context, BIM has emerged in order to address all the matters associated with interoperability, sharing, exchange and integration of building information over its entire building lifecycle (Isikdag and Underwood, 2010; Isikdag *et al*., 2008).

The Building Information Models (BIMs) of today have resulted from the exchange of drawing formats such as Drawing eXchange Format (DXF) via semantic Architectural, Engineering and Construction (AEC) information models which are in principle based on the technologies of the STandard for the Exchange of Product (STEP) data model (Isikdag and Underwood, 2010;

Isikdag *et al*., 2008). STEP also known as ISO 10303 (Industrial Automation Systems-Product Data Representation and Exchange) is an ISO standard which has emerged in order to overcome the shortcomings related to the translation of Computer Aided Design (CAD) data and also to meet the needs of the industry-based research groups for a new generation of standards effort (Isikdag and Underwood, 2010). In particular, in 1984, ISO through the development of STEP standard, it aspired to improve the communication of engineering information and also to allow its integration via the coordination of open standards for data sharing and exchange. For data storage and exchange, STEP identifies four implementation levels (Isikdag and Underwood, 2010): The data storage and exchange, the file exchange, the working form as well as the database and knowledgebase levels. The first level is charged with the information exchange between applications while the second and the third level supply methods for handling the product data and information sharing (Isikdag and Underwood, 2010).

### ***BIM and BIMs: Definitions.***

Succar (2009), states that BIM is a growing field of study which incorporates multiple knowledge domains in the context of AECO industry. BIM can be defined as a set of interacting policies, processes and technologies which develop a methodology for the management of the necessary building design and project data in digital format throughout the building's lifecycle (Succar, 2009; Penttilä 2006). Hu *et al*. (2008), see BIM as a mature digital framework which models building components and their relationships and it digitizes complete building data, contributing to the protection of the facility-related information from possible loss during its transfer from one phase to another or from one stakeholder to another. BIM is classified by the National Building Information Modelling Standard (NBIMS) initiative as (Isikdag and Underwood, 2010; NIBS, 2007):

- A *product* which digitally represent a building in an intelligent manner;
- A *collaborative process* which support business drivers, automated process functionalities and utilization of open standards for information viability and accuracy;
- A *facility* of information exchanges, workflows and processes which functions as an information based environment during the building lifecycle.

NIBS (2007), determines the process helix, the knowledge core and the external suppliers of products and services as key components of the building lifecycle. The knowledge core acts as the information supplier for historical and current building-related data that are exchanged between all the stakeholders involved in the building lifecycle processes. In this context, BIM is defined as a new way of developing, sharing, exchanging and manipulating information during the entire building's lifecycle (Isikdag and Underwood, 2010).

According to Eastman (1999), BIMs stem from the concept of building product model. The associated General Contractors Guide (AGC, 2006) determines BIMs as data rich, object oriented, intelligent and parametric digital representations of a particular facility where facility views and data that meet the needs of different users can be exported and analyzed in order to generate reliable information which in turn can be utilized in the decision making process as well as in the improvement of the delivery process of the facility itself. The National Institute of Building Sciences (NIBS) (2007) defines BIMs as computable representations of the physical and functional attributes of a facility and its associated project and lifecycle information, aiming to serve as an information library and thus a shared knowledge resource for the building owner and/or administrator to use and maintain during the building's lifecycle. Isikdag *et al*. (2008), perceive BIMs as data rich for representing a high amount of geometric and semantic information, comprehensive, open, extensible and vendor neutral (open) which are usually in three dimension geometrical form where geometries are spatially related to each other and represented within an object oriented structure. Azhar *et al*. (2008) note that BIMs describe the geometry, spatial relations, geographic information, quantities and properties of building elements, cost estimates, material inventories and project schedule. CRC Construction Innovation (2007) considers as BIMs' most important strength, the precise geometrical representation of a building in an integrated data environment.

For the description of the multi-facets of a building, BIMs are organized in clusters with a certain hierarchy, where each cluster corresponds to an aspect of building information (Shen *et al*., 2010). The different aspects of building information include building elements such as walls, columns and beams, building structures like group of walls that form a room or a floor, equipment e.g. Heating, Ventilating and Air-Conditioning (HVAC), plumbing and electrical wiring and material. For the reutilization of common information, later BIMs use the object-oriented approach with inheritances from an extensive parent-child hierarchy (Shen *et al*., 2010).

Succar (2009) exploring many writings, seminars and workshops, identifies that BIM is seen as a catalyst for change (Bernstein, 2005) which will reduce AEC industry's fragmentation (Dawson, 2004), improve its efficiency and effectiveness (Hampson and Brandon, 2004) and reduce the costs of inadequate interoperability (Gallaher *et al*., 2004). Isikdag *et al*. (2008) state that BIM focuses on addressing issues related to interoperability and information integration. In this context, BIMs serve as interoperability enablers and also as information sharing and exchange facilitators between software applications (Isikdag *et al*., 2008; Motamedi and Hammad, 2009). The several model views that can be generated from a single BIM (Isikdag *et al*., 2008) will always serve as important facilitators of information sharing and exchange. For the exchange of BIMs, physical files can be used that are transferred through physical mediums e.g. CDs and DVDs or computer networks e.g. internet (Isikdag *et al*., 2007). For the sharing of BIMs, Application Programming Interfaces (APIs), central databases, federated project databases and web services can be utilized (Isikdag *et al*., 2007). In the context of APIs, if for instance the BIM physical file is based on XML, the model can be shared through suitable XML interfaces.

### ***BIM and Standardization.***

The European Commission (EC) in (2008) pinpoints the significant role of standardization in the way towards innovation. Cerovsek (2011) states that "standards provide three important roles: (1) inter-operability, (2) trust and (3) comparability". United Nations Industrial Development Organization (UNIDO) (2006) mentions that the role of standards can be labelled by "3C": Competitiveness, Conformity and Connectivity. EC (2008) considers standardization an important tool towards innovation.

In the context of BIM standardization, the current efforts are the CIMSteel Integration Standards 2 (CIS/2) and the Industry Foundation Classes (IFC) (Isikdag *et al*., 2008). CIS/2 are open multi-part standards for the digital exchange and sharing of information for a structural steel-framed building while IFC is the effort of buildingSMART, formerly International Alliance for Interoperability (IAI), who aims to define a common language for technology in order to improve the communication, efficiency, productivity, delivery time, cost and quality throughout the design, construction and maintenance processes of a facility (Isikdag *et al*., 2008).

Shen *et al*. (2010) determine CIS/2 as a standard which supports analysis, design and detailing of the steel frame of a building as well as the transfer of the resulting design information to the shop fabrication. The data model of CIS/2 is called Logical Product Model. According to Shen *et al*. (2010) the key feature of this standard is the detailed design of the main and secondary structural steelwork of a facility including purlins, side rails, cleats and cladding, the full manufacturing assembly of the frame composed of parts and joints systems as well as the structural analysis of the steel frame using combination of rigid, plastic and elastic analysis models.

The initial version of IFC has been released in 1997 while in 2005 it became an ISO Publicly Available Specification as ISO 16739 (Isikdag *et al*., 2008). IFC has matured as a standard BIM aiming to support and facilitate interoperability as well as information sharing and exchange between different AEC disciplines throughout a building's lifecycle (Motamedi and Hammad, 2009; Isikdag *et al*., 2008). Nowadays, BIMs are increasingly represented and exchanged using IFC (Stadler and Kolbe, 2007; Adachi *et al*., 2003). Motamedi and Hammad (2009) determine IFC as an object-based, non-proprietary building data model which captures information about all the aspects of a facility throughout its lifecycle towards interoperability. Khemlani (2004) sees IFC as medium for model-based information exchange between models based applications in AECO industry supported by most of the major CAD vendors as well as by other applications. In addition, as IFC is an open data exchange format, public access is provided and thus it can be employed by various applications, including commercial, for data exchange (Khemlani, 2004).

Isikdag *et al*. (2008) indicate that IFC provides generalized and relatively high level description of both physical and non-physical object types related to the construction process and the building itself. The IFC objects enable sharing of a central project model allowing the involved stakeholders to formulate their own view of the objects contained on that model. In the context of IFC standard, each commonly agreed specification termed “class” is utilized in the description of a range of entities with common characteristics i.e. wall, window, door, column, beam etc. Regarding the geometry of an IFC object, this is determined by its relative or absolute placement in 3D space as well as by its geometrical representation in the form of Sweeping, Constructive Solid Geometry (CSG) and Boundary Representation (BRep) individually or combined (Isikdag *et al*., 2008). Concerning, the spatial relationship between elements, this is specified by the spatial structure of the model. The IFC spatial structure is defined as a decomposition of the model into manageable subsets according to spatial arrangements

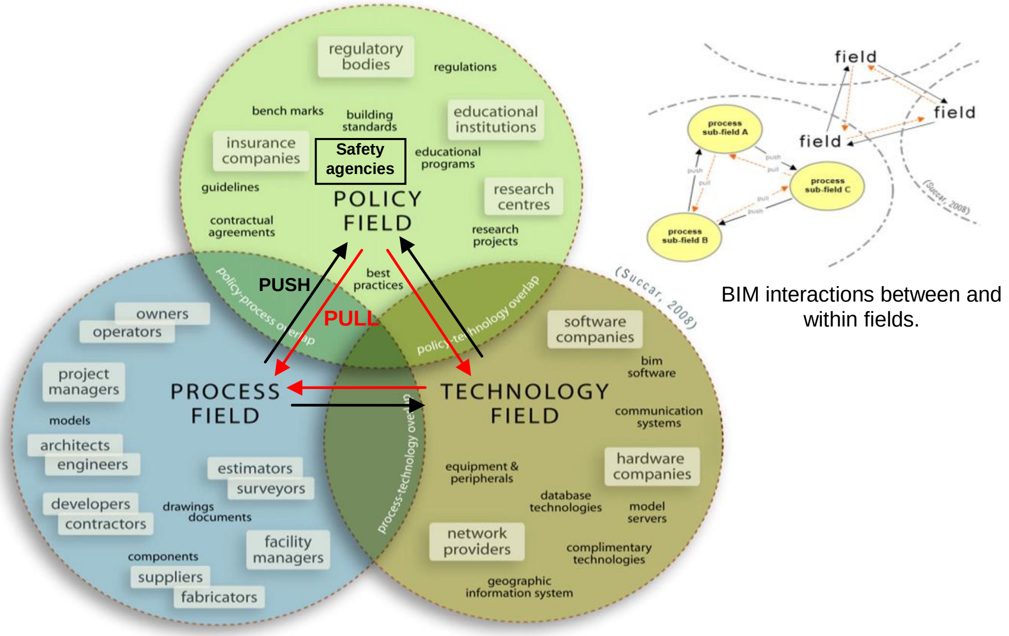
(Isikdag *et al*., 2008). More information about the geometric representations of building elements and their spatial relationships are provided at Liebich (2004).

Shen *et al*. (2010) determine as IFC standard's key contents, the conceptual model and the space utilization of a building; the information about the construction site in terms of location, dimension etc.; the product structure and the detailed model of a building so that the various facility elements including relations between them such as number of storeys, shape and properties of each wall, door, floor, etc. to be feasible to be captured; the structural elements (e.g. footings, reinforcements etc.) and the structural analysis of a building, the equipment specifications and the information on the actual units installed in a building like HVAC, filter, pump, reservoir with their associated capacity etc.; the electrical wiring and the plumbing details of a facility.

Works that implement and employ BIMs and in particular IFCs can be found at Halfawy and Froese (2007); Song *et al*. (2007); Plume and Mitchell (2007); Nour (2007); Schevers *et al*. (2007); Bletzinger and Lähr (2006); Chen *et al*. 2005; Halfawy and Froese (2005); Tanyer and Aouad (2005); Stephens *et al*. (2005); Lee *et al*. (2003); Yu *et al*. (2000) and Vanlande *et al*. (2008). Cerovsek (2011) considers that BIM standards such as IFC have achieved partial but important progress in terms of interoperability, but still they do not exhibit trust or allow comparability.

### ***BIM fields in the context of risk management.***

Succar (2009) determines technology, process and policy as the overlapping fields of BIM (see figure 3.11). Each one is consisted of two sub-fields: the stakeholders and the deliverables.



BIM interactions between and within fields.

Figure 3.11: The interlocking BIM fields in a Venn diagram showing BIM clusters, overlaps and interactions (adapted from Succar, 2009).

According to Compact Oxford English Dictionary (2014), technology is termed as “the application of scientific knowledge for practical purposes”. In the context of BIM’s technology field all the stakeholders e.g. organizations involved in the development of software, hardware and network systems are grouped in order to increase the collaboration, efficiency and productivity throughout the building’s lifecycles (Succar, 2009). Eastman *et al*. (2008) note that with BIM technology, the digital construction of a precise virtual model of a building i.e. Building Information Model which carries all its physical and functional characteristics is feasible. In particular, this computer generated model includes accurate geometry and other information associated with the construction e.g. structural and anti-seismic details, construction materials, building elements, interior structures etc., fabrication and procurement of a particular facility which can prove useful in the risk management process. For instance, structural elements, construction materials and possible fabrication defects are taken into account in the estimation of building exposure and resistance to identified hazards while building geometry, installed equipment and interior structures including openings of the doors are used in the preparation of evacuation plans as part of risks' mitigation measures throughout the facility lifecycle. Furthermore, information related to building infrastructure including the energy, water, electricity supply and communication systems is important in the identification of potential internal hazards which can form secondary sources of large magnitude with severe consequences on their receptors in the case of incidents such as floods, fires, earthquakes etc. These incidents can cause building's natural gas pipes failure and explosion, crack of its water and drainage pipes and short circuit of its electric and communication wiring with high impact on the facility itself, its residents and its surrounding environment.

Isikdag *et al*. (2008), mention that as a Building Information Model is by definition covering the entire lifecycle of a building, when the status and usage of its elements change in time given that the usage of this building evolves, the updated information about the current condition and usage of the building elements can always be found in the BIM databases. For instance, a door represented as an exit in a building evacuation plan can later become permanently closed when the usage of a room alters. Therefore, BIMs (e.g. in the form of IFC) will always be more accurate as they represent the current condition of the building elements compared to the information in the evacuation plan which is prepared in advance. In brief, significant real time geometric and semantic information can be extracted on demand from BIMs' databases in the context of risk management and crisis response.

Davenport (1993) defines process as "a specific ordering of work activities across time and place, with a beginning, an end, and clearly identified inputs and outputs: a structure for action". In BIM's process field, all the stakeholders who are charged with the design, construction, use, management and maintenance of buildings i.e. architects and engineers, contractors and property developers, facility owners and managers are clustered in order to urge collaboration during building's lifecycle, from inception onwards. Azhar *et al*. (2012) see the BIM's virtual process as a way to encompass all aspects, disciplines and systems of a facility within a single virtual model, enabling all the involved stakeholders to collaborate more accurately and efficiently than traditional processes. In addition, they point out that as the BIM foundations are laid on the pillars of communication and collaboration, the successful implementation of BIM calls for early involvement of all project stakeholders which means that traditional project delivery systems have limited role in BIM-based projects. Azhar *et al*. (2008) state that in contrast to the "new" BIM process, the "traditional" 3D CAD delineates a building by independent 3D views such as plans, sections and elevations. In addition, data in 3D CAD are represented by graphical entities e.g. lines, arcs and circles while in the intelligent contextual semantic BIM models information is defined in terms of buildings elements and systems e.g. spaces, walls, columns, beams. Figure 3.12 demonstrates the difference between "traditional" and BIM processes.

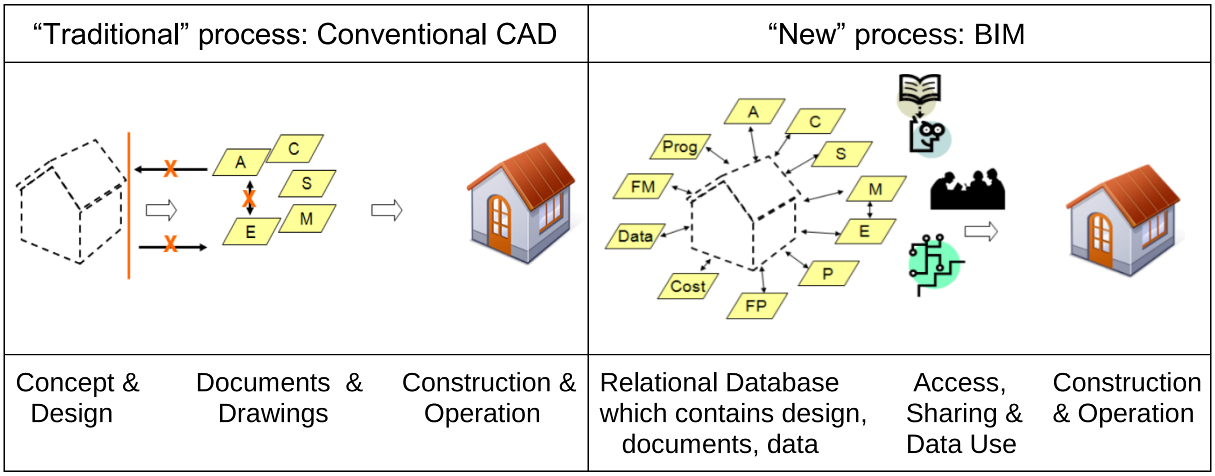


Figure 3.12: Comparison between "traditional" and "new" processes.

(Azhar *et al*., 2012; Azhar *et al*., 2008)

Clemson (2007) defines policies as "written principles or rules to guide decision-making". In BIM's policy field all the stakeholders dealing with education and research, risk mitigation and management, identification and minimization of conflicts are clustered (Succar, 2009). These stakeholders include research centers, educational institutions, safety agencies, insurance companies and regulatory bodies who play significant role in the definition of the contractual and construction rules as well as in the regulation of the facilities. In the context of risk management, special attention must be paid by the policy stakeholders in the determination of the general terms and conditions of the buildings at high risk (Isikdag *et al*., 2008) which include hospitals, secondary and primary schools, civic and heritage facilities, retail and department stores. For these premises which can potentially host vulnerable population such as disabled people, elder population and children, provisions for evacuations plans must be regulated towards mitigation of risks throughout buildings' lifecycle.

Succar (2009) states that BIM interactions are push-pull knowledge transactions which take place within or between fields or sub-fields (see figure 3.11), where push mechanisms (Holsapple and Joshi, 2006) transfer knowledge to another field or sub-field, while pull mechanisms transfer knowledge to answer a query from another field or sub-field. In the context of risk management, this two-way (reciprocal) transfer of knowledge between all the interested parties at the smaller scale of a building, it can enable them to become informed and risks-aware. Furthermore, the BIM overlapping fields can be seen as an opportunity for communication, collaboration and integration of the roles of all the participants involved in a particular project including those dealing with risk management and mitigation. In this respect, efficiency and unity between the stakeholders who in the past could see themselves as opponents can be delivered. In addition, intelligent, transparent and shared digital representations of buildings founded on open standards, for instance IFC, can be achieved. In brief, BIM through its fields and sub-fields, can contribute to participatory identification and assessment of risks at the building scale as well as to the development of emergency preparedness plans including shortest alternative building's (internal and external) evacuation routes for crisis response.

## 3.5 A concept proposal for efficient flood risk communication and management: An interoperable 3D information system based on virtual 3D city models.

The conceptual 3D information system which bases on the virtual 3D city model presented at figure 3.5 and extended by open standards i.e. CityGML and IFC (see figure 3.13), it aims to provide all the stakeholders involved in risk management and crisis response with an innovative, versatile and intuitive platform to access, visualize and comprehend risk related spatial information. In particular, this system through standards, workflows and rules, intends to integrate heterogeneous and distributed data from GIS and BIM domains into a cross-disciplinary and multifunctional integration conceptual platform which targets to support the cognition of risk situations and functional relations in the context of the S-P-R model. In this frame, the proposed system via its components purports to enable equal and interoperable access to spatial information towards communicating risks, ensuring transparency, building trust, raising awareness and engaging stakeholders to an interactive and solution oriented risk management process.

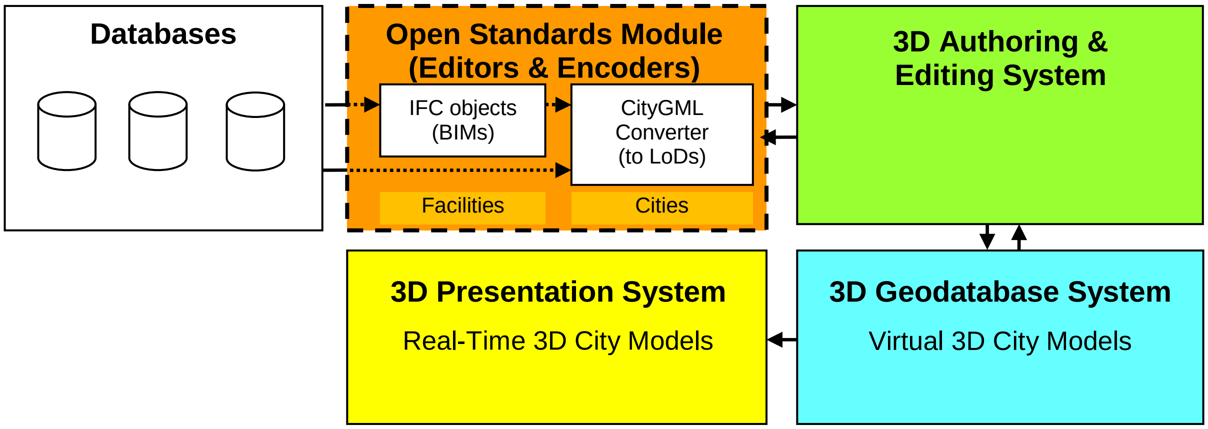


Figure 3.13: Overview of the conceptual 3D information system.

Detailed risk-related information at the micro (building) and/or the macro (regional-city) scale is of utmost importance in the participatory management of risks and the preparation of evacuation plans. Döllner and Hagedorn (2008) mention that the integration at the data level, it transforms and converts data into a unified (target) model which must be powerful enough in order the different schemata to be mapped in a lossless way. Mao (2011) states that since IFC models are designed for a more detailed level, CityGML is the most suitable standard to represent a whole 3D city which through its different LoDs can be utilized for modelling small to large areas. In addition, since IFC is lacking concepts for spatial objects such as streets, vegetation objects and water bodies is not appropriate for the representation of complex city models (Kolbe *et al*., 2005). Meanwhile, BIM data in IFC format can be converted into CityGML data, thus becoming important source of 3D city objects. In this context, in the system's open standards module, facilities-related data (e.g. buildings) are initially edited in IFC format recognizing that IFC provides detailed specifications of buildings' models including their internal technical infrastructure and development history. Afterwards, they are converted to CityGML LoDs, therefore becoming geo-referenced. The remaining city-related objects e.g. terrain, transportation networks, water bodies, vegetation, plants etc., are directly converted to CityGML. The LoD in which the city objects are eventually represented should correspond to the accuracy of the available data. With IfcExplorer (2007), a complete IFC model can be exported into CityGML or vice versa. In addition, Laat and Berlo (2011) have described a CityGML extension called GeoBIM to get semantic IFC data into a GIS context and convert IFC to CityGML. Also, Isikdag and Zlatanova (2009) have presented a general overview of semantic and geometric information transformation from BIM and in particular from IFC into CityGML models. By supporting regional 3D models, CityGML can consist of hundreds of buildings integrating all the information derived from the individual IFC models. Nevertheless, it should be recognized that the construction of CityGML LoDs is challenging while considerable time and effort are required for the representation of data in a lossless way. In addition, attention must be paid in the collection of semantics as well as in the check of the validity of the city objects' geometry.

The presented conceptual 3D information system through its components, it delineates the physical and functional characteristics and relations of the city objects in a detailed geometric way at the macro and micro scale and it facilitates analysis functionalities. During the risk management process, it can be required for example to identify all the buildings which their designated internal evacuation routes lead to emergency exits (doors) that have width and height above a specified threshold and are located along a specified street. The geometric and semantic information derived from the detailed open data models of the system, are very important in the querying of the city model which leads to a report with the corresponding buildings having the required attributes. Otherwise, all the building models along the specified street should be virtually explored. The widths and heights of the buildings' doors (emergency exits) as well as other key structural elements are stored semantically in IFC which are converted to CityGML, thus becoming geo-referenced in the context of the proposed 3D information system. In the preparation of the evacuation plans, other queries that can be satisfied on-demand through the conceptual 3D system can ask for example for combined information at both the macro (city) and micro (facility) scale. Such queries may request at the macro scale, the identification of the shortest routes in terms of street networks with width above a threshold that in a specified buffer zone are not intersected by water bodies, driving to a facility with particular location; while at the micro scale, they can ask for the indoor route e.g. the right side of this building where natural gas and water pipes are not installed based on its internal structures and equipment.

The conceptualized 3D information system is planned to enable interoperability[7] throughout the risk management process, thus playing significant role in efficient and time-effective management of risks. In terms of risk management, interoperability means that the involved stakeholders should be enabled to work together in a collaborative manner. But when stakeholders work together, they need to communicate in a common language ending up to mutually agreed decisions for risk minimization. For achieving semantic interoperability, the

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[7] The European Interoperability Framework (EIF) for European Public Services (EIF, 2008) defines interoperability as "the ability of disparate and diverse organisations to interact towards mutually beneficial and agreed common goals, involving the sharing of information and knowledge between the organisations, through the business processes they support, by means of the exchange of data between their respective ICT systems." The EIF in its version 1.0 (IDABC, 2004) introduces three levels of interoperability i.e. organizational, semantic and technical while in its version 2.0 adds a legal level and a political context to the interoperability levels. EIF (2008) determines organizational interoperability as the coordinated processes in which different organizations achieve a mutually beneficial and commonly agreed goal; semantic interoperability as the precise meaning of exchanged information which is preserved and understood by all parties; technical interoperability as the planning of technical issues involved in linking computer systems and services; legal interoperability as the aligned legislation so that exchanged data is accorded proper legal weight while in the political context it is required to ensure cooperating partners with compatible visions, aligned priorities and focused objectives.

system employs open XML-based standards which are essentially shared dictionaries, common sets of definitions. At the technical interoperability level, the system through its explicitly defined data interfaces, it facilitates seamless exchange and reuse of information. In the context of organizational interoperability, the system through its virtual 3D city models irrigates the risk management process with transparency and openness towards building trust, educating and raising awareness of stakeholders, facilitating cooperation and discussion between them which can lead to informed decisions that in the political context follow the stakeholders' values, objectives and priorities. The system's data models which underpin the virtual 3D city objects are inherently legitimized due to their open nature.

In short, the 3D information system intends to bring together all the stakeholders involved in the risk management process and through its 3D presentation system, it purports to provide them with accurate and interoperable digital 3D representations of risk related objects founded on open international standards, tailored to their specific needs and stored and maintained in the system's 3D geodatabase. The system based on virtual 3D city models, it intends to visually communicate risks to the stakeholders who can interactively identify S-P-R linkages, provide their inputs, adapt, query, analyze the 3D city models and evaluate the impact of their decisions in terms of risk mitigation.

## 3.6 Final remarks on the role of 3D information concepts in flood risk communication and management.

The world is becoming increasingly urbanized, while more inhabitants and assets are accumulated in disaster prone urban areas. In light of this, the cities should become more resilient to threads and the society must be prepared to tackle associated risks and residual risks. In order this to be achieved; risks should be identified, assessed, communicated to the interested parties and participatory managed.

Virtual 3D city models are certainly excellent media for communication of risk related information, fact which has been verified through extensive literature survey. They can integrate, manage, present and distribute complex risk related geo-information in an understandable manner close to what the stakeholders are used to see in the real (3D) world towards nurturing transparency and trust and promoting collaboration. These 3D city models intend to educate and inform the interested parties about risks and they purport to raise their awareness regarding the seriousness of a particular situation. In this way, they become capable to participate, exert their influence and judge the alternatives for risk minimization during the decision making process. Nevertheless, the quality of the representations of the 3D city objects is directly related to the availability and accuracy of data.

In this study, a virtual 3D city model for the case of Heerhugowaard has been developed which delineates the geometrical and appearance characteristics of the city objects providing dynamic rule-driven 3D renderings of the flood risk components on the basis of the S-P-R model. It provides concise information (graphic and non-graphic), thus enabling visual data mining, analysis and navigation. Furthermore, it facilitates interaction which urge the stakeholders to play an active role in the decision making process for managing flood risks. In essence, this virtual city model offers dynamic 3D Common Operational Pictures (COPs) or 4D COPs taking into account the temporal variable (time) and it aims to create shared understanding among the involved stakeholders regarding flood risks. In addition, it enables the interested parties to examine their alternatives by modifying the city model parameters in real time and visually assess their implications. In this context, better decisions can be made in the cognitive domain resulting to better actions in the physical domain concerning the minimization of flood risks in an area of interest.

However, in the management of risks and residual risks where the stakeholders should be prepared in the case of an emergency and evacuation plans including internal and/or external routes should explicitly be defined; semantic, topological and thematic information in regards to the 3D city objects and their components are required. This information intends to satisfy the needs of the safety agencies for querying and analyzing the 3D city models.

A key aspect for efficient risk management and emergency preparedness is the capability of the involved organizations to inter-operate i.e. work together. However, the fact that the data required for risk management are derived from different sources and are often in different formats, it calls for adopting a “common language” between the involved safety agencies which will overcome this data fragmentation.

A 3D information system based on virtual 3D city models and extended by open existing international standards from GIS and BIM domains such as CityGML and IFC respectively, it has conceptually been deployed and presented aiming to make a step towards defining a system framework for risk management and emergency preparedness. Overcoming limitations of the virtual 3D city model developed for Heerhugowaard area, the conceptual system purports to enable semantic interoperability throughout the risk management process. Additionally, it aims to provide the stakeholders with not only navigation functionalities but also easy-to-use querying and analysis capabilities. These are intended to be granted to them via the standards employed by the conceptual system which will provide semantic, topological and thematic information besides the geometrical and appearance characteristics of the 3D city models. Furthermore, the 3D information system via the detailed description of the physical and functional characteristics and relations of the city objects at the macro (city) and micro (facility) scale, it aspires to allow the development of alternative external and internal building evacuation routes for management of the residual risks. In the context of this 3D information system, CityGML has been selected as target model for the representation of the complex urban space since it is more capable of modelling objects at the macro scale using five distinct LoDs while IFC classes are designed for representing information in a very detailed way at the micro scale. BIM data in IFC format is a valuable source of information in regards to city facilities which contains updated information regarding their status and structures while a literature survey demonstrated that work has already been done in the direction of their conversion to CityGML format. However, the CityGML LoD in which the city objects are eventually represented, it depends on the accuracy and availability of the required data. In addition, the construction of CityGML LoDs is challenging while the collection of semantics and the check of the validity of the city objects' geometries is demanding in terms of time and effort.

For the integration and seamless exchange of massive risk related information derived from heterogeneous and distributed sources, agreed standards should be followed. However, as risk related data can be under the control of different ownership and rights, a legal framework that must govern these data sets must be determined at the political level, following discussions between stakeholders including the public, the experts and the decision makers.

Governments and safety agencies should support the adoption and utilization of 3D city models in risk management as they purport to facilitate the cognition of risk related situations by providing a level field for equal access to information, simultaneously increasing transparency, trust and cross-disciplinary collaboration. The overlapping BIM fields indicate an opportunity for collaboration, knowledge transfer and integration of the roles of all the involved stakeholders at the facilities' level. However, collaboration neither can be imposed nor can work being just a notion in the context of a risk related institutional framework. Virtual 3D city model-based information systems can facilitate collaboration but for its practice, alterations in institutional behaviors are required.

In short, a 3D information system based on virtual 3D city models forms an ambitious concept which has the potential to support both information and communication processes towards building capacity for participatory flood risk minimization, preparedness and response. For fully setting the framework of a system for flood risk management and extending the potential as well as the academic and institutional standing of the presented conceptual system, further investigations in collaboration with interested stakeholders are needed.

# 4. A COMMON OPERATIONAL PICTURE IN SUPPORT OF SITUATIONAL AWARENESS FOR EFFICIENT EMERGENCY RESPONSE OPERATIONS.

Efficient emergency response needs a multi-disciplinary approach which in turn it calls for a high level of collaboration and coordination among the involved safety agencies. Furthermore, in order to cope with the complexity, uncertainty and dynamic nature of an emergency, flexible information and communication systems are required. Based on experiences from the military domain, strategic concepts which can improve information sharing and collaboration can be derived and adapted towards enhancing emergency response information systems and operational effectiveness. This study purports to review the state of the art in this field providing recommendations for emergency response policy makers, professionals and researchers.

## 4.1 Introduction.

Natural disasters strike since the ancient times and despite the advancements in science and technology, they still have enormous socioeconomic and environmental impacts each year (Helbing and Kühnert, 2003, Chang *et al*., 2007). In the context of the dynamic and complex task environment of a disaster, multiple organizations and stakeholders are required to convert from autonomous actors to interdisciplinary and interdependent emergency response teams (Janssen *et al*., 2010). The probably most significant question that arises for these responding teams is what is going on (Oomes, 2004)? For the latter, timely access to all relevant (geo-) information is critical (Suri *et al*., 2010).

During an emergency, several operational field units at different levels with various functional command structures coming from different organizations which may have different backgrounds, professional languages and operational expertise, they should share information acquired from various sources, communicate, co-operate and coordinate their actions within a short period of time towards normalizing an emergency situation (Comfort and Kapucu, 2006). The quality and timeliness of information can shape the effectiveness of the emergency response operations (Horan and Schooley, 2007). Furthermore, accurate and relevant information can play a pivotal role towards reducing the potential damages in lots of threatening situations (National Research Council, 2007). Finally, the need of coordination in emergency response is axiomatic as its absence drives to a number of possible failures which often result in the escalation of an incident to a disaster and even higher number of victims (Bharosa *et al*., 2010). In this connection it should be mentioned that a number of studies (e.g. Junglas and Ives, 2007; Helsloot, 2005; Pan *et al*., 2005; Dawes *et al*., 2004) verify that poor information sharing and coordination during inter-organization emergency response has a negative impact on decision making and actions. In addition, information gaps along with lack of fluent communication and absence of a common operation picture in use have been identified as the major factors that hinder the emergency response organization (Seppänen *et al*., 2013).

Information sharing and coordination stay at the top of the research agenda, despite the progress that may have been done through time (Bharosa *et al*., 2010). In order to overcome the information management and dissemination problems, the emergency response organizations support the employment of more advanced and better equipped information systems derived from the logic of network enabled capabilities (Wolbers and Boersma, 2013; Boersma *et al*., 2012). Such systems should assist emergency response stakeholders to achieve shared situational awareness by deploying a Common Operational Picture (Wolbers and Boersma, 2013; Comfort, 2006; Endsley, 1995). Having shared situational awareness, the responding organizations can dynamically understand “what is going on” while their subsequent decisions and actions highly depend on it.

In short, emergency response organizations still struggle with information sharing, communication and coordination (Wolbers and Boersma, 2013; Bharosa *et al*., 2010; Comfort, 2007; Netten and Someren, 2011; Quarantelli, 1997). The unforeseen, dynamic and complex nature of an emergency in which multiple groups of professionals need to cooperate is seen by various scholars (e.g. Kapucu, 2006; Heide, 1989) as the reason for which the responding agencies battle to share and coordinate information. Although information sharing and coordination in emergency response are of apparent importance, they have received relatively little scientific attention (Bharosa *et al*., 2010; Chen *et al*., 2008a; Ren *et al*., 2008). Consequently, the main goal of this study is to provide through extensive literature survey an objective and systematic overview of strategic information concepts and to illustrate their empirical usefulness and benefits for effective emergency response.

In this context, the paper commences its mission by presenting in chapter 2 a literature review on natural disasters providing a thorough classification of their different types as well as numbers and losses worldwide. Moreover, after distinguishing between incident and disaster a detailed description of the different phases of an emergency followed by characteristic types of delays during emergency response operations is provided. Next, in chapter 3 the design premises of a flexible and dynamic emergency response system are delineated based on literature. Thereafter, in chapter 4 the network centric enabled capabilities for information sharing during emergency response are analyzed and their real benefit which is reflected in their value chain is explained. Then, in chapter 5 situational awareness and in particular individual, shared and team situational awareness and models are explored. Afterwards, in chapter 6 a background to a common operation picture is presented and challenges in its achievement are identified. Furthermore, the added value service of a common operation picture in emergency response is theoretically investigated and a basis for its qualitative and quantitative assessment is proposed. Finally, this contribution concludes by discussing the main findings and providing recommendations for emergency response policy makers, professionals and researchers.

## 4.2 Natural Disasters.

Natural disasters have stigmatized the human history, causing peaks in terms of mortality and morbidity (Leaning and Guha-Sapir, 2013). The Centre for Research on the Epidemiology of Disasters (CRED) (Guha-Sapir *et al*., 2014) defines disaster as “a situation or event which overwhelms local capacity, necessitating a request to a national or international level for external assistance; an unforeseen and often sudden event that causes great damage, destruction and human suffering”. The United Nations International Strategy for Disaster Reduction (UNISDR) terminology (2009) determines disaster as “a serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources”. The International EMergency Disasters DATabase (EM-DAT) (2013) classifies natural disasters in 5 groups which in turn cover 12 disaster types (see table 4.1).

Table 4.1: Classification of natural disasters.

| | | Hydro-Meteorological | | |
|---|---|---|---|---|
| **Biological** | **Geophysical** | **Hydrological** | **Meteorological** | **Climatological** |
| **Epidemic**<br>Infectious Disease<br>• Viral<br>• Bacterial<br>• Parasitic<br>• Fungal<br>• Prion | **Earthquake**<br>• Ground Shaking<br>Tsunami | **Flood**<br>• General River Flood<br>• Flash Flood<br>• Storm Surge/Coastal Flood | **Storm**<br>• Tropical Storm<br>• Extra-Tropical Cyclone<br>• Local/Convective Storm | **Extreme Temperature**<br>• Heat Wave<br>• Cold Wave<br>• Extreme Winter Conditions |
| **Insect Infestation** | **Volcano** | **Mass Movement (Wet)**<br>• Rockfall<br>• Landslide<br>• Avalanche<br>• Subsidence | | **Drought** |
| **Animal Stampede** | **Mass Movement (Dry)**<br>• Rockfall<br>• Landslide<br>• Avalanche<br>• Subsidence | | | **Wildfire**<br>• Forest Fire<br>• Land Fires (grass, scrub, bush, etc.) |

(EM-DAT, 2013)

Over the past five decades (see figure 4.1), the number of the overall natural disasters present an increasing linear trend causing severe economic losses while the hydro-meteorological disasters are the most dominant in terms of numbers and economic damages. Biological events are not considered here, as they require specific approaches and often are not directly related to geophysical and hydro-meteorological events (Leaning and Guha-Sapir, 2013).

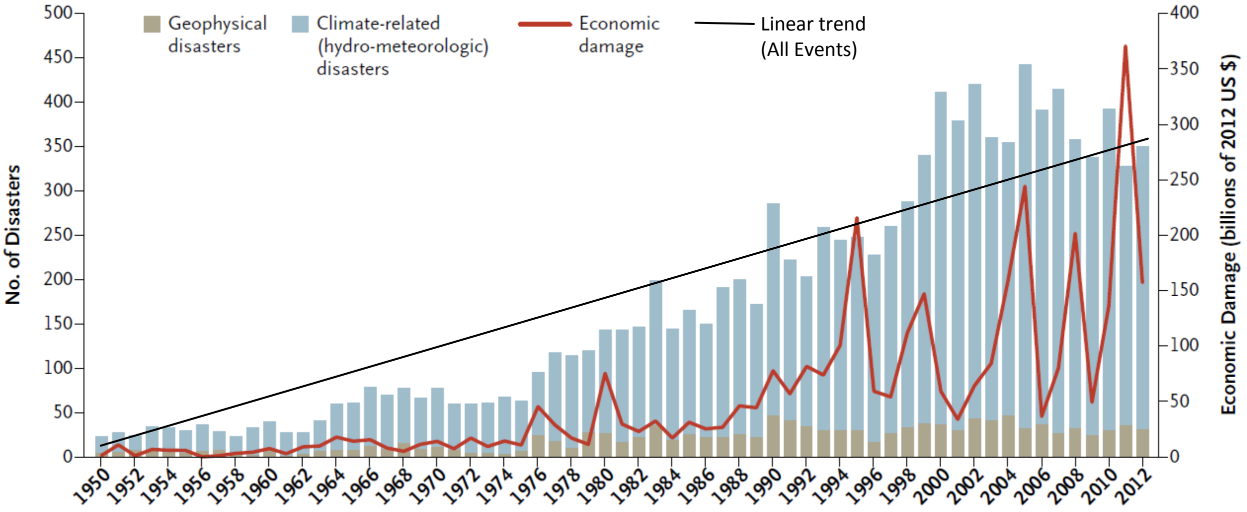


Figure 4.1: Numbers and types of historical natural disasters.

(Adapted from Leaning and Guha-Sapir, 2013)

Only in 2014, the NatCatSERVICE of the Munich RE (2015) has recorded 980 loss events distributed all over the world (see figure 4.2) that have caused overall 7 700 human fatalities and losses of around $110 billion of 2015 US dollars. From these, 900 were hydro-meteorological events which caused 6 900 human deaths and losses of $97 billion of 2015 US dollars. Looking at the geographical distribution of the events in 2014, Asia following the trend of the past three decades (UNESCAP, 2013) is the most disaster-prone region with the largest number of people killed and the greatest economic damages. In particular, according to Munich RE (2015) (see figure 4.3) Asia was the continent hit by most of the natural disasters (37%) followed by North America including Central America and Caribbean (20%), Europe (16%), Africa (10%), South America (9%) and Oceania (8%). In addition, Asia in 2014 accounted for 75% of global disaster victims followed by Africa (10%). Furthermore, Asia suffered from the 46% of the global damages followed by North America including Central America and Caribbean (29%) and Europe (16%).

○ Loss events ● Geophysical events ● Hydrological events

○ Selection of catastrophes ● Meteorological events ● Climatological events

Overall losses ≥ US $1 500m

Figure 4.2: Geographical distribution of loss events during 2014.
(Munich Re NatCatSERVICE, 2015)

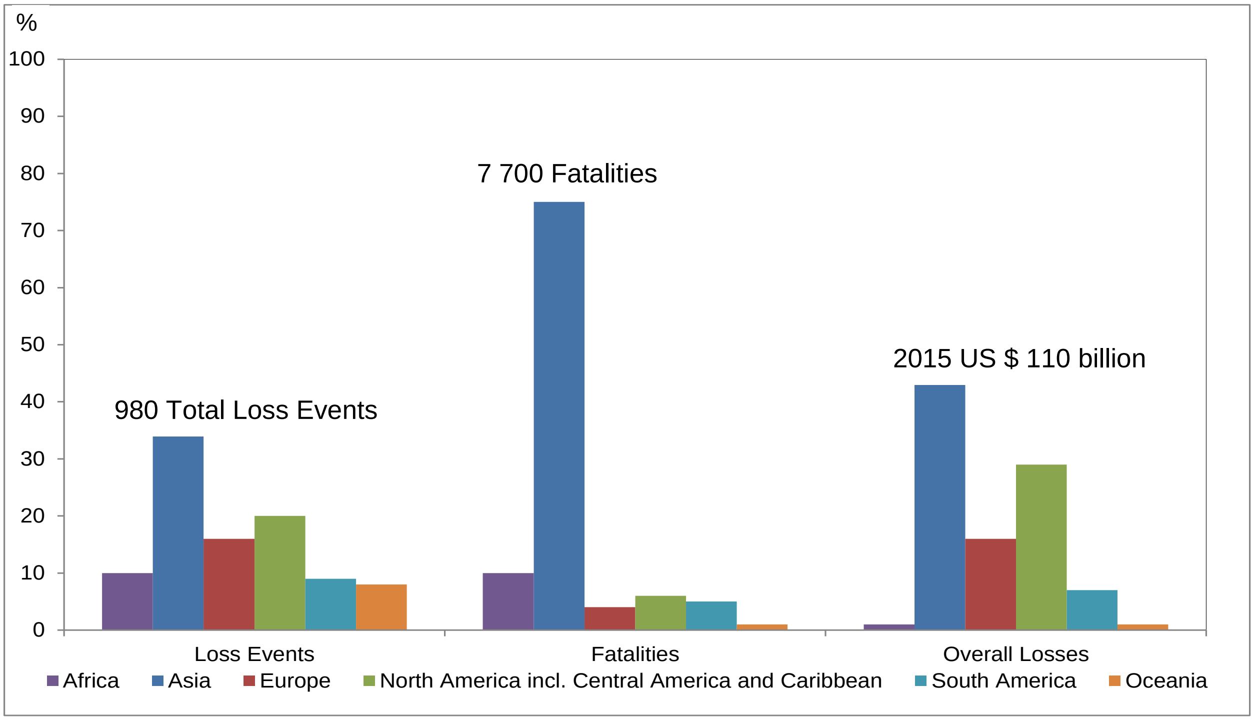


Figure 4.3: Loss events in 2014 ordered by continent.
(Adapted from Munich RE, 2015)

Natural disasters, particularly floods and storms present an increasing trend in terms of frequency and seriousness affecting the mortality, morbidity and welfare of the society. Montanari and Koutsoyiannis (2014) mention that the growing impacts of extreme events, along with the observation that the environment alters in a phenomenal manner, stresses that human facilities are becoming more exposed to natural hazards and risks. Furthermore, the level of vulnerability of an exposed community to such hazards, it specifies the extent to which a hazard can cause a disaster (EEA, 2010). In the years ahead, the international community should face the root causes of crises (Leaning and Guha-Sapir, 2013). In this context, transnational solutions enabled via an effective framework for regional cooperation by allocating resources towards better preparedness as well as by reinforcing the early warning systems are needed (UNESCAP, 2013). Humanitarian relief is and will always be required due to unforeseen natural events which call for effective emergency response during a crisis situation.

### 4.2.1 Incidents versus disasters and emergency response.

Oxford Dictionaries (2015) determine incident as “an instance of something happening; an event or occurrence” while disaster as “a sudden accident or a natural catastrophe that causes great damage or loss of life”. In order an incident not to escalate to a disaster effective emergency response is required. According to UNISDR (2009) response is “the provision of emergency services and public assistance during or immediately after a disaster in order to save lives, reduce health impacts, ensure public safety and meet the basic subsistence needs of the people”. In this context, plans and institutional arrangements that involve and guide the efforts of the multiple safety agencies in a comprehensive and a coordinated fashion towards responding to the entire spectrum of emergency needs are engaged.

Emergencies are considered as high stress situations which need organizations to respond in a way that is different from their normal operating procedures (Raman *et al*., 2012; Otim, 2006; Jennex, 2004; Turoff, 2002). Walle and Turoff (2008) note that emergencies are by definition situations in which the stakeholders are not familiar with nor likely to become familiar with; and their occurrence evokes intense feelings of stress, anxiety and uncertainty. During an emergency situation, not only will they have to manage these feelings, but also they should comprehend the situation among conflicting or missing information, deciding for the appropriate response actions in a short period of time.

Jennex (2007) see emergencies as a series of four phases (see figure 4.4) i.e. Situational Analysis (SAn), Initial Response (IR), Emergency Response (ER) and Recovery Response (RR) and five decision points i.e. the Initiating Event (IE), the Control Event (CE), the Restoration Event (RE), the Normalizing Event (NE) and a Terminating Event (TE) which are described below in details:

- *SAn phase*: During this first phase, information is acquired and assessment of the situation is performed by the safety agencies. It has a base level of activities which include monitoring and analysis of a set of predetermined conditions for detection of unusual or pre-identified deviations, identification of the IE and training and preparation of the emergency responders. When an IE is determined during the SAn phase, an emergency is considered that initiates and it causes the start of the IR phase.

- *IR phase*: This is a short duration phase in which verification of the emergency is being done, followed by generation of early warning notices, initialization of preplanned preliminary actions and introduction of the emergency response plan.
- *ER phase*: It begins directly after assuming control by the emergency response teams i.e. after a CE and in general after the completion of the immediate response actions and early warning notifications. This phase implements the emergency response plan and begins the coordination of the responders, the deployment of the assets and the allocation of the resources. Being the command and control phase of emergencies, it requires from the emergency responders to monitor conditions and progress of the response operations, adjusting them accordingly. The ER phase reaches the maximum activity level during an emergency, ending with the RE. At this point, the emergency responders deduce that the emergency conditions are under control and hence no further response actions are needed leading to the termination of the command operations of the emergency control center and the entrance of the emergency into the RR phase.
- *RR phase*: This phase has a declining level of activities during which is verified that the emergency is under control and organization, management and coordination of long term activities and reconstruction for the normalization of the situation takes place. Furthermore, lessons learned from the management of the emergency are identified and documented towards better preparation for potential future emergencies. The RR phase ends when the NE is formally declared. At this point, all the emergency response actions are completed. Moreover, long term response activities as well as a basic level of restoration have been made, the situation is normalized and the safety agencies are operating in their routine procedures being in the SAn phase.

TE can occur in the case of a false detection of an incident or in the case where another emergency has been prioritized or in the case of any event that could cause the suspension of the response. In general, TE can take place in any phase and time denoting the termination of an emergency. This is also the reason for which is not illustrated in the diagram of phases and timelines of activity levels of a typical emergency (see figure 4.4).

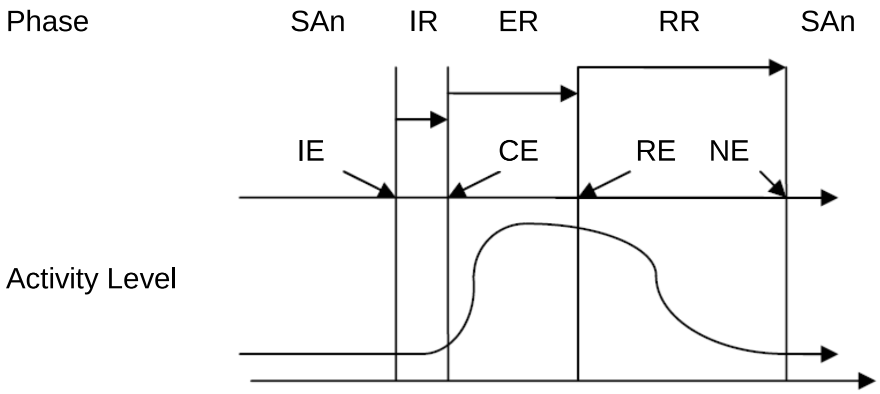


Figure 4.4: Phases and decision points with indicative amount per unit time of immediate response and decisions that need to be made following an IE.

*The figure does not correspond to scale and it is a general illustration of an emergency timeline*.

(Jennex, 2007)

### 4.2.2 Delays during an emergency response.

Chen *et al*. (2007), see emergency response as a social activity where multiple agencies across functional disciplines and jurisdictions are involved. In particular, during an emergency, several response teams from various safety agencies with different organizational goals and cultures must cooperate in order to minimize the potential negative effects of an emergency (Schaafstal *et al*., 2001). For this, good coordination and communication not just within a response team, but also among the several teams involved is required.

During the emergency response operations, Chen *et al*. (2007) identify three characteristics types of delay:

- *Type 1*: This delay is related to the dispatch process of the emergency responders due to a limited Situational Awareness (SA) and comprehension of the extent of an incident. Coordination and decision making in a limited amount of time lacking relevant, complete and accurate geo-information is crucial. Novel information concepts with the capability to integrate and present up-to-date information about the incident, the surrounding environment and the response operations in real time are often needed. Furthermore, decision support systems which build upon such information concepts incorporating and adjusting decisions are often necessary. As the understanding of the situation may change and improve through time, the capacity of adjusting the decisions accordingly is of critical importance. Such a change can occur as individual observations of the scene are often biased by the observer's comprehension, background, reminiscence and verbiage. First responders, mention that these observations are frequently contradictory resulting in delays in regards to actionable decisions, as puzzling out conflicting information is hard and time consuming. Finally, the systems used to support decisions for emergency response should not refuse information seemingly useless, but maintain and analyze such information for potential useful content.

- *Type 2*: This refers to the time spent on the preparation of the responders for the implementation of their tasks and it can be reduced by organizing ex ante relevant training exercises. This preparation time can include identification of proper outfit and suitable equipment related to the type and severity of the emergency to be managed and travel time required to reach the hot zone (location awareness). Better preparedness for emergency response as well as better coordination during the emergency may contribute to the minimization of this delay.
- *Type 3*: This delay can occur during the process of information acquisition, communication and decision making. It can be addressed by facilitating Shared Situational Awareness (SSA) among the responders. SA and SSA are defined and discussed in a later section.

## 4.3 Design principles for an emergency response system.

Information and communication of varying scopes and proportions are of utmost importance during crisis situations (Walle and Turoff, 2008). Furthermore, teams of people who often represent different organizations, resources and roles are required to work effectively in a coordinated fashion supporting each other's' objectives even when they have never before worked together (Carver and Turoff, 2007). For this, flexible and dynamic emergency response information systems resting on generic design principles and tailored to the needs of the different safety organizations are required. Based on historic experience, Turoff *et al.* (2004 a, b) suggest nine design premises for a Dynamic Emergency Response Information System (DERMIS) (see table 4.2a, b).

Table 4.2a: Design premises for a DERMIS.

| **Design premises** | **Discussion** |
|---|---|
| System training and simulation | An emergency response system which has functions for the day-to-day operations, it partly eliminates the need for training and simulation. This occurs due to the fact that the professionals who must operate the system, they already gain extensive experience with it just by using it for their daily routine. |
| Information focus | The professionals dealing with the emergency response are often flooded with information and hence the emergency response systems should filter information according to the needs of the different actors. However, these should still be able to access all contextual information related to an emergency as information elements that are filtered by the system may be of utmost importance under unforeseen conditions. |
| Crisis memory | The system should enable logs of the events' chain during an emergency, without charging the emergency responders with extra workload. The information included in these logs can be used for system improvements for future emergencies as well as for analysis of the emergency situation itself. |
| Expectations as norms | Most of the emergencies are unique and hence a planned response to an emergency is not feasible to be followed in details. Furthermore, the majority of the actions are expectations to the earlier defined norms. Therefore, an emergency response system should be flexible enough to enable alterations in the configuration and allocation of resources during response operations. |
| Scope and nature of crisis | Depending on the nature of an emergency, the different response teams may have to be structured with members who will provide the appropriate knowledge and experience for fulfilling the teams' tasks. In addition, attention should be paid on the fact that some teams may operate for a specific amount of time transferring their tasks to other teams or actors. This applies also for individual team members who due to exhaustion may need to be replaced by others. |
| Role transferability | Emergency responders must be able to pass their roles to others when they are not capable to deal with an emergency. This means that an emergency response system's software should explicitly describe these roles and also the tasks, responsibilities and information needs of each of them. |

(Walle and Turoff, 2008; Turoff *et al*., 2004 a, b)

Table 4.2b: Design premises for a DERMIS.

| **Design premises** | **Discussion** |
|---|---|
| Information validity and timelines | During emergency situations, actions are taken based on incomplete information. Thus, it is of utmost importance for an emergency response system to be capable to store all the available information in a central database equally open to all those involved in the management of an emergency situation. In this manner, all the involved stakeholders can count on a wide base of information which in turn it may support them towards more effective and efficient decision making for the management of an emergency. Furthermore, when these stakeholders require unexpected (unpredicted by humans or technology i.e. the system) information, they need to be able to identify whether this exists or not and also who can or must be providing it. |
| Free exchange of information | During an emergency response, a vast amount of information should be shared and exchanged between the involved stakeholders in order these to become aware, gain control of the situation and supervise the response operations. However, a large amount of exchanged information can lead to information overload which can have negative contribution to the emergency response. Hence, the system must prevent the information overload of its users by assuming all the bookkeeping of communications and all the organization occurred. |
| Coordination | Due to the unforeseen nature of an emergency, the actions that should be taken as well as the responsibilities of the emergency response teams and individuals cannot be predetermined. In this context, an emergency response system should support flow of authority towards where the actions take place (usually on a low level of hierarchy) and simultaneously reverse flow of accountability and situational information upward and sideways through the organization. |

(Walle and Turoff, 2008; Turoff *et al*., 2004 a, b)

People can deal with a high degree of uncertainty to make timely decisions as long as they know that these are not based on hidden information which will make their actions to look wrong later. In this context, the persons required to make decisions during an emergency should be ensured that they can find and precisely understand all the information relevant to their decision in a timely manner; as in an emergency what might be considered the most relevant, may simply not exist (Turoff *et al*., 2004b).

An emergency management system should face the reality of an emergency situation which requires movement of authority to lower levels and rapid responses (Turoff *et al*., 2004b). Otherwise, the system will be designed inadequately without being capable enough to handle the oversight function in a timely and effective manner during an emergency. As many serious decisions are irreversible (Pauwels *et al*., 2000), the latter can lead to incorrect decisions which cannot be altered or to delays in making a decision that eliminates the opportunity for choosing the best alternatives.

The nine design premises suggested by Turoff *et al*. (2004 a, b), can lead to an emergency response system flexible, robust, dynamic and capable to support the information and communication needs of the emergency responders at all the levels. Furthermore, according to Eede *et al*. (2006), they can allow the development of a dynamic emergency response information system capable to support and be integrated across different organizations.

## 4.4. Network centric enabled capabilities for emergency response.

When a disaster strikes, coherent coordination requires acquisition of relevant information from multiple sources, verification of its accuracy and sharing among responding organizations, all within a short period of time (Janssen *et al*., 2010). Information quality and timeliness can shape the effectiveness of the emergency response operations (Horan and Schooley, 2007). Furthermore, accurate and relevant information can significantly reduce the potential losses in lots of threatening situations (National Research Council, 2007). Lack of information and knowledge, their incorrect interpretation or discharge as irrelevant are among the main reasons of disaster management failure (Cooper and Block, 2006; Wiese, 2006; Dyson, 2006; US Select Bipartisan Committee, 2006). Furthermore, at the peak of an emergency when information accessibility, flow and distribution are of utmost importance; the lack of interoperability among the variety of databases, the information generation systems and the telecommunication platforms utilized by these systems are some of the most obtrusive contributors to mismanagement (Lubitz *et al*., 2008b; Lubitz and Wickramasinghe, 2006a; Lubitz and Wickramasinghe, 2006b; Lubitz and Wickramasinghe, 2006c; Lubitz and Patricelli, 2007; Dizard, 2006).

Architectures to support complex problems solving as well as coordination and information sharing during emergencies can be traditionally characterized as hierarchical solutions (Bigley and Roberts, 2001; Simon, 1996). Furthermore, Janssen *et al*. (2010) state that hierarchical control is often viewed as a necessity for managing disasters. However, Comfort and Kapucu (2006) mention that under the urgent and dynamic conditions of a disaster, such procedures almost always crash. In addition, Comfort (1999) points out that under cumulative stress, the hierarchical organization tends to fail and personnel are obstructed by a lack of information, constraints on innovation and an inadequacy to shift resources and actions to timely meet new demands. Schraagen *et al*. (2010) experimentally demonstrated that in complex environments, the network centric structures were more efficient in terms of speed, accuracy, information distribution, knowledge sharing and decision making compared to the hierarchical structures.

For complex, time dependent operations carried out in dynamic environments, the concept of “network-centric warfare” based on extensive use of information technology, information management and progressively increasing incorporation of knowledge management techniques, it has been introduced several years ago by the US Department of Defense (DoD) (Alberts *et al*., 2001). In particular, the Network Centric Operations (NCOs) have emerged as the solution to the major information and knowledge deficiencies and requirements during complex, large-scale crisis management operations (Cebrowski and Garstka, 1998; Lubitz and Wickramasinghe, 2006a; Lubitz and Wickramasinghe, 2006b; Lubitz and Wickramasinghe, 2006c; Lubitz and Patricelli, 2007). The NCOs' concept recognizes the need of empowering humans during emergency response. By incorporating NCOs, the military aimed at a broad sharing of situational awareness through the utilization of a Joint Operational Picture (Alberts *et al*., 2002). According to Alberts and Hayes (2007), DoD has identified four propositions of a NCO and a set of governing principles for a network centric force which are the tenets of netcentric warfare: i) a robustly networked force improves information sharing; ii) information sharing and collaboration reinforce the information quality and share situational awareness; iii) shared situational awareness allows self-synchronization and strengthens sustainability and command speed; iv) All these in turn are significantly increasing the mission effectiveness.

Lubitz *et al*. (2008b) mention that the concept of network-centricity has emerged in two parallel approaches. These are the Doctrine of Network-centric Warfare (DNW, Wilson, 2004) and the Network Enabled Capabilities (NEC, NATO, 2005) also known as Network Enabled Operations (NEO). From the two approaches, Lubitz *et al*. (2008b) identify that the NEC concept is more adaptable to the conditions of emergency response in which multiple uncoordinated and disorganized governmental, non-governmental, local and volunteer organizations are required to collaborate within the same operational environment, yet entirely without common information sharing capability. This is because unlike the network centric doctrine, NEC enables effects-based operations at the level of command and control as well as on the level of operational capability. Lubitz *et al*. (2008b) state that the “NEC may be the essential tool required to change the persisting individualism of the participating organizations”. Furthermore, NEC is a potential enabler of an adaptive management philosophy which can allow collaborative and flexible responses to future disasters (Wiese, 2006).

Networks, information and humans are the three overlapping and mutually dependent dimensions of NEC, which need continuous development for achieving full realization of the concept (UK Ministry of Defense, 2005). The networked information environment offers the capability to acquire, generate, manipulate and distribute information which in turn is crucial for the decision makers. The real value of NEC is reflected in its value chain (see figure 4.5). In essence, NEC value chain corresponds to the tenets of net-centric working (Alston, 2005; Alberts, 2002) and it attempts to indicate the NEC cause and effects chain that leads in “Better effects” i.e. the desired emergency response outcomes.

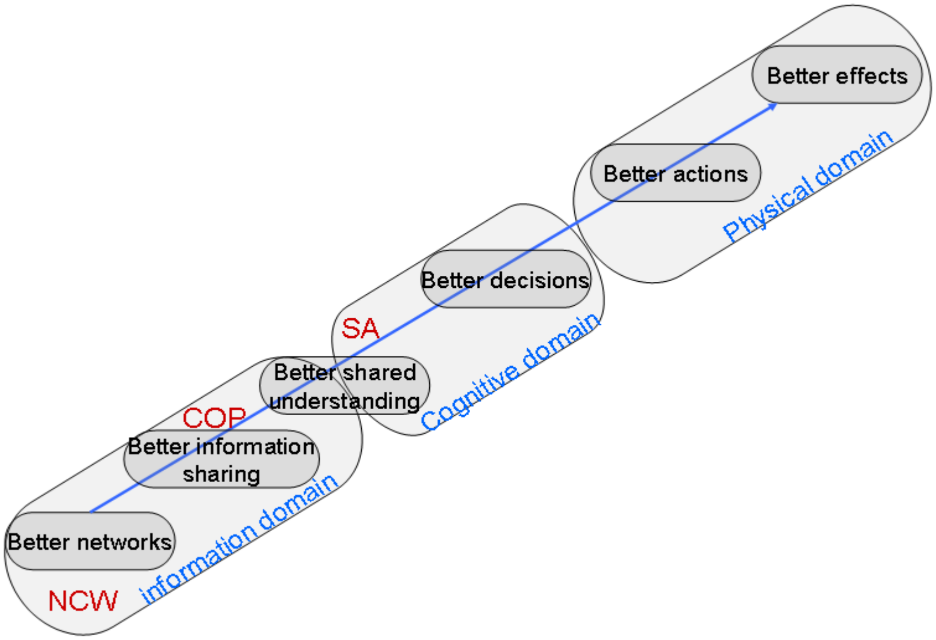


Figure 4.5: The value chain of Network Enabled Capabilities (NEC).
(Steenbruggen *et al*., 2012; UK Ministry of Defense, 2005)

NEC timely provides and exploits information and intelligence to enable effective decision making and versatile actions (UK Ministry of Defense, 2005). However, despite the fact that they offer decisive advantages in emergency response, they have some deficiencies. For example, Lubitz *et al*. (2008b) mention that these concepts are technology driven, with technology itself being one of the first victims of a major emergency. As a solution to this, Patricelli *et al*. (2008), suggest that preparation and planning can contribute in assuring that in spite of severe infrastructure damage, the essential network capabilities either keep operational or are timely restored to an acceptable functional level. Some other issues on NCO have been identified by Bharosa *et al*. (2009b, 2009c), who have done field research and in particular empirical analysis on the implementation of NCO and the resulting problems. Through their research, they identified that the implementation of NCO can unveil some shortcomings which cannot be addressed by NCO descriptions. In addition, they found that NCO can highlight some issues such as information overload making also the validation of information quality a difficult task. Furthermore, they acknowledged that despite the technological advances, the NCO concept’s effectiveness depends on the formulation of new institutional policies and roles in regards to information sharing. For all these matters, further research needs to be carried out. Therefore, the concept of net-centricity is not a panacea which solves all the crisis management problems, but it is a part of the solution.

## 4.5 Situational Awareness.

Many definitions of Situational Awareness (SA) exist (Endsley, 1988a; Fracker, 1988). Most of them converge that SA is about “knowing what is going on” (Endsley, 1995). According to Gilson (1995), the concept of SA has been identified during the World War I by Oswald Boelke who understood “the importance of gaining an awareness of the enemy before the enemy gained a similar awareness, and devised methods for accomplishing this” (Lagervik *et al*., 2006; Stanton *et al*., 2001). In technical and academic literature, the area did not receive much attention until the late 1980s, but thereafter diligent work has been done (Stanton *et al*., 2001). The aviation industry where pilots and air traffic controllers are required to develop better SA has been the driving force for research and development in this domain (Jenson, 1997). In this context, Nofi (2000) mentions that the concept of SA entered military usage through the aviation community. Both the concepts of SA and Common Operational Picture (COP) have been employed by the military as a guiding principle to define and/or supervise warfare operations (Steenbruggen *et al*., 2012).

Lack or inadequte SA has been found as one of the main causal factors in accidents attributed to human error (see Steenbruggen *et al*., 2012; Hartel *et al*., 1991; Redding, 1992; Merket *et al*., 1997; Nullmeyer *et al*., 2005). For example in the aviation industry, a review of over 200 aircraft accidents revealed that their main cause was the poor SA. Despite the fact that SA has its roots in aviation, the concept is equally applicable to human supervisory control for ground based industries (Kaber and Endsley, 1998). Some researchers criticize the concept for being very subjective (Gilson, 1995), very intuitive (Flach, 1995) and lacking a coherent definition (Sarter and Woods, 1991) while other researchers overcome these accusations, claiming that SA is a useful concept with utmost importance for operational settings (Gilson, 1995). Steenbruggen *et al*. (2012) see SA as especially important in work domains where the information flow can be quite high and poor decisions can cause disastrous results. Klein (2000) considers SA as a critical concept because: it is linked to performance; limitations in SA may result in errors; it may relate to expertise; it forms the ground for decision making. SA can be distinguished as individual or shared/team SA which will be analyzed in the following sections.

### 4.5.1 Individual SA: Definitions and models.

A commonly accepted definition of the SA of individuals is still missing (Sarter and Woods, 1991). In a high level of simplification, SA can be seen as an appropriate awareness of a situation (Smith and Hancock, 1995). Individual SA can be considered as a personal attribute (Nofi, 2000). The world around the individuals is approached in personal terms, based on their cultural background, education and experiences as well as on the strengths and limitations of their senses (Nofi, 2000).

According to Stanton *et al*. (2001), three main definitions dominate in the literature: Ensdsley's (1988) which focuses on an information processing framework; Smith's and Hancock's (1995) that pinpoints the reflective quality and Bedney's and Meister's (1999) which presents an embedded world view. In essence, Endsley's (1988) definition focuses on the perception and understanding of the world employing future projection of its current situation. In contrast to the latter, Smith and Hancock (1995) determine SA in terms of the interaction between the person and the world and hence it focuses on the way in which the two main systems cooperate.

Bedney and Meister (1999) pinpoint the reflective perspective of SA and in particular the relation with mental models incorporating understanding of the present system. The differences between these definitions are identified on the orientation of SA either as cognitive process used to develop and maintain SA or tangible product; as well as in terms of the underlying psychological approach.

As suggested by Stanton *et al*. (2001), three main theoretical approaches dominate in the SA domain: the information processing approach which is represented by Endsley's theoretical three - level model (Endsley, 1995); the activity theoretic approach which is best described by Bedney's and Meister's interactive sub-systems model (Bedney and Meister, 1999) and the ecological approach which is delineated by the Smith's and Hancock's perceptual cycle model (Smith and Hancock, 1995). In terms of SA orientation, the interactive sub-systems and the perceptual models focus on the process while the three-level model mainly concentrates on the product. However, Stanton *et al*. (2001) mention that in measuring SA none of these product-process perspectives should be ignored as the latter can be determined by the former.

From the theories of individual SA, based on Salmon *et al*. (2007), Endsley's three tier model of information processing has been the most useful for describing SA of an operator as well as for informing system design and evaluation (e.g. Endsley *et al*., 2003). In addition, Gorman *et al*. (2006) mention that many SA researchers have agreed in principle on Endsley's three part definition of SA. Endsley (1988) defines SA as: "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future". Therefore, SA is about perceiving critical factors i.e. status, attributes and dynamics of relevant elements in the environment (Level 1), understanding of the meaning of these elements after being synthesized, in light of the decision maker's goal (Level 2) and at the highest level (Level 3) predicting of what will occur with the system in the near future. Higher SA levels are dependent on the success of the lower levels (Wickens, 2008). An extensive review of Mica Endsley's articles on SA theory and measurement can be found in Wickens (2008).

Endsley's theories do not employ concepts such as COP and network centric operations in the definition of individual SA. The latter is more determined as a set of goals and decisions tasks for a certain job or activity of individuals within an organization and thus its context depends on what is the right information to support a SA environment (Steenbruggen *et al*., 2012). However, when the individuals work as team members and are required to perform their tasks in a network centric environment based on individual SA, there is an interrelation between the qualities of shared SA in terms of interaction. In addition to the different SA levels of the environment, relevant is the SA of the own organization also known as organizational awareness which is defined by Oomes (2004) as “an understanding of the multiple parties that make up the organization and how they relate to each other”.

### 4.5.2 Shared and team SA backgrounds.

Perla *et al*. (2000) mention that “With all the imprecision and debate surrounding the basic meaning of the idea of situational awareness, it is hardly surprising that the broader concept of shared situational awareness suffers from similar conceptual and semantic difficulties”. In general, when actors are working together towards achieving a common goal, a “compatible” understanding of the situation is supportive (Seppänen et al., 2013). Endsley *et al*. (2003), introduce shared SA as the degree to which team members have the same SA on shared SA requirements where shared SA is dependent not on a complete sharing of awareness between team members, but only on a shared understanding of that subset of information which is necessary for each of their goals. Therefore, shared SA is about the level of overlap in common SA elements between team members (Seppänen *et al*., 2013). However, each team member has specific SA requirements of its task, from which some may overlap with other team members' requirements (Seppänen *et al*., 2013). The latter is related to what team SA is about. Endsley (1995) defines team SA as “the degree to which every team member possesses the situation awareness required for his or her responsibilities”. Shared SA and team SA are not the same. Endsley (1989) and Endsley and Jones (2001), make the distinction between the two. However for successful team performance, the individual team members should have good SA on their specific elements and simultaneously the same SA for those elements that are shared (Endsley and Robertson, 2000).

Seppänen *et al*. (2013) state that interaction is critical in building SA, while communication is in the heart of interaction being the driving force in the formation of an adequate shared SA. Salmon *et al*. (2008) identify that most researchers have focused on communication as the key component in the development of team SA. In this line, Nofi (2000) finds communication as the most crucial element in the formation of team or shared SA. Endsley (1995) reflects the latter by suggesting that a team member’s SA of shared elements can provide team coordination or communication. Entin and Entin (2000) stress that communication is a prerequisite for achieving a high level of team SA. Furthermore, Salas *et al*. (1995) pinpoint the significance of communication in the acquisition of team SA.

Nofi (2000) point out that “shared situational awareness obviously differs from individual SA because it involves a number of persons trying to form a common picture”. For the development of shared SA, Bolstad and Endsley (2000) identify four factors: (1) shared SA requirements (e.g. the degree to which team members understand which information is required by other team members); (2) shared SA devices (e.g. network systems, communication devices, shared displays and the share environment); (3) shared SA mechanisms (e.g. shared mental models) and (4) shared SA processes which is about efficient team processes that enable sharing of relevant information. However, for the development of SA for the team as a whole, Endsley and Jones (2001) state that this depends on: (1) a high level of SA among individual team members for the aspects of the situation relevant to their job and (2) a high level of shared SA between members, based on an accurate common operational picture of those aspects of the situation common to the requirements of each member.

## 4.6 A common operational picture for emergency response.

During emergencies, agencies with heterogeneity in terms of background, specific operational expertise and professional language need to organize their actions across jurisdictional and institutional boundaries in a coordinated fashion for efficient and timely response operations (Comfort and Kapucu, 2006). In this context, a Common Operational Picture (COP) can be utilized for overcoming coordination and information management problems throughout emergency response. Following, the COP concept is introduced and its contribution to emergency response operations is explored.

### 4.6.1 Background to a COP.

According to Hager (1997), early studies of Common Operational Pictures (COPs) were carried out in the eighties. A major milestone was the deployment of a large group display to facilitate the development of SA in military command posts (Deschamps *et al*., 2002). However, as Wolbers and Boersma (2013) suggest, a single definition of a COP does not exist both in the operations field and the literature. Copeland (2008) stresses that disagreements exist in terms of COP considerations as it is treated as a product, process or operating environment. In the literature, two types of definitions are the most common: the first focuses on the capabilities of information distribution while the second pinpoints the need for developing an adequate level of shared understanding (Wolbers and Boersma, 2013).

Based on Merriam-Webster’s Collegiate Dictionary (2015), a picture can be seen as a design or representation made by several means or as a description so vibrant or graphic which provides either a mental image or an accurate idea of something. Also, it can be a mental image itself. Similarly, this dictionary defines common as something that belongs to or is shared by two or more individuals or things or by all group members which has a connotation to widespread or general knowledge. Finally operational is of, or relating to, or utilized for or in operations (Merriam-Webster’s Collegiate Dictionary, 2015). Kuusisto *et al*. (2005) building upon these frames, consider a COP, as a shared representation of widespread and general knowledge regarding operation.

A COP provides stakeholders with a “common picture” of the field of operations at the same time, on a terminal device at their location (Hager, 1997), while the operational picture refers to a predefined representation of information related to the operations. The US military Doctrine for Joint Operations (Shelton, 2001) defines COP as “a single identical display of relevant information shared by more than one command”. Furthermore, the doctrine sees the COP as a facilitator of collaborative planning which supports all echelons to achieve SA. In emergency response, COP can be seen as an auspicious solution towards improving the quality of information sharing and supporting the development of SA (Comfort, 2007).

A COP can also be treated as a boundary object because its deployment is about sharing and building information in regards to the response operations by enabling users to constantly redefine and adapt their relationships (Wolbers and Boersma, 2013). By utilizing a COP, coordination and negotiation of the polyphony of the experts’ perspectives via general procedures of exchange without making their points of view uniform or completely transparent to each other are facilitated (Trompette and Vinck, 2009; Hsiao *et al*., 2012).

A COP often represents geographic information as typical applications are tied to a possible large geographic area (location awareness) (Björkbom *et al.*, 2013). In this line, COP is considered as a geographical representation (geo-COP) combined with a checklist that delineates the evolution of an emergency along with the characteristics and progress of the emergency response operations. The information tailored in terms of content and detail is merged into a common frame of reference and visualized on a screen, supporting the comprehension by the response organizations of the current view of the situation (Björkbom *et al.,* 2013).

The US Department of the Army mentions that a COP which may cross horizontal, vertical and functional boundaries is made of three components (Bessler, 1998): (1) situation maps and overlays (the current status of an emergency, the projected emergency situation and the available resources); (2) friendly battlefield resource report and (3) intelligence products. In a network centric information environment, a COP is fed with (automatically updated) data derived from different sources such as reconnaissance and surveillance assets, emergency response teams in contact, intelligence acquired from analysis, information from higher echelons and estimates about incomplete information (Blais *et al*., 2005). By employing networks as well as emerging technologies, the different emergency response organizations can use current positional information to obtain the desired operational picture on one display. Access to a common picture that displays the evolution of an emergency and the progress of the response operations can enable these organizations to collaboratively plan and execute comprehensive tactical operations (Hager, 1997).

In emergency response operations, a COP depicts static information predetermined in the preparedness phase of emergency management as well as dynamic information related to the evolution of an event which needs to be shared between different emergency response chain members (see table 4.3a, b). It may contain geographical displays of emergency resources and assets, alternative evacuation routes as well as other tactical information all on a single display. In essence, a COP contains elements common to all the types of emergencies as well as critical variables which can be extracted at the time of the event through different sources of information including emergency responders. For example, by taking advantage of inputs from different intelligence sources all the deployed units in the field of operations can be mapped in real-time (Phillips *et al*., 2002). Therefore, with the suitably implemented information/knowledge management services, all the relevant to an emergency factors can automatically be incorporated into a comprehensive, real time description of the present and future needs, which may include availability of resources and assets, their appropriate deployment and field control i.e. actionable knowledge (see Lubitz *et al*., 2008b). In short, Hager (1997) mentions that a COP displays all acquired and combined data derived from different means in a single presentation to the user. As a consequence of realizing a COP, SA can be increased because every emergency responder can have the same information regarding the evolution of an emergency and the progress of the response operations.

Table 4.3a: Examples of common and variable elements included in a COP.

| **COP considerations** | **Common elements** | **Specific elements (related to an emergency)** |
|---|---|---|
| Incident/Disaster | • Digital maps at national level which include hazards, vulnerable objects and risk analysis results related to different potential types of events. | • The nature and the magnitude of the critical event;<br>• Geographic location of the event, size of the affected area, location and magnitude of the affected population. |
| Networks (e.g. streets) | • Networks infrastructure is depicted in maps;<br>• Networks accessibility, condition and capacity are known;<br>• Alternative evacuation routes are predetermined during the preparedness phase of emergency management. These take into account the nature of a potential emergency, estimated numbers of evacuees based on the population of different areas as well as time availability for the evacuation. | • The maximum size of an area affected by the emergency and consequently the networks became or about to become inaccessible;<br>• Degraded and destructed networks due to event related conditions, weather;<br>• Non-forecasted networks' degradation due to traffic congestion. |
| Resources | • Material resources such as ambulance and police vehicles, fire brigade engines, trucks, aerial means, supplies. | • Degradation due to event related specific factors which can cause for example damage of the resources, inaccessibility of the place(s) in which they are located;<br>• Due to allocation of the emergency resources to the response operations' scene, the number of the available resources changes dynamically as the response operations escalate. |

(Adapted from Lubitz *et al*., 2008b)

Table 4.3b: Examples of common and variable elements included in a COP.

| **COP considerations** | **Common elements** | **Specific elements (related to an emergency)** |
|---|---|---|
| Assets | • The number of personnel in all categories (e.g. policemen, firemen, field medics, support staff) available for deployment to the response operations' scene is known;<br>• Personnel requirement for traffic control, barrier maintenance, evacuated territory security patrol;<br>• Deployment sites for personnel predetermined in the preparedness phase of emergency management; based on different types of events with different magnitudes and the associated evacuation sizes. | • The required personnel number for the emergency response operations which depends on the nature of the event.<br>• Due to allocation of the personnel to the operations' scene, its availability changes dynamically as the response operations escalate.<br>• The unavailable personnel who are unable to reach the deployment sites due to specific factors related to the evolution of the emergency. |
| Shelters/ Healthcare Units | • Location and capacity of available short/long term shelters and field medical facilities as well as optimal access routes predetermined during the preparedness phase of emergency management;<br>• Location and capacity of local and national healthcare resources/advanced treatment facilities and triage/treatment/evacuation plans. | • Need for ad-hoc facilities arising from the evolution of an event;<br>• Unavailability of facilities due to event-related specific factors (e.g. location within a radius of influence, damaged). |
| Spatial models' outputs | • Simulations' forecasts based on hypotheses related to different types of emergencies. Risk maps are based on such forecasts. | • Forecasts based on dynamic inputs (real observations) derived from the evolution of an event. |

(Adapted from Lubitz *et al*., 2008b)

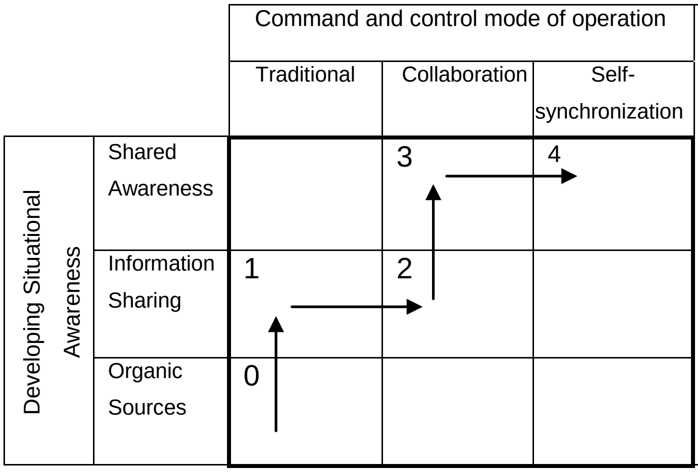
Regarding the role and the function of a COP within multi-agency operations, McMaster and Baber (2009) suggest that there are several perspectives. The potential alternatives of a COP are delineated in table 4.4. However, for facilitating multi-agency planning and implementation of response to a complex environment, the distributed cognition point of view can be seen as the only one in which the COP product becomes part of the decision making process enabling the different agencies to share multiple perspectives on the problem and achieve a common understanding of the situation (McMaster and Baber, 2009).

Table 4.4: Potential roles and functions of a COP.

| Nature of interaction | Product | Process |
|---|---|---|
| **Passive** | Static view | Live COP<br>(observe the dynamic COP as it is updated) |
| **Active** | Demand feeding<br>(COP as the product of information, surveillance, target of emergency response operations acquisition and reconnaissance). | Distributed cognition<br>(process of command driven by the COP). |

(Adapted from McMaster and Baber, 2009)

A robust network for information sharing can contribute in achieving shared SA based on a COP which in turn will result in improved decision making. Nevertheless, in order the emergency response organizations to gain maximum advantage from the network centric working logic; they should attempt to implement self-synchronization which can lead to improved use of capabilities to control the situation. Self-synchronization needs a level of shared SA which means cross-domain SA as well as SA across domains (Ven *et al*., 2008). To achieve shared awareness, all teams are required to share information and share understanding of the situation (Alberts and Hayes, 2007). Self-synchronization is described in a maturity model (see figure 4.6) suggested by Alberts *et al*. (2002). In essence, this model proceeds from the traditional command and control process (Level 0) to self-synchronization (Level 4).



Level 0: Baseline, traditional command and control;
Level 1: Substantial amount of information sharing;
Level 2: Collaboration across location, function and organization among participants;
Level 3: Improved level 2 by not focusing on sharing information but on its meaning;
Level 4: Enables self-synchronization.

Figure 4.6: Network-Centric Maturity Model.
(Adapted from Alberts *et al*., 2002)

The implementation phase of network centric working for achieving shared SA based on a COP by the emergency response organizations is not easily described. In order to move on to the different levels of the maturity model, the focus of the response organizations should not only be on technical capabilities but also on the preparation and training of the emergency responders employing operating procedures which will eventually enable their self-synchronization. The latter is not always easy as it may stumbles upon legal issues related for instance to the structure of the emergency response organizations. Emergency response organizations have to become capable in responding to an emergency using network centric approach for information sharing as it intends to improve information processes, communication and coordination leading to the development of a COP-based shared SA. However, this requires the development of individual network centric capabilities in the emergency response stakeholders' cognitive domain.

### 4.6.2 Challenges in achieving a COP.

Coherent, accurate and timely SA as well as vertical and horizontal information integration at all command levels; they enable the emergency responders to share common knowledge at the operations' field. However, one of the major challenges is information overload (Endsley and Kiris, 1995). In the context of a COP, all information is made available to everyone, but not all information is relevant to the tasks of the different emergency organizations (Hager, 1997). Also, different command levels do not need the same level of detail and hence it must be determined which level of information is relevant to their duties.

Coordination between actors with heterogeneity in terms of institutional background can be seen as a process of dialogic coordination where professionals can confront their different professional languages via scientific contestation achieving collective sensemaking (Faraj and Xiao, 2006). However, during complex emergencies, responders should make rapid coordination decisions in order to support fast response (Chen *et al*., 2008b). Achieving a shared goal among the emergency responders in a limited amount of time, it is extremely challenging due to the dynamic nature of the emergencies where the situation continuously changes and the goal becomes outdated. As a result, the responders frequently do not share information because from their perspective, they consider this information no longer significant or even outdated. This can lead to a dynamic information sharing situation constantly in flux, but dependent on the perceived by the response actors' information relevance (Wolbers and Boersma, 2013).

An extensive literature survey demonstrates that emergency response organizations struggle with information sharing, communication and coordination (Wolbers and Boersma, 2013; Bharosa *et al*., 2010; Comfort, 2007; Netten and Someren, 2011; Quarantelli, 1997). Furthermore, Wolbers and Boersma (2013) based on empirical research mention that despite the fact that emergency response organizations rely upon each other's information to align work processes, they do not share information tending to operate within their own professional boundaries.

Information management can play a critical role in addressing the coordination and information sharing problems between the involved organizations' boundaries (Donahue and Tuohy, 2006; Manzi *et al*., 2002). Information management can also be seen as both the problem and the solution for adequate SA to support coordination (Wolbers and Boersma, 2013). However, emergency response organizations may attempt to solve the information management problems through information systems which support its users to reach shared SA by deploying a COP (Comfort, 2007; Endsley, 1995). Such systems can be derived from the logic of Network Enabled Capabilities (see section 3) (Boersma *et al*., 2012).

### 4.6.3 The added value service of a COP in emergency response.

The familiar three Cs (Communication, Coordination and Control) of emergency response necessitate an interdependent, evolving process of organizational management. In the language of practice, creating a COP is crucial for clear communication and coordination of actions as it enables the achievement of a sufficient level of shared information among the different organizations participating in emergency operations. In particular, a COP enables data fusion providing a collection of correlated recognized pictures which facilitate a shared picture of operations (Chmielewski, 2008; NATO, 2006). In this way, all the involved actors can understand each other's constraints as well as the potential combinations of collaboration and support among them under a given set of conditions (Comfort, 2007)

SA is about how individuals and teams know and comprehend what is going on around them (Endsley, 2000). Furthermore, good SA provides a firm ground for effective decision making. The development of this good SA is facilitated through the deployment of an effective COP which visualizes the relevant information (Eide *et al*., 2013). Furthermore, a COP can ease collaborative planning and it can support several levels of command across the various agencies involved in an operation to achieve shared SA (McMaster and Baber, 2009). On the contrary, Comfort (2007) stress that the lack of a COP tend to drive the emergency response operations to a hierarchical structure of control, fact that creates asymmetry in the information processes. This asymmetry results from the fact that organizations with higher level of responsibility and authority transmit their orders to lower levels without having any operational feedback from the ground of field operations outside the formal chain of command. Thus, a COP tends to support the development of a shared perspective on priorities for emergency operations.

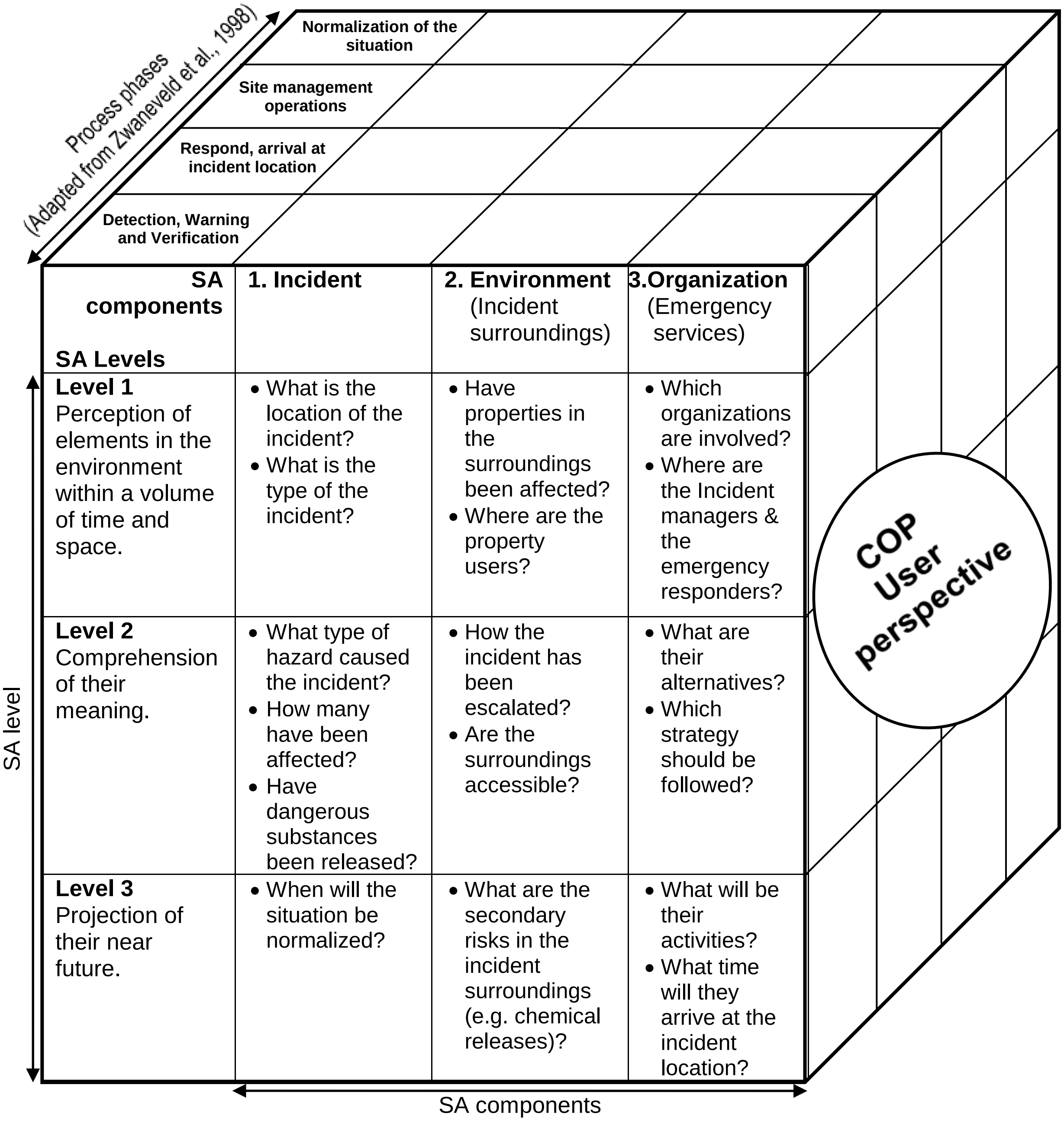
For achieving shared SA based on a COP between different emergency response organizations, systems underpinned by the network centric working logic must be employed. The relation between the NEC value chain components and the emergency response process phases (adapted from Zwaneveld *et al*., 1998) is attempted to be demonstrated in table 4.5. The basic idea is that better networks can lead to better information which feeds detection, warning and verification processes, which in turn can contribute to the development of better situational interface. Better information leads to improved response by the emergency organizations which in turn it contributes to the more efficient utilization of resources and assets so that better actions can take place in the field of operations. Better actions lead to better outcomes i.e. faster normalization of the situation and hence minimization of the incident's or disaster's consequences (socioeconomic and environmental losses).

Table 4.5: The NEC value chain components and the emergency response process phases.

| NEC value chain | | Emergency response phases | Benefits |
|---|---|---|---|
| BETTER | Networks | Technical infrastructure | Emergency organizations and responders |
| | Information sharing | Detection, warning | Better situation interface |
| | Shared understanding | Verification | Based on better situation interface |
| | Decisions | Respond, driving and arrival | Optimal use of resources and assets |
| | Actions | Site management operations | More efficient response operations |
| | Effects | Normalization | Faster treatment of the situation and minimization of socioeconomic and environmental consequences |

(Adapted from Steenbruggen *et al*., 2012)

For measuring the added value service of SA for emergency response, a 3D cube (see figure 4.7) is introduced which bases on: 1) SA levels derived from Endsley's definition (see Hone *et al*., 2006); 2) SA components of emergency response; 3) emergency response process phases (adapted from Zwaneveld *et al*., 1998).



| **SA components**<br>**SA Levels** | **1. Incident** | **2. Environment** (Incident surroundings) | **3.Organization** (Emergency services) |
|---|---|---|---|
| **Level 1** Perception of elements in the environment within a volume of time and space. | • What is the location of the incident?<br>• What is the type of the incident? | • Have properties in the surroundings been affected?<br>• Where are the property users? | • Which organizations are involved?<br>• Where are the Incident managers & the emergency responders? |
| **Level 2** Comprehension of their meaning. | • What type of hazard caused the incident?<br>• How many have been affected?<br>• Have dangerous substances been released? | • How the incident has been escalated?<br>• Are the surroundings accessible? | • What are their alternatives?<br>• Which strategy should be followed? |
| **Level 3** Projection of their near future. | • When will the situation be normalized? | • What are the secondary risks in the incident surroundings (e.g. chemical releases)? | • What will be their activities?<br>• What time will they arrive at the incident location? |

Figure 4.7: 3D cube for measuring Situational Awareness for emergency response.

(Adapted from Steenbruggen *et al*., 2012)

The proposed 3D cube can form the basis for quantitative and qualitative measurement of the value added service of a COP in supporting emergency response processes between the involved organizations. The qualitative aspects focus on the economic effects (Blackstone *et al*.,

2007) in the sense of reduction of losses and casualties which may result from a false detection of an incident or disaster. The quantitative aspects focus more on cooperation, system and information quality (Steenbruggen *et al*., 2012; Strong *et al*., 1997; Perry *et al*., 2004; Singh *et al*., 2009; Bharosa *et al*., 2009a).

## 4.7 Final remarks on the contribution of a COP in emergency response operations.

Emergencies are unique, dynamic and complex situations where it is virtually impossible to forecast their evolution. Furthermore, during the emergency response operations several teams coming from different safety organizations with different backgrounds, cultures and goals have to cooperate in order to minimize the negative impacts of an emergency in terms of human injuries and casualties, environmental disruption and economic losses. Nowadays, information systems have become increasingly important in supporting emergency response tasks which can range from management of routine and small scale incidents to the more severe and large scale disasters. Nevertheless, information sharing between different emergency response organizations is still in its infancy. Noteworthy is that one of the primary factors in accidents attributed to human error is the lack or inadequate information which limits situational awareness (Chmielewski, 2008).

For effective response, flexible information and communication systems which facilitate communication and coordination not only within but also among the multiple teams involved are required. In this context, the concept of network centricity which is rooted in the military domain, it can be seen as a vehicle towards better information sharing which in turn can support faster decision making and enhanced spatiotemporal organization of resources and assets in the increasingly fluid environment of the emergency response. In particular, by working in a network centric way, information sharing advantage can be gained through technology and effective network mechanisms delivered for geographically dispersed resources and assets. Military battlefield situations can be as chaotic as emergency response operations and they may require even faster response times. Therefore, the concept of network centricity can be adapted from the military field and it can be applied for emergency situations tailored to their specific conditions towards creating a surplus value for the response operations. However, the successful adoption of such a concept requires its careful introduction in different stages based on a maturity model. In addition, it requires training of the emergency response stakeholders in order to overcome potential lack of knowledge.

Network centric information systems facilitate networking of emergency response stakeholders towards achieving operational effectiveness as well as integration of new information derived from multiple sources with other knowledge. Furthermore, they enable unobstructed flow of information and knowledge among the entirety of the emergency response administrative structure. Instead of information passed vertically within the command chain where it may be lost or even discarded, it is circulated freely among all the involved emergency response actors. In essence, the information shared for developing a common operational picture is conveyed to all the parties involved in the operation, the field team and people in the command post. As a consequence, while officers at the uppermost levels of the involved safety agencies are aware of the real time conditions at the emergency response site through a common operational picture, the field personnel can have readily access to tactically relevant information if needed as much as to this common operational picture, if such may affect their operations. In general, by incorporating the network enabled capabilities in emergency response, the attributes and flexibility needed by adaptive management can be facilitated, which as suggested by Wiese (2006) it can be the most effective management approach to potential disasters.

Data acquisition from multiple sources and dissemination of the collaborative information through network centric systems contribute to the development of a common operational picture which can support all the responding units to have the same understanding and awareness (shared situational awareness) of information and emergency status when conducting operations. Thus, network centric systems and a common operational picture are basic components to achieve improved situational awareness. Developing shared situational awareness in the complex and dynamic environment of an emergency, it can drive to self-synchronization and better coordination of the emergency response stakeholders. As a consequence, operational risk can be reduced and at the same time the total performance of decision-makers as well as the speed of operations and responsiveness in the physical domain can be increased towards improving mission effectiveness.

In the context of emergency response, the criteria which should drive the design of information systems in order to meet the requirements of the end-users, they go beyond the technological capabilities. Such information systems must satisfy the information requirements of the emergency response agencies but also they should support cognitive and psychological capabilities in the information-rich and complex dynamic environment of emergency situations. In particular, special attention needs to be paid to the cognitive domain. Humans are limited by working memory and attention. New information from multiple sources must be integrated with other knowledge. How people direct their attention when acquiring new information has a fundamental impact on which elements are incorporated in their situational awareness. Therefore, network centric information systems should be designed to support working memory and attention which in turn they can assist in addressing information overload. Otherwise, the limits of working memory can cause constraints on situational awareness (Endsley, 1988b). Furthermore, as not all the information is relevant to the tasks of all the safety agencies, a comprehensive inventory of which information is relevant for each safety organization needs to be done towards preventing information overload.

In short, a common operational picture achieved through network centric systems, it can contribute to create shared situational awareness towards faster normalization of an emergency situation. Hence, it can be seen as an emergency response tool with an added value not only in effective sharing of information but also in understanding the real meaning and the temporal value of the required and used information for the operation, communication and coordination processes. In the cognitive domain, technology combined with organization, processes and people can provide efficient decision making behaviors with better actions and effects in the physical domain. This article has shown through an extensive literature survey from different domains and perspectives that the utilization of a common operational picture is a promising instrument for smart emergency response. However, more work still needs to be done towards empirically measuring in a statistical consistent way the added value of incorporating such systems in emergency response operations. Furthermore, not only training of the emergency response professionals in a network centric way of thinking and handling of information is required, but also the institutional and legal implications of utilizing such networks for sharing and exchanging information between the involved safety organizations have to be addressed.

# 5. AN EMPIRICAL APPROACH TO THE ASSESSMENT OF THE EFFECTIVENESS OF NETWORK-CENTRIC SUPPORT TOOLS FOR FLOOD EMERGENCY RESPONSE: RESULTS OF A FIELD EXERCISE.

Successful emergency response operations require capable systems to support efficient information sharing, communication and coordination of the multiple involved safety agencies. Many authors have identified that Information Quality (IQ) and System Quality (SQ) are major hurdles for efficient and effective multi-agency response and simultaneously they are key components for the success of information systems. Furthermore, IQ and SQ are important requisites for achieving Situational Awareness (SA) which in turn is essential for decision making and effective response actions. Nevertheless, literature on the quality of information sharing among the various emergency services and the systems used for this purpose is very limited and empirical support is almost non-existent. In this context, this chapter reports and qualitatively discusses the results of an empirical research study on the effectiveness of network centric information systems which aim to improve the interaction and cooperation among the involved safety agencies. In particular, this research comprises a field experiment with alternative realistic flood scenarios and the participation of emergency response professionals. During the experiment, experts' judgment is acquired through field research techniques such as questionnaire surveys and observers' notes. Drawing on two opposing information coordination approaches and systems, traditional (hierarchical) vs. network-centric, the main findings imply that a network-centric system tends to improve information sharing by helping to create a Common Operational Picture which can be used as a means of better supporting SA, decision making and effective emergency response operations. However, for successfully implementing such a system, this system needs to be carefully introduced in different stages, taking into account organisational structures, institutional rules, norms and in particular the human factor.

## 5.1 Introduction.

Disasters caused by large floods have increased worldwide as a result of the changing physical and built environment, despite the improvements in terms of infrastructure, forecasting systems and spatial planning and management (Efstratiadis *et al*., 2014). Furthermore, the European Environmental Agency (2016), on the basis of historical data between 1980 and 2010, has observed significant increase in terms of floods and floods' consequences which will only get worse as time goes on. In light of all this, increasing flood response preparedness by implementing emergency response planning activities is just as instrumental as mitigating the flood risks with engineering and spatial solutions designed to make areas safe.

The response to emergencies is a complex (Bigley and Roberts, 2001; Chen *et al*., 2008b; Lee *et al*., 2011; Bharosa *et al*., 2009a; Bharosa *et al*., 2009b), dynamic and information-intensive process (Bruijn, 2006; Davenport and Prusak, 1998) during which multiple autonomous safety agencies and stakeholders are involved on the basis of available information, they have to make decisions and coordinate their actions under time pressure (Smithson and Hirschheim, 1998; Smith and Hayne, 1997) and high uncertainty (Longstaff, 2005; Argote, 1982). Furthermore, emergencies need fast and effective treatment in order to minimise their socio-economic and environmental impacts. In this context, professionals from different fields and with varying backgrounds and expertise are required to communicate, interact and cooperate with one another (Luokkala and Virrantaus, 2014).

Response operations are based on the relevant facts regarding the situation concerned and therefore access to information in a timely manner is essential. In particular, professionals require real-time, spatio-temporal situational information in order to respond in an efficient manner (Luokkala and Virrantaus, 2014; Seppänen *et al*., 2013; Steenbruggen *et al*., 2012; Goodchild, 2010a). However, information itself is not sufficient if the quality of that information does not satisfy the stakeholders’ needs (Seppänen and Virrantaus, 2015). Achieving a high level of information quality is a crucial and also challenging requirement of successful response operations (Bharosa *et al*., 2009a; Bharosa *et al*., 2009b; Bharosa *et al*., 2009c; Bharosa *et al*., 2008; Helsloot and Scholtens, 2007; Davenport and Prusak, 1998; Bruijn, 2006; Fisher and Kingma, 2001; Turoff *et al*., 2004b). Conversely, poor information quality can be fatal for the emergency responders and the victims (Lee *et al*., 2011; Turoff *et al*., 2004b; Fisher and Kingma, 2001).

For effective emergency response, professionals with a high-level of Situational Awareness (SA) need to get involved (Luokkala and Virrantaus, 2014). SA is normally supported by information systems that improve information sharing and facilitate the development of a Common Operational Picture (COP). In essence, a COP allows the involved stakeholders to achieve and share situational information in a geographically distributed environment (Luokkala and Virrantaus, 2014; Steenbruggen *et al*., 2015; Steenbruggen *et al*., 2012; Vesterinen, 2009; Fanti and Beach, 2002; Shelton, 2001). Through a COP, the on-scene and off-scene stakeholders can have the same information about the status of an emergency, its impact on the surrounding environment and the progress of the response operations including resources and assets availability and location, as well as the condition and location of requests for assistance. Nevertheless, information sharing, along with coordination and SA, are some of the most common challenges in emergency response operations (Seppänen and Virrantaus, 2015; Salmon *et al*., 2011; Bharosa *et al*., 2010; Comfort *et al*., 2004; Quarantelli, 1988).

In the context of the multi-agency emergency response which is characterised by highly volatile, chaotic, temporary, fragmented and ad-hoc environments, the assurance of information and system quality is certainly not easy. Furthermore, the professionals involved in the response operations may have no history of working together, they may not have developed trusting or understanding of their abilities (Walle and Turoff, 2007) and they may have different organisational goals (Aedo *et al*., 2010). Nevertheless, under these circumstances the stakeholders have to make fast decisions which can put them under significant psychological stress given the potentially disastrous consequences of a wrong decision (Lee *et al*., 2011). Although there is an abundance of literature on information quality and information systems success in the profit-oriented business environment, research on the success of information systems in the civic safety sector, which targets the public good, is relatively scarce and empirical support is almost non-existent (Steenbruggen *et al.*, 2015; Lee *et al*., 2011; Bharosa *et al*., 2009a; Bharosa *et al*., 2009b; Bharosa *et al*., 2009c). Moreover, in contrast to the business environments where information and communication needs are relatively predictable, the respective requirements in emergency response are highly diverse and massive in terms of their nature (Bharosa *et al*., 2009a; National Research Council, 2007). This also reflects the various purposes, activities and needs for information and communication which occur at different times and locations with respect to a particular emergency situation. Hence, previously developed models for information and system quality in a business environment are likely to fall short in terms of applicability in the public domain of emergency response operations. This study, through a series of steps (literature survey, field exercise with realistic flood scenarios and questionnaires for the acquisition of the experts' judgment) aims to assess the effectiveness of network centric information systems tailored for flood emergency response operations. In particular, it intends to explore the appreciation of the participants i.e. the professionals with respect to selected IQ and SQ attributes, initially based on the systems experienced in their daily practice and later based on the experience gained with the network centric system used during this exercise. Furthermore, it purports to identify capabilities and constraints associated with the network-centric system experienced by the end users (the professionals) during this exercise. In addition, it aspires to identify the effects of scenario complexity on the benefits of network-centric systems. In this connection, a field exercise was organised in order to provide researchers with more opportunities for the acquisition of professional opinions (data collection) compared with the opportunities for collecting such data during the unforeseeable dangerous nature of a real flood and the turbulent processes of the response operations. Nevertheless, data collection is difficult even in simulated emergency field studies because of various contexts, events, scope, control and time-related issues (Killian, 2002).

This chapter is organised as follows. Firstly, it describes the theoretical foundation of the field exercise in section 2. In particular, through a literature review it identifies a number of constructs relevant to measure Information Quality (IQ) and System Quality (SQ) in emergency response operations and it shortlists and tabulates those utilised for the field experiment of this study. Thereafter, it analyses the hierarchical (traditional) vs. the network centric information coordination structures in the context of public safety networks, identifying the pros and cons. Next, in section 3, the design of the case study is described. More precisely, after a short introduction to Dutch civil security procedures, this section elaborates on the set-up of the exercise; the demographics of the professionals who participated in the field experiment; the network-centric technology used and the flood scenarios utilised in order to achieve the objective of this chapter; the experimental protocol and finally the limitations and assumptions of the case study. Then in section 4, the chapter proceeds by tabulating and qualitatively discussing the results of the exercise i.e. the experts' judgment on selected IQ and SQ dimensions. The chapter concludes in section 6 by discussing the main empirical findings of this study and their implications and then proceeding to make recommendations for the successful introduction of network-centric systems in flood emergency response services. In short, based on the experts' judgment, it can be concluded that it would appear that the network-centric tools tend to improve SA by facilitating better information sharing and by achieving a COP. However, their introduction to safety agencies should be done carefully and in different stages, with the strong involvement of those in the upper echelons of the emergency response organisations.

## 5.2 Theoretical background to the field exercise.

In this section, based on an extensive literature survey, constructs for measuring Information Quality (IQ) and System Quality (SQ) during emergency response are identified and described. Furthermore, the IQ and SQ constructs selected for the field experiment of this study are tabulated. Thereafter, the theoretical foundation which underpins the hierarchical (traditional) vs. the network centric information coordination structures is elaborated.

### 5.2.1 Information quality.

A common denominator of all the activities related to emergency response is information (Bui *et al*., 2000). During the complex (Bigley and Roberts, 2001; Chen *et al*., 2008b), pressing (Smithson and Hirschheim, 1998), uncertain (Longstaff, 2005) and dynamic environment of emergency response, several autonomous organisations need to develop a response network and share information at strategic, tactical and operational levels (Bharosa *et al*., 2009a; Bharosa *et al*., 2009b; Bharosa *et al*., 2009c). Accurately and timely information is as critical as fast and coherent coordination among the emergency response organisations (Walle and Turoff, 2007). The information should delineate the emergency along with its consequences and it must feed the response needs (ACT, 1998; The Economist, 1997; Harrald *et al*., 1992). Based on this information, the emergency response stakeholders can make decisions under severe constraints which are likely to have long-lasting consequences (Lautze *et al*., 1998).

In information systems literature, quality of information is considered as ill-defined (Nelson *et al*., 2005). However, the concept of quality is frequently considered as fitness for use (Juran and Godfrey, 1999) and it is widely utilised in business, as well as in information systems-related domains (Lee *et al*., 2011). Broadly, information quality (IQ) can be seen as the extent to which information meets the requirements of its users (Singh *et al*., 2009; Stvilia *et al*., 2007). In Oxford dictionaries (2016), quality is determined as “the degree of excellence of something” which, in this study, is about the degree of excellence of information acquired, shared and distributed during the emergency response operations. In information systems research, IQ is not something new and despite its relatively brief history, it has been studied extensively (e.g. Miller, 1996) and has experienced significant developments (Wang, 1998). IQ can be seen as a comprehensive social concept as well as a key forerunner of the success of information systems (Delone and McLean, 1992).

During emergency response, IQ is the most important issue (Sagun *et al*., 2009) and it is about the quality of the content of the information exchanged (Lu and Yang, 2011). Information sharing and dissemination can be seen at the same time as critical and problematic (Manoj and Baker, 2007), whilst poor IQ can be disastrous for both the emergency responders and the victims (Fisher and Kingma, 2001), as it hinders the efficiency and effectiveness of multi-agency response activities (Lee *et al*., 2011). As the emergency responders' operations are information intensive (Bruijn, 2006) and their effectiveness relies on the available information (Davenport and Prusak, 1998), high IQ is of the utmost importance. Furthermore, as IQ is a basis for good decision making (Petter *et al*., 2013), the provision of high IQ can contribute to the achievement of shared SA during the response operations. However, while it is necessary to achieve a high degree of IQ, it is also a challenging requirement for successful emergency response operations (Bharosa *et al*., 2009a; Bharosa *et al*., 2009b; Bharosa *et al*., 2009c; Bharosa *et al*., 2008; Bruijn, 2006; Turoff *et al*., 2004b; Fisher and Kingma, 2001; Davenport and Prusak, 1998).

Many scholars have investigated the IQ concept (e.g. Ballou and Tayi-Kumar, 1999; Strong *et al*., 1997; Miller, 1996) and as a consequence, many frameworks for identifying IQ dimensions have been proposed (e.g. English, 1999; Levitin and Redman, 1995; Wang and Strong, 1996). In the literature, IQ is not defined (Bharosa *et al*., 2011) and it can even be considered to be a confusing concept (Evans and Lindsay, 2005). IQ is a multi-dimensional concept (Lee *et al*., 2011) determined by a set of attributes that are important for end-users and it can be measured through its multiple dimensions (Miller, 1996). The multi-dimensional nature of IQ is verified by a number of studies (Huang *et al.*, 1999; Wang and Strong, 1996; Ballou and Pazer, 1985; Wand and Wang, 1996). However, the number and types of IQ dimensions proposed by scholars are different (Bharosa *et al*., 2011). A literature review demonstrates that there is no general agreement on data quality dimensions (Wang *et al*., 1995a; Wang *et al*., 1995b). Furthermore, despite extensive discussion in the data quality literature, there is no consensus regarding what is considered a good set of IQ dimensions and what is a suitable definition of each dimension (Wand and Wang, 1996). In short, until now, a uniform list which includes all the IQ attributes (constructs) cannot be found (Steenbruggen *et al*., 2015). For example, Miller (1996) distinguishes 10 dimensions for IQ, while Pipino *et al*. (2002) suggest 16 dimensions. Lee *et al*. (2002), in a thorough overview of IQ dimensions, propose the categorisation of 21 constructs in four categories. Strong *et al*. (1997) also group IQ dimensions in four main categories, all with a similar degree of information quality. These categories are: accessibility, contextual, intrinsic and representational and are broadly accepted in the literature (Li *et al*., 2002), being the only framework provided over the years. In addition, this framework proposes items, empirically tested for measuring IQ (Lee *et al*., 2002). However, not all IQ items are relevant for multi-agency emergency response (Bharosa *et al*., 2009a; Bharosa *et al*., 2009b; Lee *et al*., 2002). For this, Steenbruggen *et al*. (2015), by analysing 12 papers from the literature, distinguish between generic IQ dimensions (Miller, 1996; Wang and Strong, 1996; Strong *et al*., 1997; Lee *et al*., 2002; Delone and McLean, 2003; Eppler, 2003; Wixom and Todd, 2005; Parker *et al*., 2006) and specific IQ dimensions for emergency response agencies (Perry *et al*., 2004; Singh *et al*., 2009; Bharosa *et al*., 2009a and Bharosa, 2011), identifying five IQ categories which are most suitable for the purposes of the emergency services (see table 5.1).

Table 5.1: Overview of the IQ dimensions most relevant for the emergency services.

| **IQ categories** | **IQ constructs** |
|---|---|
| Accessibility | Accessibility, access security. |
| Contextual | Timeliness, completeness, relevance, value added, quantity (information overload). |
| Intrinsic | Accuracy, objectivity, believability, reputation. |
| Representational | Interpretability, understandability, conciseness, consistency, comprehensiveness. |
| Others | Availability, correctness, currency, precision, format, availability, reliability (validation), personalisation. |

(Adapted from Steenbruggen *et al*., 2015 and Bharosa *et al*., 2009a)

The *accessibility* IQ dimension focuses on the role of information systems in storing, manipulating and providing access to the end-user so that information relevant to the tasks of the emergency response agencies can be securely and easily accessed and retrieved (Lee *et al*., 2002). Steenbruggen *et al*. (2015) state that it is debatable whether accessibility relates to IQ or SQ, while some scholars perceive accessibility more as the SQ dimension. *Contextual* IQ pinpoints the necessity to consider IQ within the context of the task at hand, being relevant, timely, complete and efficient in terms of quantity-creating added value (Wang, 1998; Lee *et al*., 2002). *Intrinsic* IQ suggests that information has quality in its own right (Wang, 1998; Lee *et al*., 2002) and consists of dimensions which are context-independent. *Representational* IQ is about the way (easily interpretable, understandable, concise, consistent and comprehensive) in which information is presented. Another point that can be made is that both accessibility and representational IQ highlight the role of information systems (Wang, 1998; Lee *et al*., 2002).

Other IQ dimensions which are relevant to emergency response can be found in the literature. For example, *correctness* is mentioned as an important IQ dimension which is related to the contextual IQ construct *completeness*; *data validation* is significant and it is associated with correctness and reliability, while *personalisation* and *context awareness* are two relatively new dimensions which are interrelated with the contextual IQ dimension *quantity* (Steenbruggen *et al*., 2015). As Bharosa *et al*. (2011) mention, the relative importance of each IQ category depends on unforeseen events during the life cycle of an emergency. For example, at the starting point of an emergency, accessibility to information is the greatest concern, while, later on, issues related to the contextual, intrinsic and representational attributes of information may arise. If any difficulty faced along one or more quality dimensions makes information completely or largely unsuitable for use, this is recorded as an IQ problem (Strong *et al*., 1997).

Wand and Wang (1996) state that the *intrinsic* IQ dimension accuracy, the *contextual* IQ constructs completeness and timeliness, as well as the *representational* IQ attribute consistency are frequently mentioned in the literature and their choice is based on intuitive understanding (Ballou and Pazer, 1985), industrial experience (Firth and Wang, 1996), or literature survey (Kriebel, 1979). For emergency response, Lee *et al*. (2011) mention that a recent study (Singh *et al*., 2009) on information dimensions has shown that only three attributes of IQ, i.e. two *accessibility* IQ dimensions (information accessibility and security) and one *contextual* IQ dimension (timeliness) were emphasised in large scale disaster management situations. Furthermore, other studies (e.g. Cooper and Block, 2006; Dawes *et al*., 2004; Horan and Schooley, 2007; Quarantelli, 1997) verify that accessibility (*accessibility* IQ dimension) and timeliness (*contextual* IQ dimension) are seen as important dimensions in emergency response. Nevertheless, for the latter, empirical support is relatively absent (Lee *et al*., 2011).

Generally, in the emergency response literature the most used *representational* quality dimension is consistency (Singh *et al.*, 2009; Perry *et al.*, 2004; Strong *et al.*, 1997) while the most utilised contextual IQ constructs are timeliness (Singh *et al.*, 2009; Walle and Turoff, 2007; Horan and Schooley, 2007; Cooper and Block, 2006; Dawes *et al.*, 2004; Quarantelli, 1997), completeness (Townsend, 2006; Samarajiva, 2005) and relevance (Singh *et al*., 2009). Special attention should be given to the *contextual* IQ dimension information quantity, as in an information-rich environment, users can be easily overloaded (Endsley and Kiris, 1995) in the sense of receiving too much information compared with what they need. In this context, Bharosa *et al*. (2010), claim that emergency responders are very concerned about being distracted by information overload during their operations. Furthermore, Oh *et al*. (2013) mention that, from the emergency responders' point of view, too many inquiries and reports, many of which are not reliable or correct, hamper the vision of emergency response teams to efficiently deliver the right information to the right responders at the right moment. The IQ constructs used for the field (emergency response) exercise of this study are listed below in table 5.2.

Table 5.2: Synopsis of the IQ constructs selected for the field exercise of this study.

| **IQ category** | **IQ Construct** | **Description** |
|---|---|---|
| Contextual | Timeliness (Currency) | The degree to which the currency of information is appropriate for its use (Perry *et al*., 2004). Timely information is up to date and it represents the current state of the ground truth (Singh *et al*., 2009). |
| | Completeness | The degree to which information is not missing with respect to the relevant ground truth. (Singh *et al*., 2009; Perry *et al*., 2004). The literature considers a set of data as complete when all necessary values are included (Wand and Wang, 1996; Ballou and Pazer, 1985). |
| | Quantity (Information Overload) | Occurs when the amount of acquired information exceeds the processing capacity of a receiver (Lee *et al*., 2011). |
| | Relevance | The proportion of information collected that is applicable and supportive for the task at hand (Singh *et al*., 2009; Perry *et al*., 2004). |
| Representational | Consistency | The degree to which information is in accordance with related or prior information (Perry *et al*., 2004). |
| Others | Correctness | The extent to which information is in accordance with ground truth (Perry *et al*., 2004). |
| | Reliability (Validation) | Indicates whether the data is correct and can be counted on to convey the right information (Wand and Wang, 1996). |

In short, information assurance requires the right people to get the right information at the right time (Singh *et al*., 2009), so that emergency response stakeholders can have enough resources to comprehend the situation and achieve SA (Aedo *et al*., 2010). However, it should be mentioned that SA is not achieved only by having the right information at the right moment, as it is a condition of each individual (emergency response stakeholder) and hence many factors, such as background, previous experience, expectations and organisational goals, influence each individual's awareness of a situation as well as the ability to take required actions for the effective and fast normalisation of an emergency situation.

### 5.2.2 System quality.

System Quality (SQ) is considered to be a key component for effective emergency response (Bharosa *et al*., 2009a). While IQ is about the attributes of the information derived and/or shared through an information system, SQ is used to delineate the attributes of an information system itself (e.g. Nelson *et al*., 2005; Delone and McLean, 1992). In the Delone and Mclean (1992) information systems success model, which is one of the highest cited models (Jun and Jung, 2013), SQ measures technical success, while IQ measures semantic success. According to Shannon and Weaver (1949), the technical level is the accuracy and efficiency of the system which produces the information, while, the semantic level is the success of the information in transmitting the intended meaning.

In the information systems literature, SQ has received less attention compared with IQ (Lee *et al*., 2011; Bharosa *et al*., 2009a; Steenbruggen *et al*., 2015). Jun and Jung (2013) state that the definitions of SQ are not consistent, as some studies consider it as user-friendliness or ease of use (e.g. Rai *et al*., 2002; Doll and Torkzadeh, 1988), while other studies look at the performance characteristics of the system, such as reliability, flexibility, response, time, integration (e.g. Delone and McLean, 2003; Delone and McLean, 2004; Nelson *et al*., 2005). Furthermore, Nelson *et al*. (2005) mention that the SQ dimensions are frequently intermixed with components associated with service quality and ease of use, a fact which demonstrates the importance of ensuring conceptual clearness in terms of specification and distinction of constructs.

In essence, SQ is a concept utilised to assess the multiple dimensions of the information system needed to generate the output (Delone and McLean, 1992; Lee *et al*., 2011). The information system stores, processes and distributes information which is communicated to the end-users, who subsequently maybe influenced or not by this information (Delone and Mclean, 1992). Regarding SQ requirements, these represent end-user views on dynamic interaction with the system (Bharosa *et al*., 2009a). In the context of emergency response, SQ attributes can be seen as the required functionalities and capabilities of a response system.

SQ leads to user satisfaction and intention to use and thus is judged as important (Seddon, 1997; Delone and McLean, 2003; Nelson *et al*., 2005; Wixom and Todd, 2005). According to Delone and Mclean (2003), higher SQ can lead to higher user satisfaction and use, which, in turn can have positive impacts on individual productivity, resulting in organisational productivity improvements. Five studies (Wixom and Watson, 2001; Teo and Wong, 1998; Etezadi-Amoli and Farhoomand, 1996; Goodhue and Thompson, 1995; Seddon, and Kiew, 1994) have all examined the relationship between system quality and individual impact and have verified that those associations are statistically significant.

Examples of variables identified by Delone and McLean (1992) for SQ are: system flexibility, accessibility, ease of use, integration, efficiency and response time, while Nelson *et al*. (2005), in addition to system flexibility, integration and response time, include system reliability in the most commonly used system performance measures. SQ constructs such as system reliability and availability are traditionally addressed as technical engineering requirements (Bharosa *et al*., 2009a). Flexibility and interoperability can be seen as requirements for determining SQ, taking into account that technical systems are becoming increasingly tightly coupled (Bharosa *et al*., 2009a). Moreover, system flexibility and information integration functionalities are of particular importance, as information demand and supply are dynamically changing over time during emergency response operations (Bharosa *et al*., 2009a). In this connection it should also be mentioned that systems which integrate data from various sources can improve organisational decision making while system flexibility can facilitate decision makers in easily modifying their applications as their information needs change (Gray and Watson, 1998; Sakaguchi and Frolick, 1997). A description of selected constructs which are considered to be the most relevant for measuring SQ during the emergency response field exercise of this study is provided in table 5.3. Most of the selected SQ constructs reflect the more engineering-oriented performance attributes of the system under consideration.

Table 5.3: Outline of the SQ constructs selected for the field exercise of this study.

| **SQ category** | **SQ construct** | **Description** |
|---|---|---|
| System-related | Accessibility | The level to which a system and its related information can be accessed with fairly low effort (Nelson *et al*., 2005). |
| | System reliability | The level to which a system is reliable (e.g. technically stable) over time (Nelson *et al*., 2005). |
| | System response time | The level to which a system provides fast or timely responses to requests for information or actions (Nelson *et al*., 2005). |
| Task-related | Format | The extent to which a system is arranged for processing, storing or displaying information in an effortlessly comprehensible, interpretable, concise and consistent way (based on Oxford dictionaries, 2016). |
| | Integration | The level to which a system eases the combination of information from multiple sources to support decision making (Nelson *et al*., 2005). |
| | Memory | The degree to which a system is capable of storing for retrieval (semi-static, dynamic and model) information and knowledge (based on Oxford dictionaries, 2016). |
| | Situational awareness | The level to which a system helps a user to undestand what is going around him/her (Salmon *et al*., 2008; Endsley, 1995). |
| Perceived operational satisfaction | Ease of use | The users' level of satisfaction regarding the system's interface (Nelson *et al*., 2005). |
| | Usability | Appropriateness for a purpose of any particular system (Brooke, 1996) which is based on the degree to which can be utilised by specified users to achieve specific goals with effectiveness, efficiency and satisfaction in a specified context of use (ISO 9241-11, 1998). |

(Adapted from Steenbruggen *et al*., 2015)

### 5.2.3 Hierarchical vs. network centric structure of information coordination in public safety networks.

The traditional approach in complex problem-solving has been hierarchical, involving multiple stakeholders and tasks (Simon, 1996). Furthermore, most of the information coordination architectures in public safety networks are based on hierarchical structures (see Mackenzie *et al*., 2007; Bigley and Roberts, 2001; Hale, 1997). This is because the hierarchical approach is seen as a means of stability, transparency and accountability (Bharosa *et al*., 2011). In addition, a hierarchy is used to establish and maintain control, allocate tasks and responsibilities, as well as to report processes and probably to gain reliability and efficiency in workflow (Janssen *et al*., 2010). In a hierarchical coordination system, strictly speaking, the commands flow from top down and feedback information flow from bottom up, while the relationships among commanders and subordinates are limited to “master-slave” connections between parent and child nodes in a tree-shaped hierarchy (Bongaerts *et al*., 2000). Bharosa *et al*. (2011) state that the advantage of the hierarchical approach is that interactions and interdependencies between emergency responders are frequently known and limited as their linkage is based on predefined relationships and procedures.

However, the hierarchical approach has some limitations. For example, the information sharing flow in the hierarchical structure is coordinated via adjacent steps by controlling and directing information to the higher and lower echelons (Malone *et al*., 1987). However, as the decisions taken at the higher levels move down to the lower levels, they are enriched with more details (top-down and bottom-up tactic) that can result in asymmetry of the information load, which, in turn, can create fragmented SA (see Militello *et al*., 2007). The hierarchical approach works reasonably well on routine occasions when time for planning actions, training personnel, identifying problems and correcting mistakes exists (Janssen *et al*., 2010). Nevertheless, under the urgent, complex and dynamic conditions of emergencies, such procedures almost always tend to fail (Comfort and Kapucu, 2006). In brief, hierarchical conditions imply structural features which can restrict the flexibility of public safety networks to effectively cope with the complex, uncertain and unsteady emergency environment (see Adler *et al*., 1999). Furthermore, system and task complexities, combined with the need for immediate local adaptation, may limit direction from the superior hierarchical echelons in an efficient and timely manner (Weick, 1990).

On the other hand, the network-centric approach which is rooted in the military domain focuses on horizontal communications among peers rather than vertical communication among higher and lower echelons in the hierarchy (Bharosa *et al*., 2011). Alberts *et al*. (2002) delineate the four tenets of network centric operations which basically form the benefits of adopting them: (1) information sharing is improved through robust networks; (2) the quality of information and shared situational awareness are strengthened by information sharing and collaboration; (3) shared situational awareness allows self-synchronisation and reinforces sustainability as well as command tempo (4), which in turn remarkably increase the mission effectiveness.

Emergency response agencies are showing an increasing interest in the concept of network-centric operations, as they prepare for complex response operations (Stanovich, 2006). However, the military field is different from the emergency response environment. Although both cases have to deal with complicated, perilous and unforeseen events, public safety networks are characterised by heterogeneity that can hamper the emergency response stakeholders from gaining maximum advantage from the capabilities of network-centric operations (Bharosa *et al*., 2011). In particular, public safety networks consist of a variable set of agencies, where each one has its own information coordination procedures and technologies (Bharosa *et al*., 2010).

In an information-rich environment, emergency response stakeholders can be easily overloaded (Endsley and Kiris, 1995). Information overload is seen as the amount of data that exceeds the finite limits of information which can be processed and acted upon by a human functioning in a demanding and complex multi-tasking environment (Stanovich, 2006). Network-centric information coordination has inherently a large number of participating nodes and thus information overload may occur more often compared with the case of hierarchical coordination (Bharosa *et al*., 2011). Therefore, in a network-centric environment, special attention should be paid to information overload. The quantity of information should be in accordance with the bounded rationality concept (Simon, 1972), as overload can obstruct the response stakeholders from filtering the right and high quality information from noise and hence it can delay the response stakeholders in making timely and effective decisions (Bharosa *et al*., 2011).

Other concerns that Bharosa *et al*. (2011) have identified regarding network-centric information coordination are the dilution of decision making and responsibility boundaries, as well as bottom-up freelancing. In particular, the dilution of decision making and responsibility boundaries, which is addressed as an advantage of hierarchical information coordination, can be seen as a concern in a network-centric environment which enables all the responders to have access to all information in the network (Bharosa *et al*., 2011). For the latter, Stanovich (2006) observed that the availability of a large amount of near real-time information frequently makes commanders wrongfully believe that they have the same comprehension and SA as the local responders who have to deal with an emergency at the scene. Regarding bottom-up freelancing, this can be less problematic in the case of hierarchical coordination compared with the network-centric approach (Bharosa *et al*., 2011) which is justified by the argument that, in a hierarchy, the lower echelons receive partial information in the context of decisions and instructions. In a network-centric environment, owing to the availability of a COP, freelancing can be seen as a deviation from higher intent and can cause severe disruption in the unified emergency response effort (Bharosa *et al*., 2011).

Finally, in order to effectively deal with the unforeseen nature and the unpredictable information requirements during emergency response operations, the adaptability level of an information coordination approach has to be addressed as a matter of utmost importance (Bharosa *et al*., 2011). In essence, adaptability is a broad and multidimensional concept and hence, in the case of the complex and dynamic environment of emergency response, it can be limited to the capability of the information sharing structure in delivering the right information at the right moment to the right person. Johansson and Hollnagel (2007) mention that the ability to adapt to situations can make things work, in spite of technical constraints, the dynamics of the task and contextual factors. By exploiting the human and technical network capabilities, a high level of adaptability can be achieved (Bharosa *et al*., 2011). In this context, the network-centric approach tends to utilise the autonomy of individuals (emergency responders), helping them to be able to adapt to the dynamic conditions of an emergency. Conversely, as the hierarchical structure inherently involves vertical communication and piecewise information flow among commanders and subordinates, it can be characterised by limited adaptability.

## 5.3 Design of the case study.

This section contains a detailed description of the design of the field experiment. In this context, the set-up of the experiment is explained; the profiles of the participants (professionals) are described; the network-centric technology and the flood scenarios used during this exercise are described; the experimental protocol is illustrated and finally, the limitations of the study are discussed.

### 5.3.1 Treating disasters in the Netherlands.

The civil security system in the Netherlands has been greatly influenced by the ubiquity of water and the flood potential (Kuipers and Boin, 2013). According to The Netherlands Red Cross (2010), the main aim of Dutch security policy is the enhancement of both the efficiency of disaster response and its quality. In the Netherlands, legislation considers both emergencies and crises to be subtypes of disasters, where emergencies are triggered by a single event and crises occur due to a combination of factors (The Netherlands Red Cross, 2010). Furthermore, Dutch legislation distinguishes between emergencies and crises, in the sense of having a separate line of command (responsibilities) when it comes to disaster management on the local, regional and the national level. In particular, for emergency management, the authority and responsibilities lie with the municipality or the safety region, while the coordination of emergency responders in a crisis situation is performed at the national level (Ministry of Interior Affairs, 2008). Currently, the responsibilities for these disasters are legally institutionalized, in accordance with the Safety Regions Act (2010) (Ministry of Security and Justice, 2013), which provides the administrative and operational framework for the physical aspects of civil protection.

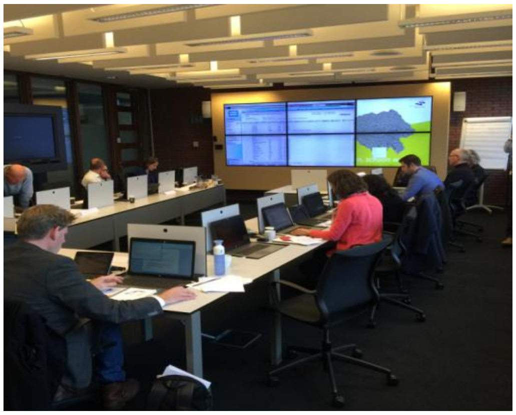
In order to respond to an emergency, safety regions, the fire service, emergency medical services and the police implement policy at the local and regional level, while, the municipalities have the responsibility for local crisis communication, the provision of shelters and aftercare and the listing of missing persons (Kuipers and Boin, 2013). In particular, the safety regions are in charge of planning, logistics, monitoring of emergency management preparation, recruitment of qualified personnel, training, the exercise and implementation of safety regulations and prevention policies, the operation of an emergency room for the call centre, emergency response and provision of relief in their jurisdiction (Kuipers and Boin, 2013). In general, Kuipers and Boin (2013) state that the Dutch constitutional, legal and organisational framework has fragmented responsibilities and authority for emergency response and thus coordination and cooperation among the multiple involved safety agencies are vital.

Chaotic situations require efficient response operations in the form of fast and coordinated actions, as events can escalate and then the efforts needed for relief can be much greater. Furthermore, fast and effective response can minimise the number of injuries and casualties, as well as the economic and environmental impacts. However, such a response requires a high and wide range of expertise, as well as experts from several fields and teams to interact and cooperate with each other and develop shared awareness about a particular situation (Luokkala and Virrantaus, 2014). Information systems can facilitate the development of SA through the provision of real-time, spatio-temporal information in the context of a common operational picture. An operational picture shared by more than one actor enables the involved stakeholders to distribute and acquire situational information in a geographically-distributed environment (Fanti and Beach, 2002; Shelton, 2001; Steenbruggen *et al*., 2011; Vesterinen, 2009). This information is needed by the emergency stakeholders in order to carry out their response tasks in an efficient way (Goodchild, 2010a; Seppänen *et al*., 2013; Steenbruggen *et al*., 2011). Nevertheless, the shared information delivered to relevant stakeholders in minimal time should be of high quality, as missing or bad information quality can obstruct the activities and contribute to failures and damage (Seppänen and Virrantaus, 2015).

### 5.3.2 Set-up of the field exercise.

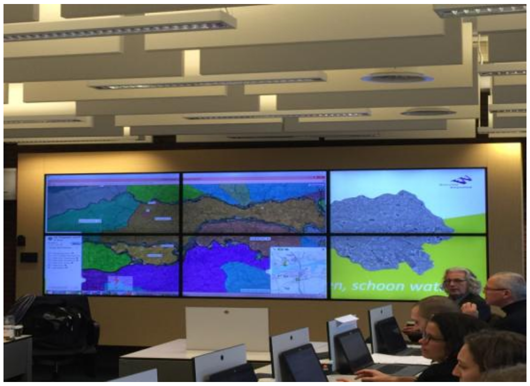
During the field exercise, novel information concepts including network-centric working and a common operational picture have been employed in order to improve information and system quality. In particular, the real value of the network-enabled capabilities, which is reflected in its chain (see UK Ministry of Defense, 2005), can be utilised in order to normalise the flood emergencies in a fast and efficient way. In the context of this value chain, in the information domain, the network-centric information coordination aims to achieve better information sharing through a realised COP, which, in turn, can lead to the achievement of shared SA and better decisions in the cognitive domain and consequently to better response actions and effects in the physical domain of operations.

A national exercise with two flood scenarios simulated for this purpose took place on the 10th December 2015 at the headquarters of the Rivierenland Water Board in the city of Tiel (in the Netherlands). The two scenarios had increasing complexity and severity, involving multiple safety agencies and response stakeholders (see picture 5.1), in order to measure the added value of network-centric systems. The network-centric software tool used in this exercise is called the national crisis management system (in Dutch: Landelijk Crisis Management Systeem), abbreviated as LCMS. The network-centric system has enabled the participants in the exercise to exchange information in both textual and map format at the same time, thus being able to view the evolution of the flood scenarios and the progress of the response operations, as well as the allocation of resources and assets on the response scene in real time (see pictures 5.2 and 5.3). The participants in the exercise were emergency response stakeholders (panel of experts). Questionnaires with five ordered response levels were handed to all of them. Before the start of the exercise, the stakeholders had to fill out the first part of the questionnaire, which consisted of questions about the quality of the information, as well as about the quality of the system that they experience in their daily practice which is based on a hierarchy. After the exercise was initiated, at the end of each scenario, the stakeholders had to answer questions about information quality, while, at the end of both the scenarios, they had to answer questions about the quality of the system experienced.



Picture 5.1: Stakeholders respond to the flood emergencies.

Picture 5.2: Common Operational Picture in text form.



Picture 5.3: Common Operational Picture in map form.

### 5.3.3 Participants of the field exercise.

The participants of the field exercise were emergency response stakeholders (panel of experts). The following table 4 shows their demographics which have been extracted from their answers to the questionnaires (see Appendix A) and include the number of participants, average age, gender, organisation, education, work experience and experience with coordinated regional incident management procedures (in Dutch: Gecoördineerde Regionale Incidentbestrijdings Procedure, abbreviated as GRIP) (see Info point safety, 2011).

Table 5.4: Demographics of the participants in the field exercise.

| | | |
|---|---|---|
| **Number of participants** | | **8** |
| **Average age** | | **48.6 years** |
| **Gender** | | **n** |
| Male | | 4 |
| Female | | 4 |
| **Organisation** | | **n** |
| Rijkswaterstaat's VWM (Traffic and water management services) | | 3 |
| Rijkswaterstaat Oost-Nederland (Regional information and crisis management center) | | 3 |
| DCC-IenM<br>Departmental Coordination Center for Crisis management of the Dutch Ministry of Infrastructure and the Environment. | | 2 |
| **Education** | | **n** |
| Primary education | Lager onderwijs (Basisschool) | 0 |
| Secondary education | LBO, LAVO, MAVO, MULO | 1 |
| | MBO, VMBO, HAVO | 0 |
| | MMS, HBS, Atheneum, Gymnasium | 0 |
| Higher education | HBO, Universiteit | 7 |

| | |
|---|---|
| **Experience** | **n** |
| 0-1 year | 1 |
| 1-5 years | 0 |
| 5-10 years | 4 |
| 10-20 years | 3 |
| 20-30 years | 0 |
| More than 30 years | 0 |
| **Experience emergencies at GRIP 2 level or higher** | **n** |
| 0 times | 0 |
| 1-5 times | 3 |
| 5-10 times | 1 |
| 10-20 times | 3 |
| 20-40 times | 1 |
| More than 40 times | 0 |

### 5.3.4 Technology: The network-centric software tool.

All the disaster events have temporal and spatial dimensions that identify the duration of impacts, together with their geographical extent on the Earth's surface (ground truth) (National Research Council, 2007). In this context, geospatial data and tools are useful in response operations in order to facilitate real-time data fusion and analysis, location mapping and visualisation of dynamic conditions (Chen and Peña-Mora, 2010). However, despite the massive efforts and investments made in the development of geo-tools and spatial data infrastructures, the special needs of emergency response have only roughly been considered (Neuvel *et al*., 2012; National Research Council, 2007).

Safety agencies rely on accurate and up-to-date information in order to respond to emergency situations. However, data are frequently scattered among multiple jurisdictions, in different and incompatible formats (National Research Council, 2007). For effective network centric emergency response, various institutional factors have to be addressed and the relevant technology has to be deployed. In order for the benefits of network-centric working in response operations to be utilised, the operationalisation of a system based on its principles is required. The requirements of the network-centric emergency response dictate the incorporation of novel geographical systems and particularly architectures (Neuvel *et al*., 2012). In this context, the architecture of geo-enabled network centric software solutions should underpin the connection of all the involved safety agencies, stakeholders, services and networks, so that existing (semi-static) and dynamic in-situ and model data can be available and easily accessible upon request.

During an emergency, the existing technological infrastructure may encounter serious damage (Lubitz *et al*., 2008a). Furthermore, a constant network with enough capacity for all the involved stakeholders and particularly for the field workers is not ensured and therefore peer-to-peer (P2P) networks can be utilised to connect actors in the field between them (lower hierarchy echelons) as well as with those in the coordination centers (upper hierarchy echelons) (Neuvel *et al*., 2012). Bortenschlager *et al*. (2007) mention that P2P technology allows systems to be functional even when a constant network connection with a server is not available because a P2P network enables the exchange of information via other available nodes such as a wireless local area network (WLAN) or mobile network or ad hoc P2P networks. Hence, a P2P network permits offline working and information can sync when online connection is regained.

Although P2P technology is widely adopted and used in military command (Wilson, 2004; Jonas, 2005) where the network-centric concept is also rooted, it is still inadequately explored in applications related to national civil security and in particular in emergency response operations (Lubitz *et al*., 2008b; Bortenschlager *et al*., 2007). Nevertheless, despite the limited civilian implementation of network-centricity, it has been credited with significant operational value (Tucker, 2008; IBM, 2006; Cisco, 2006; Cebrowski and Garstka, 1998). In the context of a P2P network, information is not shared in a hierarchical way, where a central point of information normally does the distribution. The latter forms the basis of the more traditional (hierarchical) client-server architecture in which a relatively low number of servers (sources) provide information to different clients or applications (recipients) (see figure 5.1). Instead, in a P2P network which underpins the logic of the network-centric approach, the safety organisations and stakeholders involved are considered as equal entities (peers or nodes) which serve both as a source and a recipient of information (see figure 5.2). It is therefore apparent that in a P2P network, a distinction between clients and servers does not exist.

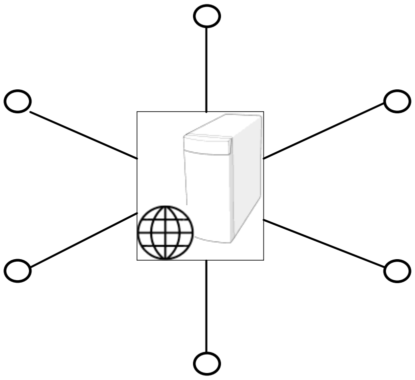


Figure 5.1: Client-server network (Hierarchical approach of information sharing – once with each).

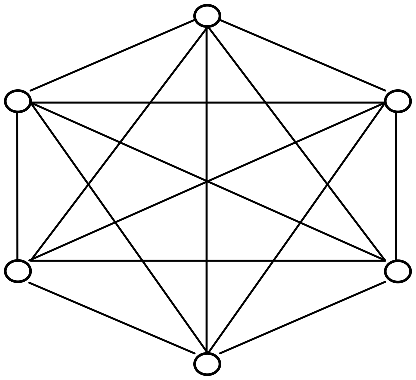


Figure 5.2: Peer-to-peer network (Network-centric approach of information sharing – once with all).

The network-centric technology has the potential to address issues related to the inadequate, vertical distribution of knowledge and information during emergency response. Furthermore, as an instrument of adaptive management (Wiese, 2006) that provides unobstructed access to information and knowledge to all actors in the response space, it can overcome the limitations of rigid vertical control of operations which, during the complex environment of emergency situations, can rapidly become another layer of chaos (Cooper and Block, 2006; Wiese, 2006; Walter, 2005). Therefore, a network centric system can contribute to the achievement of the vision of "the right information at the right moment to the right person" and in a way that is cognitively and physically usable for its end users (stakeholders) (Endsley, 2000), so that emergency responders can have enough resources to comprehend the situation and achieve SA (Aedo *et al*., 2010). The latter can result in a better deployment and also in increased efficiency during the response operations.

In a network-centric environment underpinned by the relevant technology, information is derived in a reciprocal relationship from multiple sources and areas of knowledge and expertise. This information, which is distributed to the different involved stakeholders, inherently incorporates the geospatial dimension (location awareness). This is because the emergency under treatment along with the resources and assets that have to be deployed at the scene and also the routes which will be utilised for the response operations are spatially correlated. In this connection, it should also be mentioned that, although all the information is made available to all the involved actors at once in a network-centric system, these retain their roles in the hierarchy. More precisely, decision making always takes place within the management hierarchy. In this context, a COP in text and map form (alternatively called, respectively sitreps-situation reports and sitplots-situation plots); it both facilitates and supports the decision makers.

Regarding the functionalities of the LCMS (see section 5.3.2), a text application for typing and sending messages between the involved actors is included. In order to check whether the sent messages have been read, relevant signs are used. Furthermore a Geographic Information System (GIS) is incorporated and enables users to acquire, create, edit, share, combine, analyse, interpret and visualise data. In this GIS, users are provided with tools for adding, editing and deleting geographic features (polygons, polylines and points) and symbols related to the evolution of the emergency and the progress of the response operations on the map interface. Overall, LCMS can be seen as a fit-for-purpose system that can be expanded to employ more facilities, functionalities, data and participants if required.

Traditionally, a COP was shared in text form via static *sitreps* whose distribution followed a hierarchical approach. Although these situation reports have been useful in providing information about the evolution of an emergency and the progress of the response operations to the involved stakeholders, they are credited with a number of weaknesses (Ven *et al*., 2008). In particular, these sitreps can be delayed in arriving at the interested stakeholders, especially to those in the upper echelons of the hierarchy, which may result in their receiving outdated information. In addition, as these sitreps frequently have information spread over pages of text, they require the end-users (stakeholders) to spend considerable time reading and comprehending them and therefore they can cause extra delays in communicating their content. Furthermore, in the hierarchical way of sharing the sitreps, not all the stakeholders who need their information can have immediate access to them. The network-centric LCMS effectively addresses the weaknesses of the traditional hierarchical systems through its P2P network-based architecture and interface that support sharing of both textual and map information simultaneously in the context of a COP.

The LCMS system component used for sharing textual information is known as *sittext* (situation text). In essence, sittext is a collective workspace influenced by a location driven approach that enables its users to create, edit, send and receive (spatial) information in text form. It includes different tabs for the different safety agencies involved in the response operations. Furthermore, the system's interface shows which users are online. In short, sittext can provide a dynamic view of the actual situation in text form that can be shared and exchanged between all the involved actors in a fast and efficient way.

The LCMS system component utilised for the visualisation and communication of information is known as *sitplot* (situation plot). Basically, sitplot is a geographic interface which allows its users to create, edit, view, analyse and share (spatial) information in order to create a complete and up to date COP of the situation under treatment. Sitplot's interface includes different layers of semi-static, dynamic and model data. Furthermore, it allows different users to add, edit and delete geographic features and symbols. Online users are displayed in the interface and if they add or amend data in a sitpot, a notification message is generated. In addition, when a user is clicked, the map layers created by him/her are added to the total list of map layers. In general, the shared picture presented in the context of sitplot is a result of various inputs from different sources and actors and is available on every PC where sitplot is installed and running. Therefore, all the interested safety organisations and actors can have access to the shared picture at once. In addition, the different organisations have the ability to create, through their plotters, a situation picture separately.

In brief, the network-centric LCMS system through its sittext and sitplot components supports the interested stakeholders to gain access to all the available information, as well as to have a thorough and dynamic overview of the location of an emergency, the impacts on the surrounding environment and the progress of the response operations in achieving shared SA. This, in turn, can support the decision making process at both the policy and operational levels for the timely and efficient normalisation of an emergency situation.

### 5.3.5 Description of the flood scenarios.

During this field exercise, two alternative simulated flood scenarios with increasing complexity that required multiple emergency response agencies to collaborate and coordinate their actions were employed and played out in near-real time. In order for the scenarios to be realistic, these were based on inputs from well-trained emergency actors, as well as on reports such as the National High Water and Flooding Emergency Response Plan (The Dutch Ministry of the Interior and Kingdom Relations, 2007), which describes how the national response has to be coordinated and scaled up towards improving coordination for the effective management of major flood events. In the following table 5.5a, b, a brief description of both the scenarios used during this exercise, along with their goals, is provided.

Table 5.5a: Description of the scenarios used for the field exercise.

| **Scenario 1: Dyke failures and evacuation (GRIP 2).** |
|---|
| **Description:** Dyke failures are visible in the Zaltbommel municipality and in particular within the Tieler and Culemborgerwaard dyke rings of the province of Gelderland in the Netherlands. The water depth is increasing and the area in the vicinity of the dyke is flooding progressively. Schools and healthcare facilities which host vulnerable population and are located in the surroundings of the emergency location have to stop functioning immediately. The emergency response agencies have to decide about and organise the evacuation of all the people who are located within the radius of effect from the potential dyke failure, giving priority to the most vulnerable. |
| **Goal of the Scenario 1:** This is a large flood emergency which involves various emergency services. The aim of this scenario is to show that fast information exchange among all the involved safety agencies and an early shared COP can support them to better coordinate their actions and apply effective measures in order to normalise the situation more rapidly. |

Table 5.5b: Description of the scenarios used for the field exercise.

| **Scenario 2: Dam failure, dyke failures, hazardous gas networks in the radius of effect and evacuation (GRIP 3/4).** |
|---|
| **Description:** A dam failure is observed in the municipality of Culemborg which is located in the province of Gelderland in the Netherlands. The embankment has subsided over a depth of approximately 16 meters. A berm needs to be constructed as soon as possible. Furthermore, the water depth is increasing and the area in the vicinity of the dam is flooding progressively. Several municipalities in the surroundings, including Zaltbommel, Geldermalsen, Lingewaal and Neerijnen of the province of Gelderland are affected. More than 1000 field workers, such as policemen and firemen, are deployed in the area of the emergency. Because of extensive water overflow and overtopping, the risk of dyke failure in the Zaltbommel area is high. Furthermore, due to high water pressure, pipes of the gas network near Gamersedijk in Zaltbommel area are in danger of exploding (secondary hazard). It is necessary to organize the evacuation of all the people located within the radius of effect from the dam and the gas networks giving priority to those located in De Zandkampen. Both ground (police vehicles, fire trucks) and aerial means (helicopters and aircrafts) will be used for the evacuation. The shortest evacuation paths have to be identified, given that network blockages and traffic jams occur progressively as the flood escalates. |
| **Goal of the Scenario 2:** This is a full, complex and severe flood scenario where several emergency services are involved. As the scenario includes secondary hazards, it requires the emergency services to efficiently allocate and manage their assets and resources over the different incidents. The aim of this scenario is to demonstrate that a COP can improve the decision making process in chaotic situations. As a result the necessary actions can be taken in a fast and effective manner. In such cases, the safety agencies traditionally struggle to acquire a good overview of the impact of the emergency and consequently there are many issues associated with applying the most suitable measures to normalise the situation. |

### 5.3.6 The experimental protocol.

This field exercise employs realistic flood scenarios with different complexities and involves diverse emergency response stakeholders (panel of experts) who have to coordinate their actions and share information and knowledge using network centric technology (LCMS) to normalise the flood situations in an efficient and timely manner. The network-centric working method incorporated during this exercise is fundamentally different from the hierarchical (traditional) way which these stakeholders experience in their routine operations. The scenarios were facilitated by the experiment's organisers (field exercise staff) who entered messages in text form in the network centric system in order to generate a starting point for each scenario. The following figure 5.3 shows the layout of the field exercise.

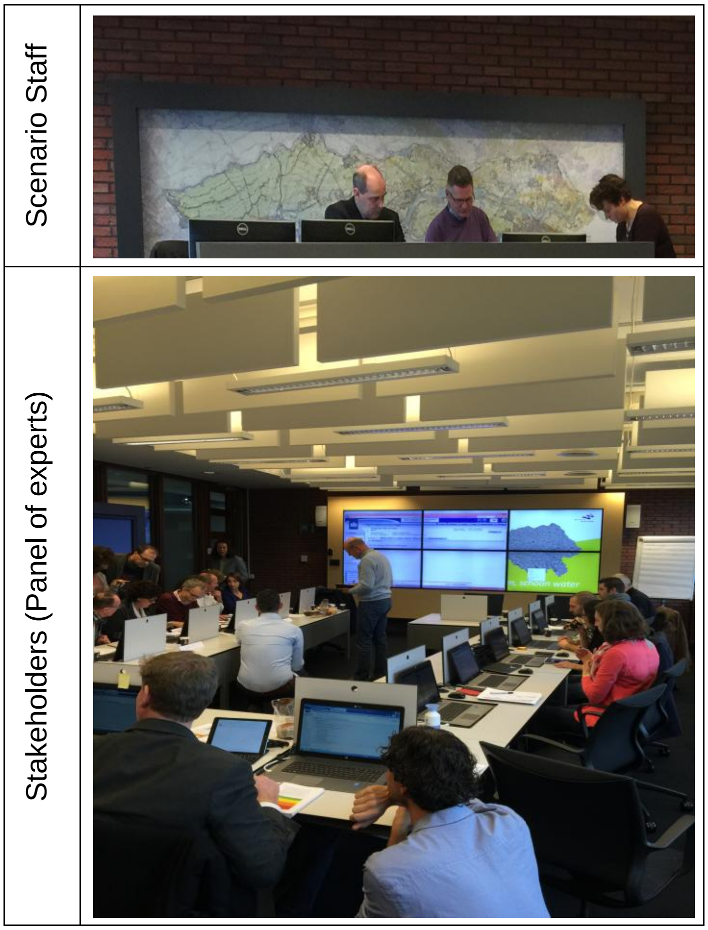


Figure 5.3: Field exercise's layout.

Information on individuals' perceptions about the tools used during the field exercise was acquired from the responses of the participants (stakeholders) to the questionnaires. Before the start of the exercise, the participants had to respond to a questionnaire about the quality of both the information and the systems experienced in their current practice. After the start of the exercise and in particular after each scenario, the participants had to fill in a questionnaire on Information Quality (IQ), while, after both the scenarios had played out, they had to complete a questionnaire on System Quality (SQ). Furthermore, after the end of the first scenario (mid-exercise), a central evaluation of the participants' experience took place, while, after both scenarios were considered (at the end of the field exercise), an evaluation of the overall experience of the participants gained from this exercise was carried out by members of the case study's organisation. In addition, during the exercise, the organisers shadowed the participants using a pre-constructed form. Figure 5.4 below shows the experimental protocol along with its timelines.

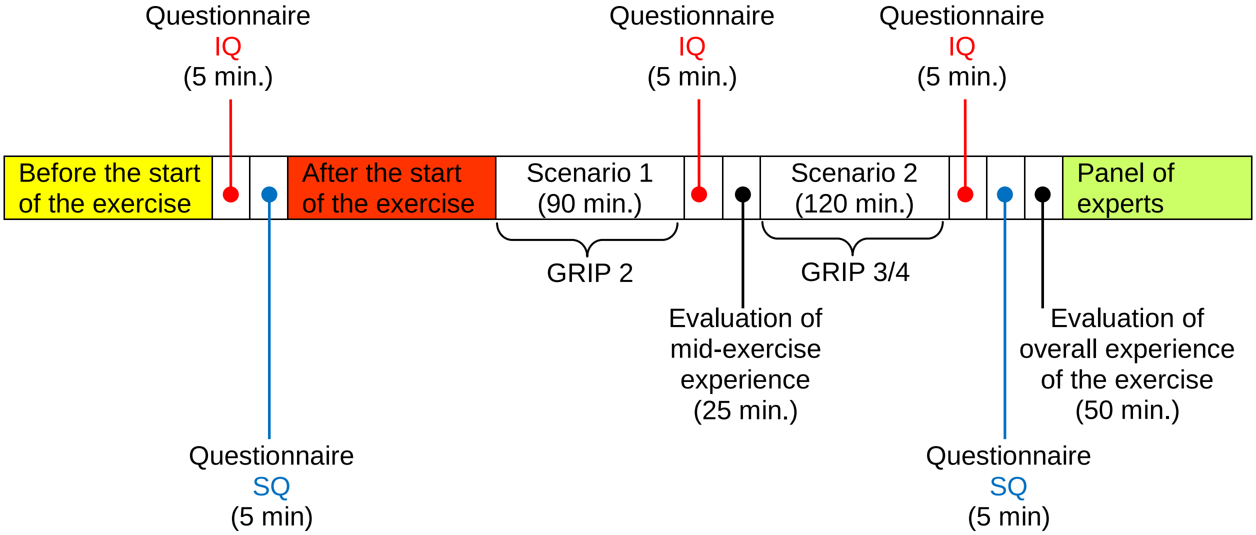


Figure 5.4: Schematic representation of the experimental protocol.

### 5.3.7 Limitations of the study.

This exercise which employs network-centric emergency response operations is based on realistic scenarios and involves well-trained professionals (panel of experts). However, an important constraint, resulting from the need and ambition to play the scenarios with stakeholders was that operational organisations such as the Dutch Ministry of Infrastructure and the Environment (In Dutch: Rijkswaterstaat) had to be asked for the provision and use of essential resources and assets. This proved to be extremely difficult, given that the activities have had to be planned in a really busy operational environment. An additional limitation is that not all the organisations and stakeholders that should normally get involved in the response and normalisation of the flood events described in the scenarios participated in this field exercise. For example, stakeholders coming from safety regions, municipalities, the fire brigade, the emergency medical services and police did not participate in the exercise. In total, the panel of experts of the field test consisted of 8 persons. Due to this relatively small group of experts, the results (responses) of the questionnaire should be treated with care. A relevant assumption made was that it was impossible to have a larger group of experts due to the unavailability of certain stakeholders.

The participants in the exercise were well trained stakeholders but with different backgrounds, whose work experience varied between 1 and approximately 20 years. All the participants had experienced severe and complex emergencies (at GRIP 2 level or higher), but had a different number of such experiences. Regarding their educational background, most of them (7 in all) had higher education except for one who had reached the secondary level of education. However, none of them practised and/or had hands-on experience of network-centric information systems. In order to overcome this limitation, the Dutch Ministry of Infrastructure and the Environment, in collaboration with the Dutch Institute of Safety (In Dutch: Instituut Fysieke Veiligheid – IFV) organised educational sessions (between Spring and Autumn 2015) on novel information concepts which included the network-centric concept and the COP in order to achieve SA. Furthermore, the participants (stakeholders) were trained in using the network-centric technology (system) i.e. LCMS, utilized during this exercise.

## 5.4 Results of the field exercise.

This study purports to evaluate the effectiveness of the network-centric information systems compared with systems based on the hierarchy that selected Dutch stakeholders experience in their daily practice. In order to identify whether network centric information systems can improve the stakeholders' (i.e. professionals') appreciation of Information Quality (IQ) and System Quality (SQ), their perceived IQ and SQ are carefully considered with regard to what they experience in their daily practice vs. their perceived IQ and SQ about the network-centric environment experienced during this exercise. The results of this exercise are expected to reveal how the different stakeholders have different opinions on and knowledge of various information and system quality dimensions.

For measuring IQ, seven constructs were utilised and three statements (in Dutch) corresponding to each one were rated in order to validate them (see Appendix A). However, these statements were placed in the questionnaires in random order. Furthermore, the statements were formulated in positive and negative forms in order to minimise the acquiescence bias, as well as extreme response bias (Sauro, 2011).

The outcomes of the stakeholders' (i.e. experts') perceptions of IQ and in particular of the attributes of the information that they experience in their daily practice are presented in table 5.6a, b. The stakeholders' perceptions of the same IQ dimensions but based on the experience gained during the two scenarios of this exercise, are provided in tables 5.7a, b and 5.8a, b. From the combination of the tabulated results, as well as from the organisers' observations, it can be deduced that, as the participants (stakeholders) gain more hands-on experience in the network-centric environment of emergency response, their appreciation increases with regard to the IQ shared in such an environment. In this context, the stakeholders' judgment (answers) on IQ after considering scenario 2 (see table 5.8a, b) is clearly influenced by the network-centric manner of working compared with their opinions (answers) on IQ resulting from the traditional (hierarchical) way of information coordination experienced in their daily practice (see table 5.6a, b). Furthermore, as the complexity and the severity of the scenarios increases (Scenario 1 corresponds to a GRIP 2, while Scenario 2 resembles a GRIP 3/4), the need for information sharing escalates; and the appreciation of the end-users (stakeholders) of the network-centric information coordination also grows.

Table 5.6a: Results of the questionnaires regarding the Quality of the Information (IQ) that the participants (stakeholders) experience in their daily practice (Statements are rated in a 5 point scale: -- = strongly disagree, - = disagree, 0 = neutral, + = agree, ++ = strongly agree. n.a. = no answer).

| | | | Rating | | | | | |
|---|---|---|---|---|---|---|---|---|
| Scale | Item | Statement | -- | - | 0 | + | ++ | n.a. |
| Timeliness (currency) | 1 | The information shared with me is up to date. | 0 | 2 | 4 | 2 | 0 | 0 |
| | 2 | The information provided to me is outdated. | 0 | 3 | 3 | 2 | 0 | 0 |
| | 3 | The information that I receive is timely. | 0 | 3 | 5 | 0 | 0 | 0 |
| Completeness | 1 | The information that I get from others is complete. | 0 | 3 | 4 | 1 | 0 | 0 |
| | 2 | The information shared with me is incomplete. | 0 | 2 | 3 | 3 | 0 | 0 |
| | 3 | The information offered to me lacks detail. | 0 | 2 | 4 | 2 | 0 | 0 |
| Quantity (Information overload) | 1 | In general, the information supplied to me is too much compared with what I need. | 1 | 1 | 3 | 2 | 1 | 0 |
| | 2 | I can share all the information that I cannot retain. | 0 | 3 | 4 | 1 | 0 | 0 |
| | 3 | The information that I get is very limited. | 0 | 2 | 3 | 3 | 0 | 0 |

Table 5.6b: Results of the questionnaires regarding the Quality of the Information (IQ) that the participants (stakeholders) experience in their daily practice (Statements are rated in a 5 point scale: -- = strongly disagree, - = disagree, 0 = neutral, + = agree, ++ = strongly agree. n.a. = no answer).

| | | | Rating | | | | | |
|---|---|---|---|---|---|---|---|---|
| Scale | Item | Statement | -- | - | 0 | + | ++ | n.a. |
| Relevance | 1 | The information that I get from others is relevant to my tasks (directly usable). | 0 | 2 | 3 | 3 | 0 | 0 |
| | 2 | I receive a lot of information that is not necessary in the performance of my duties. | 0 | 4 | 2 | 2 | 0 | 0 |
| | 3 | I receive needless information. | 0 | 3 | 2 | 3 | 0 | 0 |
| Consistency | 1 | The information shared with me is contradictory. | 0 | 1 | 5 | 2 | 0 | 0 |
| | 2 | The information that I get from others is different from the information that I already have. | 0 | 1 | 5 | 2 | 0 | 0 |
| | 3 | The information that I get from others is conflicting. | 0 | 1 | 5 | 2 | 0 | 0 |
| Correctness | 1 | The information shared with me is correct. | 0 | 2 | 3 | 3 | 0 | 0 |
| | 2 | The information shared with me contains errors. | 1 | 1 | 6 | 0 | 0 | 0 |
| | 3 | The information that I receive is incorrect. | 0 | 4 | 4 | 0 | 0 | 0 |
| Reliability (Validation) | 1 | For me, it is unclear whether the information that I get from others is reliable. | 1 | 2 | 2 | 3 | 0 | 0 |
| | 2 | I am able to verify the correctness of the information shared with me. | 0 | 0 | 3 | 5 | 0 | 0 |
| | 3 | I use available personal information to verify the correctness of the information received. | 0 | 0 | 4 | 3 | 1 | 0 |

Table 5.7a: Results of the questionnaires regarding IQ that the participants (stakeholders) experienced during Scenario 1 of the field exercise (Statements are rated in a 5 point scale: -- = strongly disagree, - = disagree, 0 = neutral, + = agree, ++ = strongly agree. n.a. = no answer).

| | | | Rating | | | | | |
|---|---|---|---|---|---|---|---|---|
| Scale | Item | Statement | -- | - | 0 | + | ++ | n.a. |
| Timeliness (currency) | 1 | The information shared with me is up to date. | 0 | 2 | 3 | 3 | 0 | 0 |
| | 2 | The information provided to me is outdated. | 1 | 2 | 4 | 1 | 0 | 0 |
| | 3 | The information that I receive is timely. | 0 | 0 | 4 | 3 | 1 | 0 |
| Completeness | 1 | The information that I get from others is complete. | 0 | 3 | 4 | 1 | 0 | 0 |
| | 2 | The information shared with me is incomplete. | 0 | 4 | 1 | 3 | 0 | 0 |
| | 3 | The information offered to me lacks detail. | 1 | 3 | 1 | 3 | 0 | 0 |
| Quantity (Information overload) | 1 | In general, the information supplied to me is too much compared with what I need. | 0 | 4 | 2 | 2 | 0 | 0 |
| | 2 | I can share all the information that I cannot retain. | 0 | 8 | 0 | 0 | 0 | 0 |
| | 3 | The information that I get is very limited. | 1 | 3 | 3 | 1 | 0 | 0 |

Table 5.7b: Results of the questionnaires regarding IQ that the participants (stakeholders) experienced during Scenario 1 of the field exercise (Statements are rated in a 5 point scale: -- = strongly disagree, - = disagree, 0 = neutral, + = agree, ++ = strongly agree. n.a. = no answer).

| | | | Rating | | | | | |
|---|---|---|---|---|---|---|---|---|
| Scale | Item | Statement | -- | - | 0 | + | ++ | n.a. |
| Relevance | 1 | The information that I get from others is relevant to my tasks (directly usable). | 0 | 0 | 1 | 4 | 3 | 0 |
| | 2 | I receive a lot of information that is not necessary in the performance of my duties. | 0 | 5 | 2 | 1 | 0 | 0 |
| | 3 | I receive needless information. | 0 | 2 | 4 | 2 | 0 | 0 |
| Consistency | 1 | The information shared with me is contradictory. | 0 | 1 | 6 | 1 | 0 | 0 |
| | 2 | The information that I get from others is different from the information that I already have. | 1 | 2 | 3 | 2 | 0 | 0 |
| | 3 | The information that I get from others is conflicting. | 0 | 2 | 3 | 3 | 0 | 0 |
| Correctness | 1 | The information shared with me is correct. | 0 | 2 | 4 | 2 | 0 | 0 |
| | 2 | The information shared with me contains errors. | 0 | 2 | 5 | 1 | 0 | 0 |
| | 3 | The information that I receive is incorrect. | 1 | 2 | 5 | 0 | 0 | 0 |
| Reliability (Validation) | 1 | For me, it is unclear whether the information that I get from others is reliable. | 0 | 5 | 2 | 1 | 0 | 0 |
| | 2 | I am able to verify the correctness of the information shared with me. | 0 | 0 | 1 | 6 | 1 | 0 |
| | 3 | I use available personal information to verify the correctness of the information received. | 1 | 0 | 0 | 6 | 1 | 0 |

Table 5.8a: Results of the questionnaires regarding IQ that the participants (stakeholders) experienced during Scenario 2 of the field exercise (Statements are rated in a 5 point scale: -- = strongly disagree, - = disagree, 0 = neutral, + = agree, ++ = strongly agree. n.a. = no answer).

| | | | Rating | | | | | |
|---|---|---|---|---|---|---|---|---|
| Scale | Item | Statement | -- | - | 0 | + | ++ | n.a. |
| Timeliness (currency) | 1 | The information shared with me is up to date. | 0 | 0 | 2 | 5 | 1 | 0 |
| | 2 | The information provided to me is outdated. | 1 | 4 | 2 | 1 | 0 | 0 |
| | 3 | The information that I receive is timely. | 0 | 0 | 2 | 6 | 0 | 0 |
| Completeness | 1 | The information that I get from others is complete. | 0 | 1 | 3 | 4 | 0 | 0 |
| | 2 | The information shared with me is incomplete. | 1 | 5 | 2 | 0 | 0 | 0 |
| | 3 | The information offered to me lacks detail. | 1 | 4 | 1 | 2 | 0 | 0 |
| Quantity (Information overload) | 1 | In general, the information supplied to me is too much compared with what I need. | 0 | 4 | 2 | 1 | 1 | 0 |
| | 2 | I can share all the information that I cannot retain. | 0 | 8 | 0 | 0 | 0 | 0 |
| | 3 | The information that I get is very limited. | 0 | 6 | 1 | 1 | 0 | 0 |

Table 5.8b: Results of the questionnaires regarding IQ that the participants (stakeholders) experienced during Scenario 2 of the field exercise (Statements are rated in a 5 point scale: -- = strongly disagree, - = disagree, 0 = neutral, + = agree, ++ = strongly agree. n.a. = no answer).

| | | | Rating | | | | | |
|---|---|---|---|---|---|---|---|---|
| Scale | Item | Statement | -- | - | 0 | + | ++ | n.a. |
| Relevance | 1 | The information that I get from others is relevant to my tasks (directly usable). | 0 | 0 | 2 | 5 | 1 | 0 |
| | 2 | I receive a lot of information that is not necessary in the performance of my duties. | 0 | 3 | 4 | 1 | 0 | 0 |
| | 3 | I receive needless information . | 1 | 3 | 2 | 2 | 0 | 0 |
| Consistency | 1 | The information shared with me is contradictory. | 0 | 2 | 3 | 3 | 0 | 0 |
| | 2 | The information that I get from others is different from the information that I already have. | 0 | 3 | 4 | 1 | 0 | 0 |
| | 3 | The information that I get from others is conflicting. | 1 | 2 | 4 | 1 | 0 | 0 |
| Correctness | 1 | The information shared with me is correct. | 0 | 1 | 2 | 5 | 0 | 0 |
| | 2 | The information shared with me contains errors. | 1 | 2 | 5 | 0 | 0 | 0 |
| | 3 | The information that I receive is incorrect. | 0 | 4 | 4 | 0 | 0 | 0 |
| Reliability (Validation) | 1 | For me, it is unclear whether the information that I get from others is reliable. | 0 | 5 | 3 | 0 | 0 | 0 |
| | 2 | I am able to verify the correctness of the information shared with me. | 0 | 1 | 2 | 5 | 0 | 0 |
| | 3 | I use available personal information to verify the correctness of the information received. | 0 | 0 | 3 | 3 | 2 | 0 |

Scenario 1, where the participants had to respond to a flood scenario in a network-centric manner using particular technology (LCMS), includes a large flood emergency that required a considerable amount of information sharing between the involved emergency services for its normalisation. Scenario 2 is a full, complex and severe flood emergency which involves all the safety services, as well as multiple incidents that complicate communication between stakeholders and also their coordination and the decision making process. From the results, it can be deduced that the experience gained during their participation in Scenario 1 helped the stakeholders to improve their performance during their participation in Scenario 2. Furthermore, the benefits of the coordination of network-centric information during the emergency response operations in terms of IQ become more visible. Regarding the IQ construct *timeliness*, while the stakeholders' opinions on whether they receive information in their daily routine in a timely manner look divided; after their network-centric experience in Scenario 1, the majority of them seem to agree that with the coordination of network-centric information they receive timely information. This result looks even stronger in Scenario 2, as except for one stakeholder (who responded differently to item 2), all the others are neutral or point out that they receive timely information in a network-centric working environment. For the IQ construct *completeness*, the stakeholders' perception does not change after practising the network-centric response operations during the Scenario 1. However, after their experience gained via Scenario 2, the majority of the stakeholders except for one, judge the information shared during the network-centric system to be more complete compared with the information shared during their daily practice that is based on hierarchical systems. Furthermore, after the network-centric experience of the Scenario 2, only two stakeholders still think that the information shared with them lacks detail. Concerning the IQ construct *quantity*, after their network-centric information sharing experience, the participating stakeholders do not alter their opinion about the quantity of the information that they receive. Nevertheless, after the experience gained during the second scenario, almost all of them state that the information received is in no way too limited for the fulfilment of their tasks. But in the corresponding question answered on the basis of their daily experience, stakeholders looked divided. Regarding the IQ construct *relevance*, the stakeholders believe that they obtain more relevant information when this is shared in a network-centric manner compared with when it is shared through a traditional (hierarchical) system. However, some of the participants (two), even after their network-centric experience (Scenarios 1 and 2), still think that they are receiving needless information. The latter is associated with the filters of personalisation of the network-centric system which for them were too complicated to use. For the IQ construct *consistency*, the experts' judgment does not seem to be affected by their participation in the network-centric exercise. With regard to the IQ construct *correctness*, the network-centric experience gained during the first scenario looks as if it did not have an impact on the stakeholders' perception about the correctness of the information received. However, after acquiring more experience in working with a network centric information system, i.e. after Scenario 2, stakeholders' appreciation of the correctness of information shared via such a system appears to have strengthened. Concerning the IQ construct *reliability*, almost half of the participating stakeholders were not sure whether the information shared with them in their daily practice is reliable. However, after sharing information in a network-centric manner, the majority of the participants perceived the net-centric distributed information to be more reliable. Overall, the IQ constructs *timeliness* and *reliability* clearly show an increase in terms of appreciation when the participants responded in a network-centric environment and in particular after the experience gained during the second scenario.

For measuring SQ, nine constructs grouped in three categories were utilised and two, three or five statements (in Dutch) related to them were rated for their validation (see Appendix A). The statements were placed in the questionnaires in random order and they were formulated in positive and negative forms in order to minimise both acquiescence bias and extreme response bias (Sauro, 2011).

The outcomes of the perceptions of the stakeholders (i.e. experts) on SQ and in particular on the attributes of the systems that they experience in their daily practice, are presented in table 5.9a, b. The stakeholders' perceptions of the same SQ dimensions, but based on the experience gained during participating in the two scenarios of this exercise, are given in table 5.10. From the organisers' observations, it can be seen that the participants (stakeholders) performed relatively better after the experience gained from working with the network-centric system (LCMS) utilised for the response operations during Scenario 1. Furthermore, the stakeholders' judgment (answers) on SQ after participating in both the scenarios (see table 5.10) is evidently influenced by the network system used for information sharing during this exercise, compared with their opinions (answers) on SQ based on the systems which they utilise in their daily practice (see table 5.9a, b).

Table 5.9a: Results of the questionnaires regarding the Quality of the System (SQ) that the participants (stakeholders) experience in their daily practice (Statements are rated in a 5 point scale: -- = strongly disagree, - = disagree, 0 = neutral, + = agree, ++ = strongly agree. n.a. = no answer).

| | | | Rating | | | | | |
|---|---|---|---|---|---|---|---|---|
| Scale | Item | Statement: The information system that I experience in my daily practice, | -- | - | 0 | + | ++ | n.a. |
| **System-related** | | | | | | | | |
| Accessibility | 1 | It gives me immediate access to the information that I need. | 0 | 5 | 2 | 1 | 0 | 0 |
| | 2 | It gives me immediate access to information that is outside the scope of my organisation. | 1 | 5 | 2 | 0 | 0 | 0 |
| System reliability | 1 | It always works properly. | 0 | 3 | 4 | 1 | 0 | 0 |
| | 2 | It works reliably. | 0 | 2 | 6 | 0 | 0 | 0 |
| | 3 | It sometimes malfunctions. | 0 | 3 | 4 | 1 | 0 | 0 |
| System response time | 1 | It lets me wait for response. | 0 | 2 | 4 | 2 | 0 | 0 |
| | 2 | It quickly responds to a command. | 1 | 1 | 4 | 2 | 0 | 0 |
| **Task-related** | | | | | | | | |
| Format | 1 | It displays information in an explicit manner. | 1 | 3 | 4 | 0 | 0 | 0 |
| | 2 | It clearly presents all the information to me. | 1 | 3 | 3 | 1 | 0 | 0 |
| | 3 | It protects me from information overload. | 0 | 3 | 5 | 0 | 0 | 0 |

Table 5.9b: Results of the questionnaires regarding the Quality of the System (SQ) that the participants (stakeholders) experience in their daily practice (Statements are rated in a 5 point scale: -- = strongly disagree, - = disagree, 0 = neutral, + = agree, ++ = strongly agree. n.a. = no answer).

| | | | Rating | | | | | |
|---|---|---|---|---|---|---|---|---|
| Scale | Item | Statement: The information system that I experience in my daily practice, | -- | - | 0 | + | ++ | n.a. |
| Integration | 1 | It brings together information derived from different organisations. | 1 | 2 | 3 | 2 | 0 | 0 |
| | 2 | It has sufficiently supported me to share information within my own organisation. | 1 | 3 | 3 | 1 | 0 | 0 |
| | 3 | It integrates information coming from different sources. | 2 | 2 | 4 | 0 | 0 | 0 |
| | 4 | It has sufficiently supported me to share information with other organisations. | 1 | 2 | 4 | 1 | 0 | 0 |
| | 5 | It brings all the information in one place. | 0 | 4 | 2 | 2 | 0 | 0 |
| Memory | 1 | It ensures that no important information is lost. | 0 | 0 | 5 | 3 | 0 | 0 |
| | 2 | It makes it possible to retrieve older information. | 0 | 1 | 4 | 3 | 0 | 0 |
| | 3 | It makes it possible to store data (situational knowledge). | 0 | 0 | 7 | 1 | 0 | 0 |
| Situational Awareness | 1 | It provides a good overview of the handling progress an emergency. | 2 | 2 | 3 | 1 | 0 | 0 |
| | 2 | It provides a comprehensive picture of handling of an emergency. | 2 | 2 | 3 | 1 | 0 | 0 |
| | 3 | It depicts in a comprehensive picture all the changes related to the evolution of an emergency. | 2 | 2 | 2 | 2 | 0 | 0 |
| **Perceived operational satisfaction** | | | | | | | | |
| Ease of use | 1 | It is easy to use. | 1 | 3 | 3 | 1 | 0 | 0 |
| | 2 | It requires little training time. | 1 | 2 | 2 | 3 | 0 | 0 |
| | 3 | It easily does what I want. | 0 | 1 | 6 | 1 | 0 | 0 |
| Usability | 1 | It enables me to acquire the information that I need. | 1 | 2 | 3 | 2 | 0 | 0 |
| | 2 | It is not sufficient to provide the information that I need. | 0 | 0 | 3 | 4 | 1 | 0 |
| | 3 | It is sufficient when dealing with an emergency. | 1 | 3 | 3 | 1 | 0 | 0 |

Table 5.10: Results of the questionnaires regarding SQ that the participants (stakeholders) experienced during both Scenarios (Statements are rated in a 5 point scale: -- = strongly disagree, - = disagree, 0 = neutral, + = agree, ++ = strongly agree. n.a. = no answer).

| | | | Rating | | | | | |
|---|---|---|---|---|---|---|---|---|
| Scale | Item | Statement: The information system that I experience during the field exercise, | -- | - | 0 | + | ++ | n.a. |
| **System-related** | | | | | | | | |
| Accessibility | 1 | It gives me immediate access to the information that I need. | 0 | 0 | 1 | 3 | 3 | 1 |
| | 2 | It gives me immediate access to information that is outside the scope of my organisation. | 0 | 0 | 1 | 5 | 1 | 1 |
| System reliability | 1 | It always works properly. | 0 | 1 | 4 | 2 | 0 | 1 |
| | 2 | It works reliably. | 0 | 1 | 1 | 5 | 0 | 1 |
| | 3 | It sometimes malfunctions. | 0 | 1 | 2 | 4 | 0 | 1 |
| System response time | 1 | It lets me wait for response. | 1 | 4 | 0 | 2 | 0 | 1 |
| | 2 | It quickly responds to a command. | 0 | 0 | 2 | 5 | 0 | 1 |
| **Task-related** | | | | | | | | |
| Format | 1 | It displays information in an explicit manner. | 0 | 1 | 1 | 4 | 1 | 1 |
| | 2 | It clearly presents all the information to me. | 0 | 1 | 4 | 2 | 0 | 1 |
| | 3 | It protects me from information overload. | 0 | 3 | 3 | 1 | 0 | 1 |
| Integration | 1 | It brings together information derived from different organisations. | 0 | 0 | 1 | 4 | 2 | 1 |
| | 2 | It has sufficiently supported me to share information within my own organisation. | 0 | 0 | 2 | 4 | 1 | 1 |
| | 3 | It integrates information coming from different sources. | 0 | 0 | 1 | 5 | 1 | 1 |
| | 4 | It has sufficiently supported me to share information with other organisations. | 0 | 0 | 2 | 4 | 1 | 1 |
| | 5 | It brings all the information in one place. | 0 | 0 | 2 | 4 | 1 | 1 |
| Memory | 1 | It ensures that no important information is lost. | 0 | 1 | 2 | 3 | 1 | 1 |
| | 2 | It makes it possible to retrieve older information. | 0 | 3 | 3 | 1 | 0 | 1 |
| | 3 | It makes it possible to store data (situational knowledge). | 0 | 0 | 2 | 5 | 0 | 1 |
| Situational Awareness | 1 | It provides a good overview of the handling progress of an emergency. | 0 | 0 | 2 | 4 | 1 | 1 |
| | 2 | It provides a comprehensive picture of handling an emergency. | 0 | 2 | 2 | 2 | 1 | 1 |
| | 3 | It depicts in a comprehensive picture all the changes related to the evolution of an emergency. | 0 | 0 | 2 | 5 | 0 | 1 |
| **Perceived operational satisfaction** | | | | | | | | |
| Ease of use | 1 | It is easy to use. | 0 | 0 | 1 | 5 | 1 | 1 |
| | 2 | It requires little training time. | 0 | 0 | 3 | 4 | 0 | 1 |
| | 3 | It easily does what I want. | 0 | 0 | 3 | 3 | 1 | 1 |
| Usability | 1 | It enables me to acquire the information that I need. | 0 | 0 | 0 | 6 | 1 | 1 |
| | 2 | It is not sufficient to provide the information that I need. | 0 | 5 | 1 | 1 | 0 | 1 |
| | 3 | It is sufficient when dealing with an emergency. | 0 | 0 | 4 | 3 | 0 | 1 |

For the system-related SQ attributes, three constructs were utilised: *accessibility*, *reliability* and *response time*. Regarding the system-related SQ construct *accessibility*, while the stakeholders believe that the system which they experience in their daily practice do not give them immediate access to the required information, the situation seems to be completely different after their experience with the network-centric system. In this context, the stakeholders perceive a network centric system as a facilitator of immediate access to essential information. The latter can be justified by the P2P network-based architecture of such a system, which consists of equal entities (peers or nodes) that serve both as clients and servers to other nodes and allow a large amount of information to be shared, including in real-time. The stakeholders' opinion with regard to the (SQ construct) *reliability* of the system that they experience in their daily practice is neutral or negative. However, the majority of them (except for one neutral and one negative) perceive the network-centric system experienced during this exercise as being generally reliable. Nevertheless, half of them think that a network-centric system sometimes malfunctions. This is logical given the network-based nature of the system utilised during the exercise. Sometimes network connectivity was lost, which is basically a technical issue that can be easily resolved. Regarding the SQ construct *response time* of the system that the stakeholders currently experience in their daily practice, they seem to be divided in their opinions, while half of them are neutral. After experiencing the network centric system, almost all the stakeholders (except for two neutral ones) consider that the network-centric system quickly responds to their commands. Furthermore, the majority of the stakeholders believe that this system does not let them wait for a response. Only two have responded negatively to the latter statement, which possibly has to do with network connectivity problems that they experienced during this exercise.

For the task-related SQ dimensions, four constructs have been used: *format*; *integration*; *memory* and *situational awareness*. Regarding the SQ construct *format*, the results indicate that half of the stakeholders believe that the systems used in their daily practice do not delineate information in an explicit manner, while the other half are neutral about this construct. After experiencing the network-centric system, the majority of them believe that such a system clearly depicts the required information. However, in terms of information overload, the stakeholders' judgment does not appear to be affected by any system. In this context, the stakeholders are neutral, or believe that neither the system that they experience in their daily practice nor the network-centric system experienced during this exercise do not protect them from information overload. This is related to the particular IQ construct as well as to the information rich environment of the emergency response. Regarding the SQ construct *integration*, it is clear that the stakeholders' judgment is affected by their experience with the network-centric system. In contrast to their opinions related to the systems that they experience in their daily practice, after their network-centric experience there are no stakeholders who negatively rate any statement related to integration. Most of them believe that a network-centric system enables them to acquire and integrate information from different sources, as well as to share information with multiple actors inside and across emergency response organisations. These stakeholders' opinions are in harmony with one of the tenets of network-centric working, according to which a robustly networked force improves information sharing. For the SQ construct *memory*, while almost all the stakeholders are neutral except for one positive response on whether the system that they experience in their daily practice has the potential to store data, which, in turn, supports situational knowledge; after their experience with the network-centric system, their views seem different. More precisely, although two stakeholders still remain neutral, the others perceive a network-centric system to be an enabler of data storage. Nevertheless, the stakeholders' judgment on the other two statements used for validating the SQ construct *memory* do not seem to improve after using the network-centric system. Regarding the SQ construct *situational awareness*, half of the stakeholders are dissatisfied with the ability of the system that they experience in their daily practice to create a COP, which, in turn, and in accordance with the value chain of the network-enabled capabilities, can lead to better shared understanding (awareness) of a situation (UK Ministry of Defense, 2005). Furthermore, the majority of the remaining stakeholders are neutral with regard to the capability of the system experienced in their daily practice to support SA. However, after their experience with the network-centric system, the majority of the stakeholders believe that a network-centric system provides a good overview of both the evolution of an emergency and the progress of the response operations. In particular, they consider that such a system can establish a COP, which means better information sharing compared with what they experience in their daily practice. The latter is in agreement with one of the tenets of network-centric working, which suggests that information sharing and collaboration reinforce information quality and disseminate SA. Nevertheless, two stakeholders have negatively rated only one of the statements used to validate the capability of the network-centric system to support SA. This may relate to limited training with the network system or to misinterpretation of the statement.

For the perceived operational satisfaction, two SQ constructs have been employed: *ease of use* and *usability*. Regarding the SQ construct *ease of use*, half of the stakeholders consider that the system which they experience in their daily practice is too complicated to use. Concerning the other half of the participants, three are neutral, while one considers this system to be easy to use. However, the stakeholders' judgment is completely different after experiencing the network-centric system during this exercise. In particular, except for one neutral response, all the other stakeholders perceive the network-centric system to be easy to use. Their judgment is possibly influenced by the ease of sharing of information when using this system. With regard to the training time that is required by the system practised in daily operations, the stakeholders' opinions look divided. However, for the network-centric system, they seem to have different judgment. In particular, expect for three neutral responses, all the other stakeholders believe that such a system does not require a lot of training time. The explanation for this is that, before this exercise, the stakeholders had participated in some training sessions organised by the Dutch Ministry of Infrastructure and the Environment in collaboration with the Dutch Institute of Safety. Moreover, during the exercise a learning effect was visible to the organisers of the exercise, as the stakeholders, after gaining experience with the network-centric system in Scenario 1, performed better during Scenario 2. With regard to whether the system experienced in their daily practice easily does what the stakeholders want, most of them are neutral. But, for the network-centric system, there is no stakeholder who believed that such a system does not easily perform what they require. Regarding the SQ construct *usability*, the stakeholders perceive the network-centric system used during this exercise to be more usable compared with the system that they experience in their daily practice. In particular, after using the network-centric system, all the stakeholders consider that a network-centric system can enable them to acquire all the required information, in contrast to the system that they experience daily. Furthermore, the majority of the stakeholders believe that, in contrast to a network-centric system, the traditional (hierarchical) system currently utilised for their operations is not adequate to provide the necessary information. Finally, while half of the stakeholders (most of the rest are neutral) consider that the traditional system experienced in their daily practice does not sufficiently support them to deal with emergencies, there are no stakeholders who have such an opinion about the network-centric system used during this exercise.

Overall, the SQ constructs which indicate an increase in terms of appreciation when a network centric system is used for the flood emergency response operations are: accessibility, which is classified as system-related, integration and situational awareness, which are considered as task-related and usability and ease of use, which are related to the end users' perceived operational satisfaction. The experts' (stakeholders) judgment on these SQ dimensions showed that they have recognised the added value of a network-centric system during the flood emergency response.

## 5.5 Final remarks on the empirical assessment of the effectiveness of network-centric support tools in flood emergency response.

This study has aimed to provide valuable insight regarding the added value of network-centric systems in flood emergency response operations. In this context, it evaluates the effectiveness of the network-centric support tools by acquiring and qualitatively comparing the experts' judgment regarding the system that they experience in their daily practice which is based on a hierarchy versus a network-centric system used during this exercise. But, although real emergency response professionals have participated to this exercise, there were a limited number of participants due to the busy operational environment of the emergency response and the experts' unavailability. Nevertheless, their opinions acquired during this exercise are extremely valuable, given the very limited amount of such data in the emergency response domain (Steenbruggen *et al*., 2015; Lee *et al*., 2011; Bharosa *et al*., 2011; Bharosa *et al*., 2009a; Bharosa *et al*., 2009b; Bharosa *et al*., 2009c;). Nevertheless, these experts' judgment can be seen as support of the chosen mode of inquiry, as well as a reason to continue future research in this direction.

The evaluation framework of this exercise is based on constructs associated with Information Quality (IQ) and System Quality (SQ) that have been identified through an extensive literature survey. IQ dimensions have been utilised for identifying whether a Common Operational Picture (COP) leads to a better shared understanding of a particular emergency situation, while SQ dimensions have been used for determining whether a network-centric system is capable of facilitating better information sharing and establishing a COP.

Overall, the IQ dimensions that have shown an increase in terms of appreciation by the professionals when they responded in a network-centric environment are *timeliness* and *reliability*. This can be explained by the peer to peer technology that underpins a network centric system which allows its end-users to get timely information immediately. Furthermore, the speed of information sharing that such a system offers enables its users to quickly identify the extent to which the shared information is correct and reliable. In contrast, the system that the participants (professionals) experience in their daily practice is based on a hierarchy. Such a system is underpinned by a more traditional client-server architecture that allows information sharing on a one-to-one basis and often lets its end-users wait in order to get the necessary information. During the scenarios of this exercise, a learning effect was observed. In particular, after the experience gained by the participants during Scenario 1 in which emergency response took place in a network centric environment, the stakeholders performed better in the more complex Scenario 2. Furthermore, from the results of the questionnaire used in this exercise, it can been seen that, as the complexity and the severity of the scenarios increases and the need for more information escalates, the appreciation of the experts on the quality of the information shared in a network centric environment also tends to rise.

Regarding the SQ dimensions which indicate an increase in terms of the experts' appreciation after their experience with the network-centric system, these are the system-related *accessibility*; the task-related *integration* and *situational awareness*; and the end users' perceived operational satisfaction related *usability* and *ease of use*. These SQ dimensions can also be viewed as the design principles of an adaptive emergency response system which, based on the experts' judgment of this study; they can better be supported by network-centric tools. In particular, the results on SQ dimensions first indicate that the experts perceive a network-centric system to be convenient in effectively facilitating accessibility to all the required information. Furthermore, they show that the experts seem to consider that such a system can enable them to integrate information derived from multiple sources leading to the creation of a COP which, in turn, can support them to achieve awareness about a particular flood emergency situation. Moreover, the results suggest that the experts tend to perceive a network-centric system as being easy to use, possibly due to the training sessions in which they participated before this exercise. Finally, by acknowledging the usability characteristics of such a system, the professionals tend to appreciate its usefulness in the response operations. The experts, by admitting the ease of use and usability characteristics of a network-centric system, can be considered satisfied with the operational capabilities of such a system, perhaps because the system experienced in the field exercise enabled them to more easily achieve their goals. Overall, the experts appear to appreciate the capabilities of a network-centric system. This seems reasonable, as the architecture of such a system is designed to exploit the network-enabled capabilities reflected in their value chain, according to which better networks can improve information sharing in the information domain. This in turn, can lead to a better understanding of a situation and better decisions in the cognitive domain, resulting in better actions and effects in the physical domain. On the contrary, the current architecture of the systems that the professionals experience in the flood emergency response domain is mono-disciplinary and characterised by hierarchical (top-down) information flows that mainly lead to the development of static-oriented and organisation-specific operational pictures. In brief, the main findings suggest that the experts tend to appreciate the added value of network centric systems in flood emergency response operations. However, as technology evolves and information can be derived from a variety of sources that increase with time (for example social media, cameras and sensors mounted even on unmanned aerial vehicles), there is a need to continuously improve and adapt the technical characteristics of such systems to include more functionalities.

However, the introduction of a network-centric system in the flood emergency response operations of the safety agencies is by no means an easy task. Response operations involve multiple safety agencies which are both autonomous and heterogeneous in their daily operations and they have specialised structures, policies and processes. This has traditionally contributed to the fragmented policy and organisational environment of information sharing and coordination among the multiple involved emergency agencies. Therefore, the adoption and implementation of a network-centric system by the relief agencies may require major institutional reforms. For instance, changes should be made in the information coordination architectures (network-centric instead of hierarchical). Furthermore, it should be determined which organisations and individuals must provide what information to which organisations and individuals during the response operations. The latter was a critical issue at the beginning of this field exercise, revealing that real emergency response professionals suffer from lack of information availability awareness. In particular, the professionals did not know who had the information that they required, which resulted in unnecessary research, a low information reuse rate and a waste of valuable time for the response operations. This indicates that the roles and capabilities regarding information sharing and coordination are currently set for hierarchical operations and they do not adapt to situational requirements.

Supplying the right information at the right moment to the right person and in a usable and reliable form (Endsley, 2000; Dawes *et al*., 2004) has been a major challenge in emergency response operations. Based on the experts' judgement of this exercise, it can be concluded that the network-centric technology has the potential to enable better information sharing, as well as to establish a COP and improve SA towards supporting effective decision making in flood emergency response. However, this technology itself cannot be a panacea for all the underlying organisational problems. Policy makers and emergency response chiefs often mistakenly assume that technology will solve all their problems (Dawes *et al*., 2004). Furthermore, SA is a psychological, mental and cognitive status of the end-user of a system and is not something created by a system in black box logic. Therefore, there are many factors that can influence the perception of a situation (SA), such as previous experience and individual educational background, organisational culture, goals and expectations. Harrald and Jefferson (2007) mention that the introduction of such concepts is extremely difficult and it is very likely that strategies with a short-term horizon will fail. This means that, in order, for the network-centric systems to be successfully adopted, these should be carefully introduced in different stages with consideration of the human factor and the strong involvement of the management of the emergency response organisations. Furthermore, central to the adoption strategy of such systems should be their gradual utilisation in the management of emergencies, starting with the simplest incidents and proceeding to the more complex and chaotic situations.

# 6. CONCLUSIONS.

Flood risk and disaster management require effective decision making, which in turn it requires stakeholders to be aware of the situation at hand. Furthermore, effective decisions need information within the context of the overall environment at any particular point in time along with communication and coordination of the interested actors. In particular, actors who are experts in different domains and with different institutional backgrounds should work together, interact and cooperate with one another. Situational Awareness (SA) and decision making which are associated with human mental processes, they are usually supported by effective support systems that lye in the information domain. There are different innovative avenues towards improving SA, where innovation according to Rogers (2003) denotes an idea, practice or project perceived as new by an individual or other units of adoption (group of individuals). In this context, the PhD thesis aims to identify and explore how SA can be improved towards better supporting decisions for flood risk and disaster management. For this, two explorative surveys which delineate the theoretical foundation of the thesis and two empirical studies have been conducted during the PhD research. Firstly, the thesis focuses on identifying how geodesign can contribute to the improvement of SA about water safety in a particular area of interest and also to better decision making in regards to optimal and more balanced flood safety measures taken in the context of the multi-layered water safety concept. Secondly, the thesis focuses on exploring how 3D information concepts via their information and communication potential can improve SA which in turn can support better decisions in the context of flood risk management and emergency preparedness. Thirdly, this thesis focuses on investigating how the traditional way of information sharing among the safety agencies can be improved through the introduction of a network centric approach. Information and system quality constructs which better fit the needs of the safety agencies towards improving SA; they are instrumental in this study.

## 6.1 Conclusions of explorative studies.

The theoretical foundation of the thesis is delineated by two explorative studies related to SA, flood risk and disaster management: a) a literature review on multi-layered water safety and theoretical systematization of the latter concept in a geodesign framework towards improving situational awareness, collaboration and decision making; b) a literature survey which explores the contribution of a common operational picture in improving SA for efficient emergency response operations. In the following sections, the main findings are highlighted and their implications are discussed.

### 6.1.1 Geodesign the multi-layered water safety.

Chapter 2 has provided an extensive literature survey on flood safety and practices in Europe with focus on the Dutch perspective which is termed multi-layered water safety. Given that floods are the most dominant natural hazards in Europe, the Dutch multi-tier concept which is an integrated approach to flood risk management based on recommendations for flood protection such as the EU flood risk directive and the UNISDR Hyogo framework, it purports to reinforce flood protection and operationalize flood resilience through three safety layers: prevention (layer 1) for reduction of flood risk probability; spatial solutions and preparation for emergency response (layers 2 and 3) towards minimizing the consequences in case of a flood event.

A multi-layer safety system resembles more a parallel than a serial system, because failure of the safety measures corresponding to one layer does not mean failure of the whole system. Nevertheless, such a system is not exactly a parallel one because in case of failure of the preventive measures, these which correspond to layers 2 and 3 can reduce the damage but not completely eradicate it. In this context, what is considered failure in layers 2 and 3 has to explicitly be agreed at the policy level. The latter will support optimal allocation of weights between the three layers of the multi-layered safety concept.

A primary concern for the multi-layered safety concept is the inventory of the required information. During this chapter an attempt to provide a comprehensive overview of the needed information is made. However, questionnaire surveys with the participation of the involved actors to this multi-tier safety concept, they can shed more light regarding the information requirements of each safety layer. In this way, overlaps in terms of information needs between the three safety layers can be identified as well. Generally, the information requirements of the multi-layered safety concept can be determined as semi-static and model information. Nevertheless, when measures such as preventive organized evacuations are decided in the context of the emergency response layer, their implementation needs dynamic information. Almost all of the required information has a spatial (geographic) component.

The value of this chapter in relation to previous research is that it theoretically orchestrates and systematize the multi-layered water safety concept in a geodesign-oriented methodological framework that motivates participation and enables interdisciplinary collaboration, determines the roles of the different actors, employs all the geographic information and knowledge, promotes communication of the situation at hand, allows the comprehension and evaluation of proposals and permits feedback when required. The systematization of the multi-layered safety concept in a geodesign framework can efficiently support decision making and it can create surplus value for the local society, economy and environment through its different and iterative feedback driven processes. It underpins trial and error logic so that all stakeholders can assess the impact of the safety measures resulting from their own points of view. In this manner, the stakeholders can achieve SA regarding the water safety status in an area of interest. Furthermore, they can identify overlaps in terms of the proposed measures which in turn can create maximum consensus between them leading to the selection of the most desirable and balanced water safety measures across different spatial and temporal scales that consider their cost efficiency, their impact on the environment and the values of the people at place.

### 6.1.2 A common operational picture in support of SA for efficient emergency response.

Chapter 4 provided an overview of novel information concepts such as network centric information sharing which can contribute to the improvement of cooperation and SA during emergency response operations through the deployment of a COP. In particular, the network centric concept which is rooted in the military domain, it can be seen as a vehicle for better information sharing which in turn can improve decision making and support enhanced spatiotemporal organization of resources and assets in the complex and dynamic environment of emergency response. In essence, network centric information systems enable networking of emergency response stakeholders towards achieving operational effectiveness as well as integration of new information derived from different sources with other knowledge. Furthermore, the network centric concept enables unobstructed flow of information and knowledge among the entirety of the emergency response administrative structure. Instead of information passed vertically within the command chain based on the logic of a hierarchical structure of information sharing where it may be lost or even discarded as useless, this is circulated freely among all the involved emergency response actors. However, in the information-rich and increasingly fluid environment of the emergency response, network centric systems should support both the information requirements of the emergency services and the cognitive and psychological capabilities of the involved actors taking into account that humans are limited by working memory and attention. Furthermore, attention should be paid towards preventing information overload given that not all the information is relevant to the tasks of the different safety agencies.

Through a network centric system, the same information is made available to everyone at the same time and a COP simply provides knowledge regarding “what is going on around you” in a single identical display. Based on Endsley’s definition of SA (Endsley, 1988), the latter is distinguished by three levels. Firstly, SA is about perceiving critical factors i.e. status, attributes and dynamics of relevant elements in the environment (Level 1); secondly it is about understanding the meaning of these elements after being synthesized, in light of the decision makers’ goal (Level 2); and thirdly at the highest level (Level 3) SA is about predicting of what will occur with the system in the near future. Furthermore, three components delineate a situation: information about the emergency situation; information related to the environment of the emergency (location awareness) and information about the emergency services involved in the response operations.

Communication processes can be divided in three related domains: the information domain which is about relevant data in context; the cognitive domain that is related to human mental processes and the physical domain which focuses on activities in the real world. Network centric systems can enable better information sharing through the deployment of a COP in the information domain which in turn it can support all the responding units to achieve the same understanding (shared situational awareness) of information and emergency status when conducting operations. Therefore, a network centric system can be seen as an emergency response tool with an added value not only in effective sharing of information but also in comprehending the real meaning and the temporal value of the needed and used information for operations, communication and coordination of emergency services. Furthermore, network centric systems and a COP are basic components for achieving improved SA. In the cognitive domain, organizations, processes and stakeholders irrigated by better shared SA and aided by technology can exhibit efficient decision making behaviors with better actions and effects in the physical domain.

The concept of network centricity can be adapted from the military field and it can be applied for emergency situations tailored to their specific conditions, creating a surplus value for the response operations. Furthermore, it can provide the attributes and flexibility needed by adaptive management which according to Wiese (2006) it can be the most effective management approach to potential disasters. However, the successful adoption of such a concept requires its careful introduction in different stages based on a maturity model and respecting that short term strategies which assume that shared SA will be easily achieved are doomed to fail. In addition, it requires training of the emergency response stakeholders in order to overcome potential lack of knowledge.

## 6.2 Conclusions of empirical studies.

The empirical part of the PhD thesis is consisted of two studies: a) a case study for exploring the usefulness of virtual 3D city models in flood risk communication and management; and conceptualization of a 3D information system based on virtual 3D city models as a step towards defining a system framework for risk management and emergency preparedness; b) a field experiment in order to measure the effectiveness of network centric support tools for flood emergency response. The scientific contribution of the empirical part of the PhD thesis is that it builds on existing theories and methodologies that apply in risk management and emergency response. The novel information concepts presented in the empirical studies of this thesis, they can be utilized in the design of flood risk management and emergency response systems. The underlying assumption is that the added value service of such concepts is the improvement of SA.

### 6.2.1 3D information concepts for flood risk management and emergency preparedness.

Chapter 3 through a series of steps (literature review, case study and model conceptualization) has introduced novel information concepts that can contribute in the improvement of SA, communication, perception, management of flood risks and emergency preparedness. In order to explore the added value service of the virtual 3D city models in risk communication and management, a case study in Heerhugowaard area in the Netherlands has been set up. The virtual 3D city model that has been developed, it provides dynamic rule-driven 3D renderings of the flood risk components on the basis of a source-pathway-receptor (risk) model and it delineates the geometrical and appearance characteristics of the city objects. In particular, this model provides concise information (graphic and non-graphic), enabling visual data mining, analysis and navigation; and facilitate interaction which urge the stakeholders to play an active role in the decision making process for managing flood risks. In short, the virtual 3D city model developed in this chapter, it offers dynamic 3D Common Operational Pictures (COPs) or 4D COPs taking into account the temporal variable (time), purporting to improve SA among the stakeholders regarding flood risks in the area of interest. Furthermore, it enables the involved actors to examine and judge their alternatives and visually assess their implications by modifying the city model parameters in real time through procedurally defined rules. In this way, transparency and trust among the stakeholders can be achieved and collaboration can be facilitated. Furthermore, the cognitive capabilities of the participants are reinforced towards exerting their influence during the decision making process. Nevertheless, the quality of the representations of the 3D city objects is directly related to the availability and accuracy of data.

Virtual 3D city models can be seen as excellent media for integrating, maintaining, presenting, distributing and communicating risk related geo-information in an understandable manner close to what the stakeholders are used to view in the real (3D) world. This has also been confirmed by the extensive literature survey that has been conducted in this chapter. However, in emergency preparedness where stakeholders should develop plans such as internal and/or external evacuation routes, topological and semantic information regarding the 3D city objects and their components are required. This information intends to satisfy the needs of the safety agencies for querying and analyzing the 3D city models. Furthermore, a key aspect for efficient risk management and emergency preparedness is the capability of the involved agencies and actors to inter-operate i.e. work together. The fact that the required data are derived from different sources and are often in multiple formats, it calls for adopting a “common language” between the different safety organizations which has the potential to overcome this data fragmentation. In this context, a 3D information system based on virtual 3D city models and extended by existing open international standards from GIS and BIM domains such as CityGML and IFC respectively, it has conceptually been deployed and presented aiming to make a step towards defining a system framework for risk management and emergency preparedness.

The 3D information system conceptualized in this chapter, it overcomes limitations of the virtual 3D city model developed for Heerhugowaard area purporting to enable semantic interoperability during the risk management and emergency preparedness. In addition, it aims to provide the involved actors with not only navigation functionalities but also easy-to-use querying and analysis capabilities via the standards employed by the conceptual system. In particular, these standards offer semantic, topological and thematic information besides the geometrical and appearance characteristics of the 3D city models. Furthermore, the 3D information system via the detailed description of the physical and functional characteristics and relations of the city objects at the macro (city) and micro (facility) scale, it aspires to allow the development of alternative external and internal building evacuation routes for management of the residual risks and emergency preparedness. This 3D information system selects the CityGML data standard from the GIS domain as the target model for the representation of the complex urban space since it is more capable of modelling objects at the macro scale using five distinct LoDs while BIM data in IFC classes are designed for representing information in a very detailed way at the micro scale being a precious source of information in regards to city facilities with up-to-date information regarding their status and structures. During this chapter, a literature survey has demonstrated that work has already been done in the direction of the conversion of BIM data in IFC format to CityGML format. Nevertheless, the CityGML LoD in which the city objects are eventually represented depends on the accuracy and availability of the needed data. Moreover, the construction of CityGML LoDs is a challenging task and the collection of semantics and the check of the validity of the city objects' geometries are demanding in terms of time and effort.

Governments and safety agencies should consider the adoption and utilization of 3D information systems based on virtual 3D city models in flood risk management and emergency preparedness since they form an ambitious concept that has the potential to support both information and communication processes towards building capacity for participatory risk minimization, emergency preparedness and response. In particular, such a system it can provide the stakeholders with a level field for equal access to information, thus facilitating the cognition of risk related situations and simultaneously increasing transparency, trust and cross-disciplinary collaboration for better decisions with better effects in the physical domain (real world). The overlapping BIM fields indicate an opportunity for collaboration, knowledge transfer and integration of the roles of all the involved actors at the facilities' level. Nevertheless, collaboration neither can be imposed nor can work being just a notion in the context of a risk related institutional framework. Virtual 3D city models-based information systems can facilitate collaboration but for its practice, alterations in institutional behaviors are required.

### 6.2.2 Field exercise for the assessment of the effectiveness of network centric support tools in flood emergency response.

Chapter 5 through a series of steps (literature review, field exercise with realistic flood scenarios and questionnaires for acquisition of experts' judgment) has assessed and reported the results of an empirical analysis regarding the value added service of network centric systems in flood emergency response. In particular, it has evaluated the effectiveness of the network centric support tools by acquiring and qualitatively comparing the experts' judgment regarding the system that they experience in their daily practice which is based on hierarchy vs. a network centric system used during this exercise. The current systems in the emergency response domain are traditionally mono-disciplinary based, that allow top-down and bottom-up (hierarchical) information flows and create static agency-specific operational pictures. On the contrary, the architecture of the network centric system used during the exercise, it focuses on facilitating horizontal information sharing and communication among peers. Furthermore, it is designed to exploit the network enabled capabilities reflected in their value chain according to which better networks can improve information sharing in the information domain, which in turn can lead to better understanding of a situation and better decisions in the cognitive domain driving to better actions and effects in the physical domain.

In the field exercise that has been set-up during this thesis; real emergency response professionals have participated. Although, there were only few participants due to the demanding operational environment of the emergency response and the professionals' unavailability, the experts' opinions acquired during this exercise are extremely valuable given the very limited amount of such data in the emergency response domain. The evaluation framework of this exercise bases on constructs about Information Quality (IQ) and System Quality (SQ) that have been identified through extensive literature survey. In order to identify whether a COP leads to better shared awareness of a particular situation, IQ constructs have been employed, while for determining whether a network centric system can enable better information sharing and generate a COP, SQ constructs have been used. IQ is associated with attributes of information and how this can satisfy the needs of the end-users. SQ focuses on system-related; task-related and perceived operational satisfaction dimensions. Both, IQ and

SQ are requisites for creating a COP and gaining maximum advantage from the potential of shared SA.

Regarding the *IQ dimensions* that have shown an increase in terms of appreciation by the professionals after their experience with the network centric system, these are *timeliness* and *reliability*. This is strongly related to the peer to peer technology that underpins a network centric system which enables its end-users to get timely information at once. Furthermore, the speed of information sharing offered by such a system, it enables its users to quickly identify the extent to which the shared information is correct and trustful in contrast to the system that the professionals experience in their daily practice that often lets its end-users to wait for acquiring the needed information. In particular, the system currently used by the involved actors is based on hierarchy and is underpinned by a more traditional client-server architecture that allows information sharing on a one-to-one basis. During the field exercise of this thesis, a learning effect has been observed due to the fact that the participants (professionals) after the experience gained in the first scenario where emergency response has been carried out in a network centric environment, they have performed better in the second and more complex scenario. From the experts' judgment that is reflected in the questionnaires' results of the exercise, it can be deduced that as the complexity and the severeness of the scenarios escalate and the need for more information increases, the appreciation of the professionals on the quality of the information shared in a network centric environment also tends to rise.

Regarding the *SQ dimensions* which have shown an increase in terms of experts' appreciation after their experience with the network centric system, these are the system-related *accessibility*; the task-related *integration* and *situational awareness*; and the end users' perceived operational satisfaction related *usability* and *ease of use*. These SQ dimensions can also be viewed as the design principles of an adaptive emergency response system framework which based on the experts' judgment of this study; they can better be supported by network centric tools. The results on SQ dimensions indicate that the experts perceive a network centric system as convenient in effectively facilitating accessibility to all the required information. Furthermore, the results suggest that the experts seem to recognize that a network centric system can allow them to integrate information derived from multiple sources towards creating a COP which in turn can support them to achieve awareness about a particular flood situation. In addition, the results show that the experts tend to consider a network centric system as easy to use possibly due to training sessions held before this exercise. Overall, the involved professionals seem to appreciate the usefulness and capabilities of a network centric system in emergency response operations.

Based on the experts' judgement of the field experiment of this thesis, it can be concluded that the network centric systems have the potential to enable better information sharing towards generating a COP and improving SA which in turn can better support effective decision making in flood emergency response. However, the introduction of a network centric system in the emergency response services is by no means an easy task given the multiple safety agencies involved in the response operations. In particular, these agencies are both autonomous and heterogeneous in their daily operations and they have specialized structures, policies and processes, fact that traditionally contributes to the fragmented policy and organizational environment of information sharing and coordination among the emergency services. The adoption and implementation of a network centric system by the relief agencies may require major institutional reforms. The existing information systems have to be critically redesigned based on novel information coordination architectures (network-centric instead of hierarchical) and the data management and the current work methods should be reconsidered towards achieving collective intelligence among the safety agencies grounded on real-time information distribution. Furthermore, it should be determined which organizations and actors must provide what information to which organizations and actors during the response operations. The latter has been a critical issue at the beginning of the field exercise of this thesis revealing that real emergency response professionals suffer from lack of information availability awareness. More precisely, the professionals did not know who had the information that they required which resulted in unnecessary research, low information reuse rate and waste of valuable time for the response operations. This confirms that the roles and capabilities regarding information sharing and coordination are currently set for hierarchical operations and they do not adapt to situational requirements.

## 6.3 Recommendations for future work.

The theoretical systematization of the multi-layered safety concept in a geodesign framework is very promising towards improving collaboration, SA and decision making for achieving optimal flood safety measures that take into account their economic efficiency, their impact on the environment, the local circumstances and the values of the people at place. Further research is required for transferring the implementation of geodesign on multi-layered safety from theory to practice. The geodesigned multi-layered water safety concept should be experimented, tested and experienced in workshop settings and in different contexts engaging safety agencies for identifying optimal measures. Furthermore, during such workshops, technology driven tools which empower stakeholders by enabling their participation in the decision making should be employed and assessed in the context of practicing geodesign for arriving at sustainable arrangements regarding water safety.

The 3D information system delineated in this thesis is based on virtual 3D city models and is extended by open existing international standards from GIS and BIM domains and it forms an ambitious concept proposal towards supporting information and communication processes for participatory flood risk minimization, emergency preparedness and response. For the integration and seamless exchange of massive risk related information derived from heterogeneous and distributed sources, agreed standards such as these employed in the 3D information system conceptualized in this thesis (CityGML from GIS domain and IFC classes from BIM domain) should be followed. However, as risk related data can be under the control of different ownership and rights, a legal framework that must govern these data sets must be determined at the political level, following discussions between stakeholders including the public, the experts and the decision makers. Furthermore, for fully setting the framework of a system for risk management as well as for extending the potential and the academic and institutional standing of the proposed conceptual 3D information system, further investigations in collaboration with interested stakeholders are needed. The conceptual form of the 3D information system can be the basis for its operationalization in a real proof of concept environment. This would make it possible to confirm and extend the findings of this thesis in regards to the added value service of 3D information systems in flood risk management and emergency preparedness.

An extensive literature survey from different domains and perspectives showed that the utilization of network centric systems and a common operational picture are promising instruments for improving SA towards smart emergency response. Further research is required towards identifying and overcoming the legal and institutional implications of employing such novel concepts for information sharing between the involved safety organizations.

During the field exercise of this thesis, the participants were real emergency response professionals. Although the experts' participation was limited due to the busy operational environment of the emergency response and their unavailability, the opinions acquired during the exercise are really valuable given the very limited amount of such data in the emergency response domain. Furthermore, as research on the success of information systems in the civic safety sector which targets the public good is relatively scarce and empirical support is almost non-existent, the experts' judgment of this thesis can be seen as support of the chosen mode of inquiry as well as a reason to continue future research in this direction. In short, the main findings of the field exercise of this thesis indicate that the experts tend to appreciate the added value service of network centric systems in flood emergency response operations. As the effectiveness of network centric support tools has been assessed in the context of simulated floods scenarios, a further direction could be their utilization in real flood emergencies' response environment. In this way, the findings of this thesis could be verified and extended. The results of the field exercise of this thesis contribute to the research and development of novel information systems based on network centric technology for emergency response. However, as technology evolves and information can be derived from a variety of sources that increase with time such as social media, cameras and sensors mounted even on unmanned aerial vehicles (drones), there is a need to continuously improve and adapt the technical characteristics of emergency response systems to include more functionalities. Such functionalities can allow new data sets to be integrated in a more sophisticated COP which in turn can lead to enhanced SA.

The findings of this thesis form a step towards developing and adopting innovative information systems that can efficiently support information sharing, communication and cooperation among the safety agencies and professionals based on improved SA for efficient flood risk management, flood incident and large-scale flood disaster response operations. However, a system itself cannot be the panacea for all the underlying organizational problems. Moreover, SA is not something created by a system in black box logic. SA is related to the psychological, mental and cognitive status of the end user of a system. In addition, previous experiences, individual educational backgrounds, organizational culture, goals and expectations can influence the achievement of shared SA. Therefore, there are many factors that can affect the development of SA. In order the introduction of novel information systems in safety agencies to be successful, it should be done carefully and in different stages with consideration of human factor and strong involvement of the management of these organizations.

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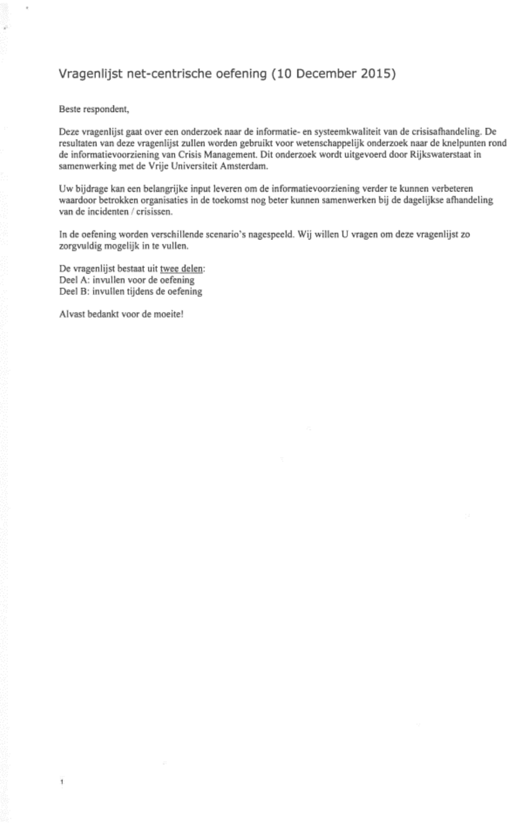
# APPENDIX A: QUESTIONNAIRES ANSWERED BY THE PARTICIPANTS OF THE FIELD EXERCISE.

The appendix provides the questionnaires (in Dutch) that have been used during the field exercise of this thesis (chapter 5). The questionnaires have been answered by the eight participants of the field exercise who were well trained emergency response professionals. Initially, the questionnaire briefly introduces the participant to its purpose and content. Thereafter, it includes general questions regarding age, gender, organization, professional experience and educational background of the participants. Then the questionnaire is consisted of two parts. The first part aims to acquire the opinion of the professionals in regards to the quality of the information and also about the quality of the systems that they experience in their daily practice. This part should be answered before the start of the flood scenarios of the field exercise. The second part purports to acquire the professionals' appreciation on information quality and system quality dimensions based on the experience gained through their participation in this exercise. In this context, the participants are required to rate statements in a five point scale (from stongly disagree to stronlgy agree) about the quality of the information experienced during the first scenario as well as about the quality of the information experienced during the second scenario. Furthermore, they are asked to rate statements in a five point scale concerning the quality of the system experienced during both the scenarios. Below, the questionnaires answered by the eight respondents of the field exercise are presented in scanned form.

*Respondent 1:*



## Vragenlijst net-centrische oefening (10 December 2015)

Beste respondent,

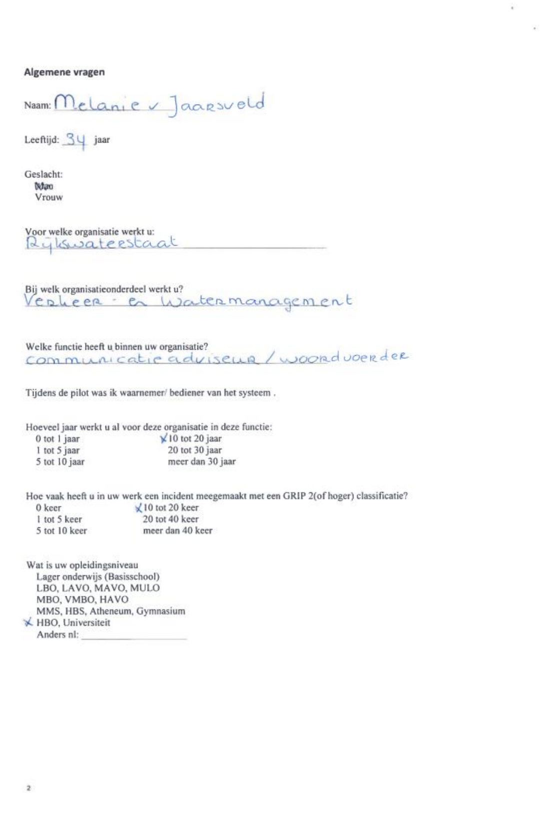
Deze vragenlijst gaat over een onderzoek naar de informatie- en systeemkwaliteit van de crisisafhandeling. De resultaten van deze vragenlijst zullen worden gebruikt voor wetenschappelijk onderzoek naar de knelpunten rond de informatievoorziening van Crisis Management. Dit onderzoek wordt uitgevoerd door Rijkswaterstaat in samenwerking met de Vrije Universiteit Amsterdam.

Uw bijdrage kan een belangrijke input leveren om de informatievoorziening verder te kunnen verbeteren waardoor betrokken organisaties in de toekomst nog beter kunnen samenwerken bij de dagelijkse afhandeling van de incidenten / crisissen.

In de oefening worden verschillende scenario's nagespeeld. Wij willen U vragen om deze vragenlijst zo zorgvuldig mogelijk in te vullen.

De vragenlijst bestaat uit twee delen:
Deel A: invullen voor de oefening
Deel B: invullen tijdens de oefening

Alvast bedankt voor de moeite!



**Algemene vragen**

Naam: Melanie v Jaarsveld

Leeftijd: 34 jaar

Geslacht:
~~Man~~
Vrouw

Voor welke organisatie werkt u:
Rijkswaterstaat

Bij welk organisatieonderdeel werkt u?
Verkeer- en Watermanagement

Welke functie heeft u binnen uw organisatie?
communicatie adviseur / woordvoerder

Tijdens de pilot was ik waarnemer/ bediener van het systeem .

Hoeveel jaar werkt u al voor deze organisatie in deze functie:
0 tot 1 jaar
1 tot 5 jaar
5 tot 10 jaar
[✓ 10 tot 20 jaar]
20 tot 30 jaar
meer dan 30 jaar

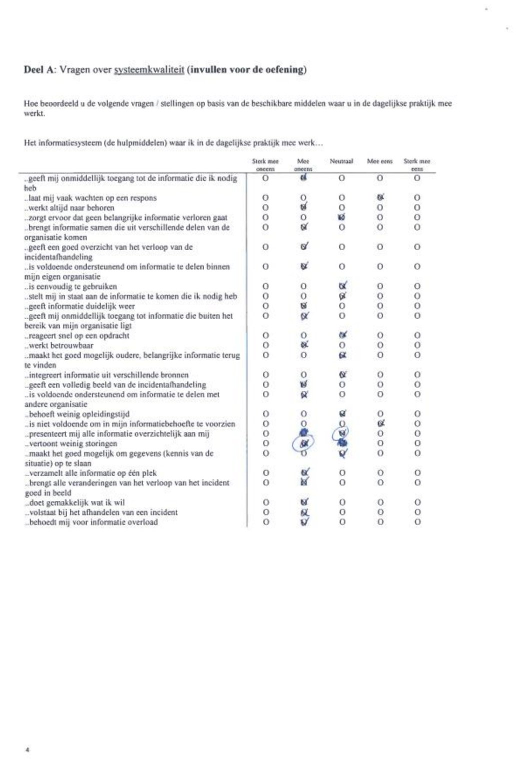
Hoe vaak heeft u in uw werk een incident meegemaakt met een GRIP 2(of hoger) classificatie?
0 keer
1 tot 5 keer
5 tot 10 keer
[✓ 10 tot 20 keer]
20 tot 40 keer
meer dan 40 keer

Wat is uw opleidingsniveau
Lager onderwijs (Basisschool)
LBO, LAVO, MAVO, MULO
MBO, VMBO, HAVO
MMS, HBS, Atheneum, Gymnasium
[✓ HBO, Universiteit]
Anders nl: ____________

**Deel A**: Vragen over informatiekwaliteit **(invullen voor de oefening)**

Hoe beoordeeld u de volgende vragen / stellingen op basis van de tools / systemen waar u in de dagelijkse praktijk mee werkt.

| | Sterk mee oneens | Mee oneens | Neutraal | Mee eens | Sterk mee eens |
|---|---|---|---|---|---|
| De informatie die met mij wordt gedeeld is up to date | ○ | ○ | ☑ | ○ | ○ |
| De informatie die met mij wordt gedeeld is correct | ○ | ○ | ☑ | ○ | ○ |
| De informatie die mij wordt aangeboden is compleet | ○ | ☑ | ○ | ○ | ○ |
| De informatie die ik krijg aangeboden van anderen is relevant (direct bruikbaar) | ○ | ○ | ○ | ☑ | ○ |
| De informatie die ik van anderen krijg is tegenstrijdig | ○ | ○ | ○ | ☑ | ○ |
| Over het algemeen is de informatie die mij wordt aangeboden teveel, vergeleken met wat ik nodig heb | ☑ | ○ | ○ | ○ | ○ |
| Het is voor mij onduidelijk of de informatie die ik van anderen krijg betrouwbaar is | ○ | ○ | ○ | ☑ | ○ |
| Ik krijg verouderde informatie aangeboden | ○ | ○ | ○ | ☑ | ○ |
| De informatie die mij wordt aangeboden bevat foutieve informatie | ○ | ○ | ☑ | ○ | ○ |
| De informatie die mij wordt aangeboden is onvolledig | ○ | ○ | ○ | ☑ | ○ |
| Ik ontvang veel informatie die niet nodig is voor het uitvoeren van mijn taken | ○ | ☑ | ○ | ○ | ○ |
| De informatie die ik krijg wijkt af van informatie die ik al had | ○ | ○ | ○ | ☑ | ○ |
| Ik kan alle informatie die ik krijg niet bijhouden | ○ | ○ | ☑ | ○ | ○ |
| Ik ben in staat om de informatie van de melding te verifiëren | ○ | ○ | ○ | ☑ | ○ |
| Ik word tijdig geïnformeerd over een incident | ○ | ☑ | ○ | ○ | ○ |
| De informatie die ik ontvang is onjuist | ○ | ○ | ☑ | ○ | ○ |
| Er ontbreekt detail in de informatie die anderen met mij delen | ○ | ○ | ○ | ☑ | ○ |
| Ik ontvang overbodige informatie | ○ | ☑ | ○ | ○ | ○ |
| Meldingen bevatten tegenstrijdige berichten | ○ | ○ | ○ | ☑ | ○ |
| De informatie die ik krijg is te summier | ○ | ○ | ○ | ☑ | ○ |
| Ik maak gebruik van eigen beschikbare informatie om meldingen te verifiëren | ○ | ○ | ○ | ○ | ☑ |



**Deel A**: Vragen over systeemkwaliteit **(invullen voor de oefening)**

Hoe beoordeeld u de volgende vragen / stellingen op basis van de beschikbare middelen waar u in de dagelijkse praktijk mee werkt.

Het informatiesysteem (de hulpmiddelen) waar ik in de dagelijkse praktijk mee werk…

| | Sterk mee oneens | Mee oneens | Neutraal | Mee eens | Sterk mee eens |
|---|---|---|---|---|---|
| ..geeft mij onmiddellijk toegang tot de informatie die ik nodig heb | ○ | ☑ | ○ | ○ | ○ |
| ..laat mij vaak wachten op een respons | ○ | ○ | ○ | ☑ | ○ |
| ..werkt altijd naar behoren | ○ | ☑ | ○ | ○ | ○ |
| ..zorgt ervoor dat geen belangrijke informatie verloren gaat | ○ | ○ | ☑ | ○ | ○ |
| ..brengt informatie samen die uit verschillende delen van de organisatie komen | ○ | ☑ | ○ | ○ | ○ |
| ..geeft een goed overzicht van het verloop van de incidentafhandeling | ○ | ☑ | ○ | ○ | ○ |
| ..is voldoende ondersteunend om informatie te delen binnen mijn eigen organisatie | ○ | ☑ | ○ | ○ | ○ |
| ..is eenvoudig te gebruiken | ○ | ○ | ☑ | ○ | ○ |
| ..stelt mij in staat aan de informatie te komen die ik nodig heb | ○ | ○ | ☑ | ○ | ○ |
| ..geeft informatie duidelijk weer | ○ | ☑ | ○ | ○ | ○ |
| ..geeft mij onmiddellijk toegang tot informatie die buiten het bereik van mijn organisatie ligt | ○ | ☑ | ○ | ○ | ○ |
| ..reageert snel op een opdracht | ○ | ○ | ☑ | ○ | ○ |
| ..werkt betrouwbaar | ○ | ☑ | ○ | ○ | ○ |
| ..maakt het goed mogelijk oudere, belangrijke informatie terug te vinden | ○ | ○ | ☑ | ○ | ○ |
| ..integreert informatie uit verschillende bronnen | ○ | ○ | ☑ | ○ | ○ |
| ..geeft een volledig beeld van de incidentafhandeling | ○ | ☑ | ○ | ○ | ○ |
| ..is voldoende ondersteunend om informatie te delen met andere organisatie | ○ | ☑ | ○ | ○ | ○ |
| ..behoeft weinig opleidingstijd | ○ | ○ | ☑ | ○ | ○ |
| ..is niet voldoende om in mijn informatiebehoefte te voorzien | ○ | ○ | ○ | ☑ | ○ |
| ..presenteert mij alle informatie overzichtelijk aan mij | ○ | ● | ☑ | ○ | ○ |
| ..vertoont weinig storingen | ○ | ☑ | ● | ○ | ○ |
| ..maakt het goed mogelijk om gegevens (kennis van de situatie) op te slaan | ○ | ○ | ☑ | ○ | ○ |
| ..verzamelt alle informatie op één plek | ○ | ☑ | ○ | ○ | ○ |
| ..brengt alle veranderingen van het verloop van het incident goed in beeld | ○ | ☑ | ○ | ○ | ○ |
| ..doet gemakkelijk wat ik wil | ○ | ☑ | ○ | ○ | ○ |
| ..volstaat bij het afhandelen van een incident | ○ | ☑ | ○ | ○ | ○ |
| ..behoedt mij voor informatie overload | ○ | ☑ | ○ | ○ | ○ |

## Deel B: Vragen over informatiekwaliteit (einde ochtend)

De volgende vragen / stellingen gaan over uw algemene indruk van de *informatiekwaliteit* tijdens de oefenscenario's.

| | Sterk mee oneens | Mee oneens | Neutraal | Mee eens | Sterk mee eens |
|---|---|---|---|---|---|
| De informatie die met mij wordt gedeeld is up to date | ○ | ○ | ● | ○ | ○ |
| De informatie die met mij wordt gedeeld is correct | ○ | ○ | ● | ○ | ○ |
| De informatie die mij wordt aangeboden is compleet | ○ | ○ | ● | ○ | ○ |
| De informatie die ik krijg aangeboden van anderen is relevant (direct bruikbaar) | ○ | ○ | ○ | ○ | ● |
| De informatie die ik van anderen krijg is tegenstrijdig | ○ | ○ | ● | ○ | ○ |
| Over het algemeen is de informatie die mij wordt aangeboden teveel, vergeleken met wat ik nodig heb | ○ | ● | ○ | ○ | ○ |
| Het is voor mij onduidelijk of de informatie die ik van anderen krijg betrouwbaar is | ○ | ○ | ○ | ● | ○ |
| Ik krijg verouderde informatie aangeboden | ○ | ○ | ● | ○ | ○ |
| De informatie die mij wordt aangeboden bevat foutieve informatie | ○ | ○ | ● | ○ | ○ |
| De informatie die mij wordt aangeboden is onvolledig | ○ | ● | ○ | ○ | ○ |
| Ik ontvang veel informatie die niet nodig is voor het uitvoeren van mijn taken | ○ | ● | ○ | ○ | ○ |
| De informatie die ik krijg wijkt af van informatie die ik al had | ○ | ○ | ● | ○ | ○ |
| Ik kan alle informatie die ik krijg niet bijhouden | ○ | ● | ○ | ○ | ○ |
| Ik ben in staat om de informatie van de melding te verifiëren | ○ | ○ | ○ | ○ | ● |
| Ik word tijdig geïnformeerd over een incident | ○ | ○ | ● | ○ | ○ |
| De informatie die ik ontvang is onjuist | ○ | ○ | ● | ○ | ○ |
| Er ontbreekt detail in de informatie die anderen met mij delen | ○ | ● | ○ | ○ | ○ |
| Ik ontvang overbodige informatie | ○ | ● | ○ | ○ | ○ |
| Meldingen bevatten tegenstrijdige berichten | ○ | ○ | ○ | ● | ○ |
| De informatie die ik krijg is te summier | ○ | ○ | ○ | ● | ○ |
| Ik maak gebruik van eigen beschikbare informatie om meldingen te verifiëren | ○ | ○ | ○ | ○ | ● |

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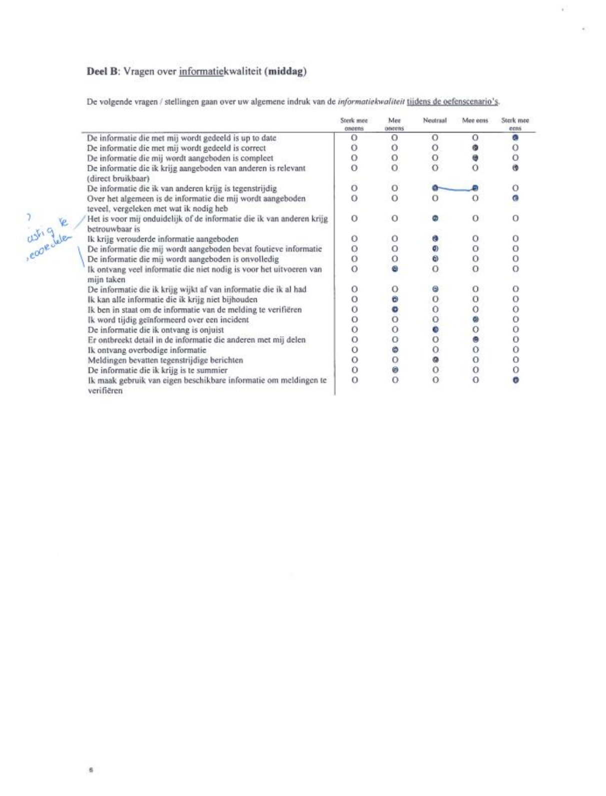


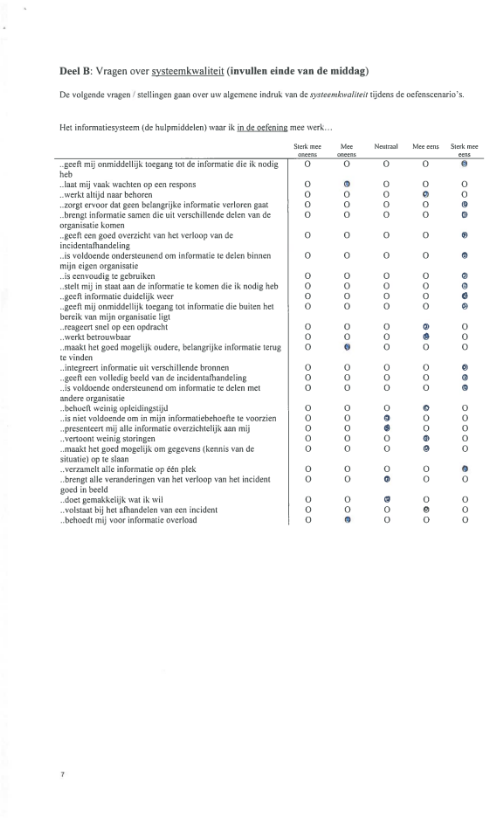
## Deel B: Vragen over informatiekwaliteit (middag)

De volgende vragen / stellingen gaan over uw algemene indruk van de *informatiekwaliteit* tijdens de oefenscenario's.

| | Sterk mee oneens | Mee oneens | Neutraal | Mee eens | Sterk mee eens |
|---|---|---|---|---|---|
| De informatie die met mij wordt gedeeld is up to date | ○ | ○ | ○ | ○ | ● |
| De informatie die met mij wordt gedeeld is correct | ○ | ○ | ○ | ● | ○ |
| De informatie die mij wordt aangeboden is compleet | ○ | ○ | ○ | ● | ○ |
| De informatie die ik krijg aangeboden van anderen is relevant (direct bruikbaar) | ○ | ○ | ○ | ○ | ● |
| De informatie die ik van anderen krijg is tegenstrijdig | ○ | ○ | ● | ● | ○ |
| Over het algemeen is de informatie die mij wordt aangeboden teveel, vergeleken met wat ik nodig heb | ○ | ○ | ○ | ○ | ● |
| Het is voor mij onduidelijk of de informatie die ik van anderen krijg betrouwbaar is | ○ | ○ | ● | ○ | ○ |
| Ik krijg verouderde informatie aangeboden | ○ | ○ | ● | ○ | ○ |
| De informatie die mij wordt aangeboden bevat foutieve informatie | ○ | ○ | ● | ○ | ○ |
| De informatie die mij wordt aangeboden is onvolledig | ○ | ○ | ● | ○ | ○ |
| Ik ontvang veel informatie die niet nodig is voor het uitvoeren van mijn taken | ○ | ● | ○ | ○ | ○ |
| De informatie die ik krijg wijkt af van informatie die ik al had | ○ | ○ | ● | ○ | ○ |
| Ik kan alle informatie die ik krijg niet bijhouden | ○ | ● | ○ | ○ | ○ |
| Ik ben in staat om de informatie van de melding te verifiëren | ○ | ● | ○ | ○ | ○ |
| Ik word tijdig geïnformeerd over een incident | ○ | ○ | ○ | ● | ○ |
| De informatie die ik ontvang is onjuist | ○ | ○ | ● | ○ | ○ |
| Er ontbreekt detail in de informatie die anderen met mij delen | ○ | ○ | ○ | ● | ○ |
| Ik ontvang overbodige informatie | ○ | ● | ○ | ○ | ○ |
| Meldingen bevatten tegenstrijdige berichten | ○ | ○ | ● | ○ | ○ |
| De informatie die ik krijg is te summier | ○ | ● | ○ | ○ | ○ |
| Ik maak gebruik van eigen beschikbare informatie om meldingen te verifiëren | ○ | ○ | ○ | ○ | ● |

?
astig te
eoordelen

6



## Deel B: Vragen over systeemkwaliteit (invullen einde van de middag)

De volgende vragen / stellingen gaan over uw algemene indruk van de *systeemkwaliteit* tijdens de oefenscenario's.

Het informatiesysteem (de hulpmiddelen) waar ik in de oefening mee werk…

| | Sterk mee oneens | Mee oneens | Neutraal | Mee eens | Sterk mee eens |
|---|---|---|---|---|---|
| ..geeft mij onmiddellijk toegang tot de informatie die ik nodig heb | ○ | ○ | ○ | ○ | ● |
| ..laat mij vaak wachten op een respons | ○ | ● | ○ | ○ | ○ |
| ..werkt altijd naar behoren | ○ | ○ | ○ | ● | ○ |
| ..zorgt ervoor dat geen belangrijke informatie verloren gaat | ○ | ○ | ○ | ○ | ● |
| ..brengt informatie samen die uit verschillende delen van de organisatie komen | ○ | ○ | ○ | ○ | ● |
| ..geeft een goed overzicht van het verloop van de incidentafhandeling | ○ | ○ | ○ | ○ | ● |
| ..is voldoende ondersteunend om informatie te delen binnen mijn eigen organisatie | ○ | ○ | ○ | ○ | ● |
| ..is eenvoudig te gebruiken | ○ | ○ | ○ | ○ | ● |
| ..stelt mij in staat aan de informatie te komen die ik nodig heb | ○ | ○ | ○ | ○ | ● |
| ..geeft informatie duidelijk weer | ○ | ○ | ○ | ○ | ● |
| ..geeft mij onmiddellijk toegang tot informatie die buiten het bereik van mijn organisatie ligt | ○ | ○ | ○ | ○ | ● |
| ..reageert snel op een opdracht | ○ | ○ | ○ | ● | ○ |
| ..werkt betrouwbaar | ○ | ○ | ○ | ● | ○ |
| ..maakt het goed mogelijk oudere, belangrijke informatie terug te vinden | ○ | ● | ○ | ○ | ○ |
| ..integreert informatie uit verschillende bronnen | ○ | ○ | ○ | ○ | ● |
| ..geeft een volledig beeld van de incidentafhandeling | ○ | ○ | ○ | ○ | ● |
| ..is voldoende ondersteunend om informatie te delen met andere organisatie | ○ | ○ | ○ | ○ | ● |
| ..behoeft weinig opleidingstijd | ○ | ○ | ○ | ● | ○ |
| ..is niet voldoende om in mijn informatiebehoefte te voorzien | ○ | ○ | ● | ○ | ○ |
| ..presenteert mij alle informatie overzichtelijk aan mij | ○ | ○ | ● | ○ | ○ |
| ..vertoont weinig storingen | ○ | ○ | ○ | ● | ○ |
| ..maakt het goed mogelijk om gegevens (kennis van de situatie) op te slaan | ○ | ○ | ○ | ● | ○ |
| ..verzamelt alle informatie op één plek | ○ | ○ | ○ | ○ | ● |
| ..brengt alle veranderingen van het verloop van het incident goed in beeld | ○ | ○ | ● | ○ | ○ |
| ..doet gemakkelijk wat ik wil | ○ | ○ | ● | ○ | ○ |
| ..volstaat bij het afhandelen van een incident | ○ | ○ | ○ | ● | ○ |
| ..behoedt mij voor informatie overload | ○ | ● | ○ | ○ | ○ |

7

*Respondent 2:*

## Vragenlijst net-centrische oefening (10 December 2015)

Beste respondent,

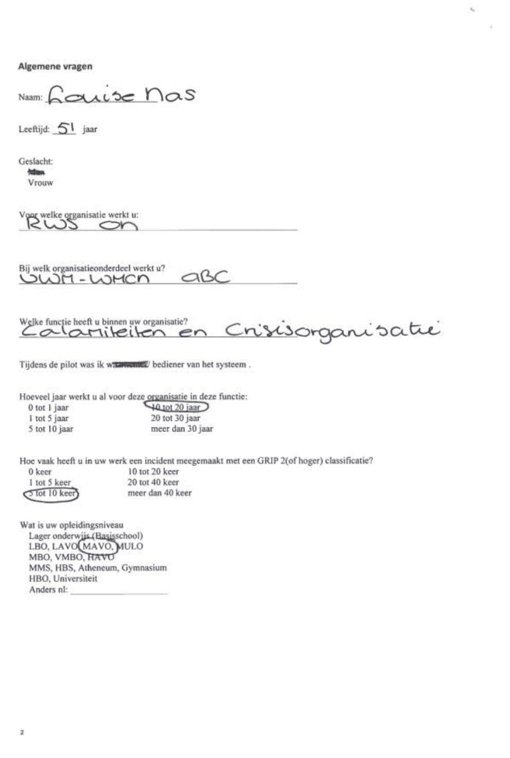
Deze vragenlijst gaat over een onderzoek naar de informatie- en systeemkwaliteit van de crisisafhandeling. De resultaten van deze vragenlijst zullen worden gebruikt voor wetenschappelijk onderzoek naar de knelpunten rond de informatievoorziening van Crisis Management. Dit onderzoek wordt uitgevoerd door Rijkswaterstaat in samenwerking met de Vrije Universiteit Amsterdam.

Uw bijdrage kan een belangrijke input leveren om de informatievoorziening verder te kunnen verbeteren waardoor betrokken organisaties in de toekomst nog beter kunnen samenwerken bij de dagelijkse afhandeling van de incidenten / crisissen.

In de oefening worden verschillende scenario's nagespeeld. Wij willen U vragen om deze vragenlijst zo zorgvuldig mogelijk in te vullen.

De vragenlijst bestaat uit twee delen:
Deel A: invullen voor de oefening
Deel B: invullen tijdens de oefening

Alvast bedankt voor de moeite!



**Algemene vragen**

Naam: Louise Nas

Leeftijd: 51 jaar

Geslacht:
~~Man~~
Vrouw

Voor welke organisatie werkt u:
RWS ON

Bij welk organisatieonderdeel werkt u?
WVM-WMCN aBC

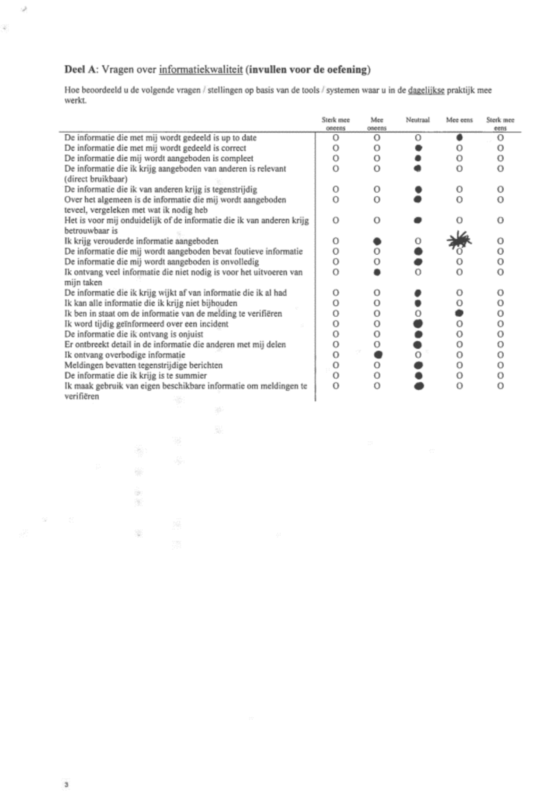
Welke functie heeft u binnen uw organisatie?
Calamiteiten en Crisisorganisatie

Tijdens de pilot was ik w[illegible]/ bediener van het systeem .

Hoeveel jaar werkt u al voor deze organisatie in deze functie:
0 tot 1 jaar [✓ 10 tot 20 jaar]
1 tot 5 jaar 20 tot 30 jaar
5 tot 10 jaar meer dan 30 jaar

Hoe vaak heeft u in uw werk een incident meegemaakt met een GRIP 2(of hoger) classificatie?
0 keer 10 tot 20 keer
1 tot 5 keer 20 tot 40 keer
[✓ 5 tot 10 keer] meer dan 40 keer

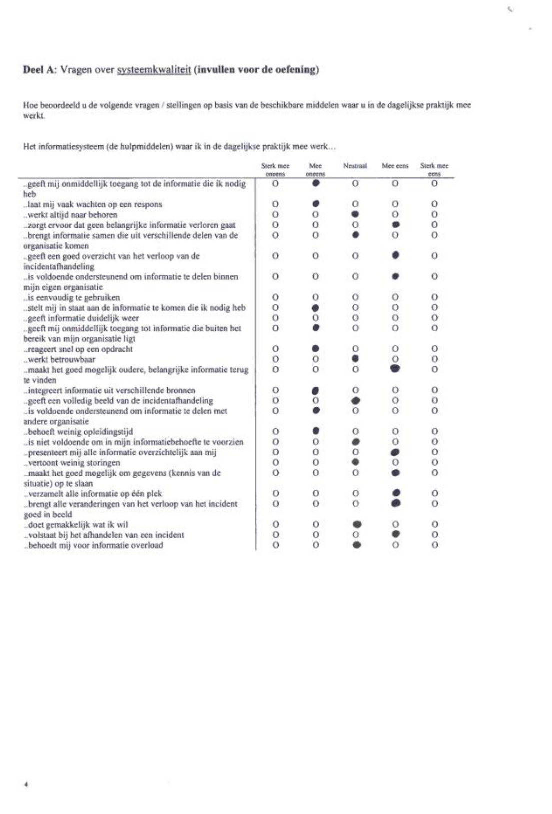
Wat is uw opleidingsniveau
Lager onderwijs (Basisschool)
LBO, LAVO [✓ MAVO,] MULO
MBO, VMBO, HAVO
MMS, HBS, Atheneum, Gymnasium
HBO, Universiteit
Anders nl: ____________



### **Deel A**: Vragen over informatiekwaliteit **(invullen voor de oefening)**

Hoe beoordeeld u de volgende vragen / stellingen op basis van de tools / systemen waar u in de dagelijkse praktijk mee werkt.

| | Sterk mee oneens | Mee oneens | Neutraal | Mee eens | Sterk mee eens |
|---|---|---|---|---|---|
| De informatie die met mij wordt gedeeld is up to date | ○ | ○ | ○ | ● | ○ |
| De informatie die met mij wordt gedeeld is correct | ○ | ○ | ● | ○ | ○ |
| De informatie die mij wordt aangeboden is compleet | ○ | ○ | ● | ○ | ○ |
| De informatie die ik krijg aangeboden van anderen is relevant (direct bruikbaar) | ○ | ○ | ● | ○ | ○ |
| De informatie die ik van anderen krijg is tegenstrijdig | ○ | ○ | ● | ○ | ○ |
| Over het algemeen is de informatie die mij wordt aangeboden teveel, vergeleken met wat ik nodig heb | ○ | ○ | ● | ○ | ○ |
| Het is voor mij onduidelijk of de informatie die ik van anderen krijg betrouwbaar is | ○ | ○ | ● | ○ | ○ |
| Ik krijg verouderde informatie aangeboden | ○ | ● | ○ | ✱ | ○ |
| De informatie die mij wordt aangeboden bevat foutieve informatie | ○ | ○ | ● | ○ | ○ |
| De informatie die mij wordt aangeboden is onvolledig | ○ | ○ | ● | ○ | ○ |
| Ik ontvang veel informatie die niet nodig is voor het uitvoeren van mijn taken | ○ | ● | ○ | ○ | ○ |
| De informatie die ik krijg wijkt af van informatie die ik al had | ○ | ○ | ● | ○ | ○ |
| Ik kan alle informatie die ik krijg niet bijhouden | ○ | ○ | ● | ○ | ○ |
| Ik ben in staat om de informatie van de melding te verifiëren | ○ | ○ | ○ | ● | ○ |
| Ik word tijdig geïnformeerd over een incident | ○ | ○ | ● | ○ | ○ |
| De informatie die ik ontvang is onjuist | ○ | ○ | ● | ○ | ○ |
| Er ontbreekt detail in de informatie die anderen met mij delen | ○ | ○ | ● | ○ | ○ |
| Ik ontvang overbodige informatie | ○ | ● | ○ | ○ | ○ |
| Meldingen bevatten tegenstrijdige berichten | ○ | ○ | ● | ○ | ○ |
| De informatie die ik krijg is te summier | ○ | ○ | ● | ○ | ○ |
| Ik maak gebruik van eigen beschikbare informatie om meldingen te verifiëren | ○ | ○ | ● | ○ | ○ |



### **Deel A**: Vragen over systeemkwaliteit **(invullen voor de oefening)**

Hoe beoordeeld u de volgende vragen / stellingen op basis van de beschikbare middelen waar u in de dagelijkse praktijk mee werkt.

Het informatiesysteem (de hulpmiddelen) waar ik in de dagelijkse praktijk mee werk…

| | Sterk mee oneens | Mee oneens | Neutraal | Mee eens | Sterk mee eens |
|---|---|---|---|---|---|
| ..geeft mij onmiddellijk toegang tot de informatie die ik nodig heb | ○ | ● | ○ | ○ | ○ |
| ..laat mij vaak wachten op een respons | ○ | ● | ○ | ○ | ○ |
| ..werkt altijd naar behoren | ○ | ○ | ● | ○ | ○ |
| ..zorgt ervoor dat geen belangrijke informatie verloren gaat | ○ | ○ | ○ | ● | ○ |
| ..brengt informatie samen die uit verschillende delen van de organisatie komen | ○ | ○ | ● | ○ | ○ |
| ..geeft een goed overzicht van het verloop van de incidentafhandeling | ○ | ○ | ○ | ● | ○ |
| ..is voldoende ondersteunend om informatie te delen binnen mijn eigen organisatie | ○ | ○ | ○ | ● | ○ |
| ..is eenvoudig te gebruiken | ○ | ○ | ○ | ○ | ○ |
| ..stelt mij in staat aan de informatie te komen die ik nodig heb | ○ | ● | ○ | ○ | ○ |
| ..geeft informatie duidelijk weer | ○ | ○ | ○ | ○ | ○ |
| ..geeft mij onmiddellijk toegang tot informatie die buiten het bereik van mijn organisatie ligt | ○ | ● | ○ | ○ | ○ |
| ..reageert snel op een opdracht | ○ | ● | ○ | ○ | ○ |
| ..werkt betrouwbaar | ○ | ○ | ● | ○ | ○ |
| ..maakt het goed mogelijk oudere, belangrijke informatie terug te vinden | ○ | ○ | ○ | ● | ○ |
| ..integreert informatie uit verschillende bronnen | ○ | ● | ○ | ○ | ○ |
| ..geeft een volledig beeld van de incidentafhandeling | ○ | ○ | ● | ○ | ○ |
| ..is voldoende ondersteunend om informatie te delen met andere organisatie | ○ | ● | ○ | ○ | ○ |
| ..behoeft weinig opleidingstijd | ○ | ● | ○ | ○ | ○ |
| ..is niet voldoende om in mijn informatiebehoefte te voorzien | ○ | ○ | ● | ○ | ○ |
| ..presenteert mij alle informatie overzichtelijk aan mij | ○ | ○ | ○ | ● | ○ |
| ..vertoont weinig storingen | ○ | ○ | ● | ○ | ○ |
| ..maakt het goed mogelijk om gegevens (kennis van de situatie) op te slaan | ○ | ○ | ○ | ● | ○ |
| ..verzamelt alle informatie op één plek | ○ | ○ | ○ | ● | ○ |
| ..brengt alle veranderingen van het verloop van het incident goed in beeld | ○ | ○ | ○ | ● | ○ |
| ..doet gemakkelijk wat ik wil | ○ | ○ | ● | ○ | ○ |
| ..volstaat bij het afhandelen van een incident | ○ | ○ | ○ | ● | ○ |
| ..behoedt mij voor informatie overload | ○ | ○ | ● | ○ | ○ |

**Deel B**: Vragen over <u>informatie</u>kwaliteit (**einde ochtend**)

De volgende vragen / stellingen gaan over uw algemene indruk van de *informatiekwaliteit* tijdens de oefenscenario's.

| | Sterk mee oneens | Mee oneens | Neutraal | Mee eens | Sterk mee eens |
|---|---|---|---|---|---|
| De informatie die met mij wordt gedeeld is up to date | ○ | ○ | ● | ○ | ○ |
| De informatie die met mij wordt gedeeld is correct | ○ | ● | ○ | ○ | ○ |
| De informatie die mij wordt aangeboden is compleet | ○ | ○ | ● | ○ | ○ |
| De informatie die ik krijg aangeboden van anderen is relevant (direct bruikbaar) | ○ | ○ | ● | ○ | ○ |
| De informatie die ik van anderen krijg is tegenstrijdig | ○ | ○ | ● | ○ | ○ |
| Over het algemeen is de informatie die mij wordt aangeboden teveel, vergeleken met wat ik nodig heb | ○ | ● | ○ | ○ | ○ |
| Het is voor mij onduidelijk of de informatie die ik van anderen krijg betrouwbaar is | ○ | ● | ○ | ○ | ○ |
| Ik krijg verouderde informatie aangeboden | ○ | ○ | ● | ○ | ○ |
| De informatie die mij wordt aangeboden bevat foutieve informatie | ○ | ○ | ● | ○ | ○ |
| De informatie die mij wordt aangeboden is onvolledig | ○ | ○ | ● | ○ | ○ |
| Ik ontvang veel informatie die niet nodig is voor het uitvoeren van mijn taken | ○ | ○ | ● | ○ | ○ |
| De informatie die ik krijg wijkt af van informatie die ik al had | ○ | ○ | ● | ○ | ○ |
| Ik kan alle informatie die ik krijg niet bijhouden | ○ | ● | ○ | ● | ○ |
| Ik ben in staat om de informatie van de melding te verifiëren | ○ | ○ | ○ | ● | ○ |
| Ik word tijdig geïnformeerd over een incident | ○ | ○ | ● | ○ | ○ |
| De informatie die ik ontvang is onjuist | ○ | ○ | ● | ○ | ○ |
| Er ontbreekt detail in de informatie die anderen met mij delen | ○ | ○ | ● | ○ | ○ |
| Ik ontvang overbodige informatie | ○ | ○ | ● | ○ | ○ |
| Meldingen bevatten tegenstrijdige berichten | ○ | ○ | ● | ○ | ○ |
| De informatie die ik krijg is te summier | ○ | ○ | ● | ○ | ○ |
| Ik maak gebruik van eigen beschikbare informatie om meldingen te verifiëren | ○ | ○ | ○ | ● | ○ |

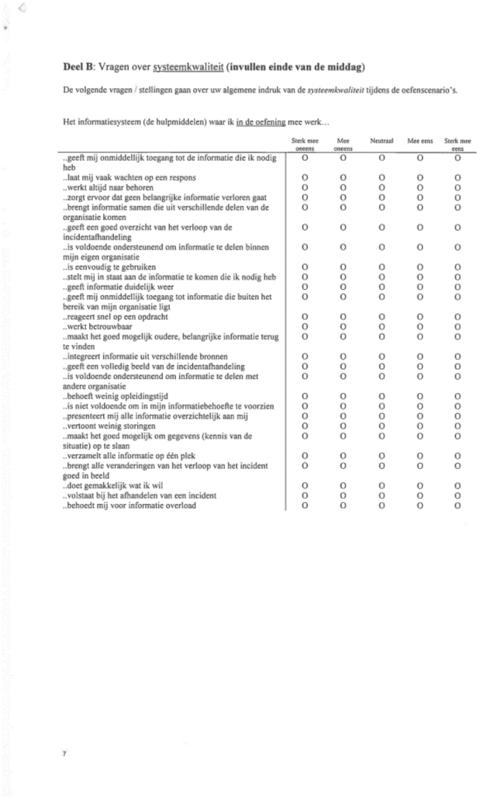
5

**Deel B**: Vragen over <u>informatie</u>kwaliteit (**middag**)

De volgende vragen / stellingen gaan over uw algemene indruk van de *informatiekwaliteit* tijdens de oefenscenario's.

| | Sterk mee oneens | Mee oneens | Neutraal | Mee eens | Sterk mee eens |
|---|---|---|---|---|---|
| De informatie die met mij wordt gedeeld is up to date | ○ | ○ | ● | ○ | ○ |
| De informatie die met mij wordt gedeeld is correct | ○ | ● | ☒ | ○ | ○ |
| De informatie die mij wordt aangeboden is compleet | ○ | ○ | ● | ○ | ○ |
| De informatie die ik krijg aangeboden van anderen is relevant (direct bruikbaar) | ○ | ○ | ● | ○ | ○ |
| De informatie die ik van anderen krijg is tegenstrijdig | ○ | ○ | ● | ○ | ○ |
| Over het algemeen is de informatie die mij wordt aangeboden teveel, vergeleken met wat ik nodig heb | ○ | ● | ○ | ○ | ○ |
| Het is voor mij onduidelijk of de informatie die ik van anderen krijg betrouwbaar is | ○ | ● | ○ | ○ | ○ |
| Ik krijg verouderde informatie aangeboden | ○ | ○ | ● | ○ | ○ |
| De informatie die mij wordt aangeboden bevat foutieve informatie | ○ | ○ | ● | ○ | ○ |
| De informatie die mij wordt aangeboden is onvolledig | ○ | ○ | ● | ○ | ○ |
| Ik ontvang veel informatie die niet nodig is voor het uitvoeren van mijn taken | ○ | ○ | ● | ○ | ○ |
| De informatie die ik krijg wijkt af van informatie die ik al had | ○ | ○ | ● | ○ | ○ |
| Ik kan alle informatie die ik krijg niet bijhouden | ○ | ● | ○ | ○ | ○ |
| Ik ben in staat om de informatie van de melding te verifiëren | ○ | ○ | ○ | ● | ○ |
| Ik word tijdig geïnformeerd over een incident | ○ | ○ | ● | ○ | ○ |
| De informatie die ik ontvang is onjuist | ○ | ○ | ● | ○ | ○ |
| Er ontbreekt detail in de informatie die anderen met mij delen | ○ | ○ | ● | ○ | ○ |
| Ik ontvang overbodige informatie | ○ | ○ | ● | ○ | ○ |
| Meldingen bevatten tegenstrijdige berichten | ○ | ○ | ● | ○ | ○ |
| De informatie die ik krijg is te summier | ○ | ○ | ● | ○ | ○ |
| Ik maak gebruik van eigen beschikbare informatie om meldingen te verifiëren | ○ | ○ | ○ | ● | ○ |

6



**Deel B**: Vragen over <u>systeemkwaliteit</u> (**invullen einde van de middag**)

De volgende vragen / stellingen gaan over uw algemene indruk van de *systeemkwaliteit* tijdens de oefenscenario's.

Het informatiesysteem (de hulpmiddelen) waar ik <u>in de oefening</u> mee werk…

| | Sterk mee oneens | Mee oneens | Neutraal | Mee eens | Sterk mee eens |
|---|---|---|---|---|---|
| ..geeft mij onmiddellijk toegang tot de informatie die ik nodig heb | ○ | ○ | ○ | ○ | ○ |
| ..laat mij vaak wachten op een respons | ○ | ○ | ○ | ○ | ○ |
| ..werkt altijd naar behoren | ○ | ○ | ○ | ○ | ○ |
| ..zorgt ervoor dat geen belangrijke informatie verloren gaat | ○ | ○ | ○ | ○ | ○ |
| ..brengt informatie samen die uit verschillende delen van de organisatie komen | ○ | ○ | ○ | ○ | ○ |
| ..geeft een goed overzicht van het verloop van de incidentafhandeling | ○ | ○ | ○ | ○ | ○ |
| ..is voldoende ondersteunend om informatie te delen binnen mijn eigen organisatie | ○ | ○ | ○ | ○ | ○ |
| ..is eenvoudig te gebruiken | ○ | ○ | ○ | ○ | ○ |
| ..stelt mij in staat aan de informatie te komen die ik nodig heb | ○ | ○ | ○ | ○ | ○ |
| ..geeft informatie duidelijk weer | ○ | ○ | ○ | ○ | ○ |
| ..geeft mij onmiddellijk toegang tot informatie die buiten het bereik van mijn organisatie ligt | ○ | ○ | ○ | ○ | ○ |
| ..reageert snel op een opdracht | ○ | ○ | ○ | ○ | ○ |
| ..werkt betrouwbaar | ○ | ○ | ○ | ○ | ○ |
| ..maakt het goed mogelijk oudere, belangrijke informatie terug te vinden | ○ | ○ | ○ | ○ | ○ |
| ..integreert informatie uit verschillende bronnen | ○ | ○ | ○ | ○ | ○ |
| ..geeft een volledig beeld van de incidentafhandeling | ○ | ○ | ○ | ○ | ○ |
| ..is voldoende ondersteunend om informatie te delen met andere organisatie | ○ | ○ | ○ | ○ | ○ |
| ..behoeft weinig opleidingstijd | ○ | ○ | ○ | ○ | ○ |
| ..is niet voldoende om in mijn informatiebehoefte te voorzien | ○ | ○ | ○ | ○ | ○ |
| ..presenteert mij alle informatie overzichtelijk aan mij | ○ | ○ | ○ | ○ | ○ |
| ..vertoont weinig storingen | ○ | ○ | ○ | ○ | ○ |
| ..maakt het goed mogelijk om gegevens (kennis van de situatie) op te slaan | ○ | ○ | ○ | ○ | ○ |
| ..verzamelt alle informatie op één plek | ○ | ○ | ○ | ○ | ○ |
| ..brengt alle veranderingen van het verloop van het incident goed in beeld | ○ | ○ | ○ | ○ | ○ |
| ..doet gemakkelijk wat ik wil | ○ | ○ | ○ | ○ | ○ |
| ..volstaat bij het afhandelen van een incident | ○ | ○ | ○ | ○ | ○ |
| ..behoedt mij voor informatie overload | ○ | ○ | ○ | ○ | ○ |

7

*Respondent 3:*

Vragenlijst net-centrische oefening (10 December 2015)

Beste respondent,

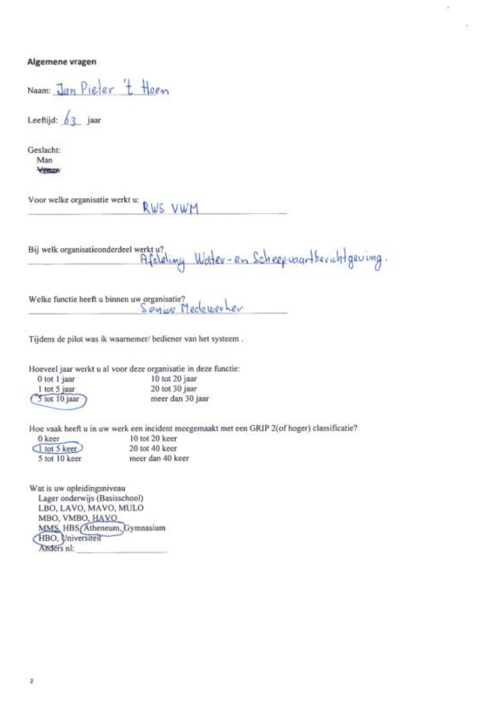
Deze vragenlijst gaat over een onderzoek naar de informatie- en systeemkwaliteit van de crisisafhandeling. De resultaten van deze vragenlijst zullen worden gebruikt voor wetenschappelijk onderzoek naar de knelpunten rond de informatievoorziening van Crisis Management. Dit onderzoek wordt uitgevoerd door Rijkswaterstaat in samenwerking met de Vrije Universiteit Amsterdam.

Uw bijdrage kan een belangrijke input leveren om de informatievoorziening verder te kunnen verbeteren waardoor betrokken organisaties in de toekomst nog beter kunnen samenwerken bij de dagelijkse afhandeling van de incidenten / crisissen.

In de oefening worden verschillende scenario's nagespeeld. Wij willen U vragen om deze vragenlijst zo zorgvuldig mogelijk in te vullen.

De vragenlijst bestaat uit twee delen:
Deel A: invullen voor de oefening
Deel B: invullen tijdens de oefening

Alvast bedankt voor de moeite!



**Algemene vragen**

Naam: Jan Pieter 't Hoem

Leeftijd: 63 jaar

Geslacht:
Man
~~Vrouw~~

Voor welke organisatie werkt u: RWS VWM

Bij welk organisatieonderdeel werkt u? Afdeling Water- en Scheepvaartberichtgeving.

Welke functie heeft u binnen uw organisatie? Senior Medewerker

Tijdens de pilot was ik waarnemer/ bediener van het systeem .

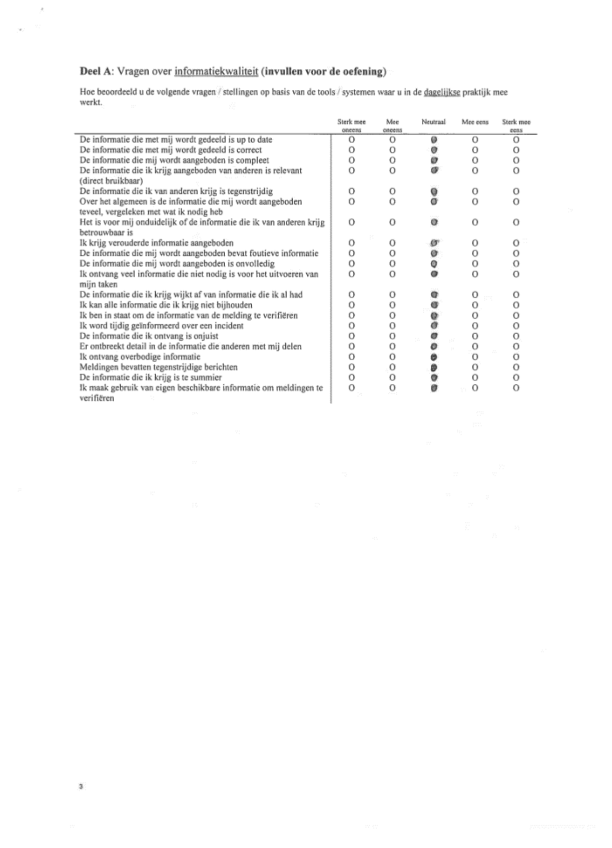
Hoeveel jaar werkt u al voor deze organisatie in deze functie:

| | |
|---|---|
| 0 tot 1 jaar | 10 tot 20 jaar |
| 1 tot 5 jaar | 20 tot 30 jaar |
| [✓ 5 tot 10 jaar] | meer dan 30 jaar |

Hoe vaak heeft u in uw werk een incident meegemaakt met een GRIP 2(of hoger) classificatie?

| | |
|---|---|
| 0 keer | 10 tot 20 keer |
| [✓ 1 tot 5 keer] | 20 tot 40 keer |
| 5 tot 10 keer | meer dan 40 keer |

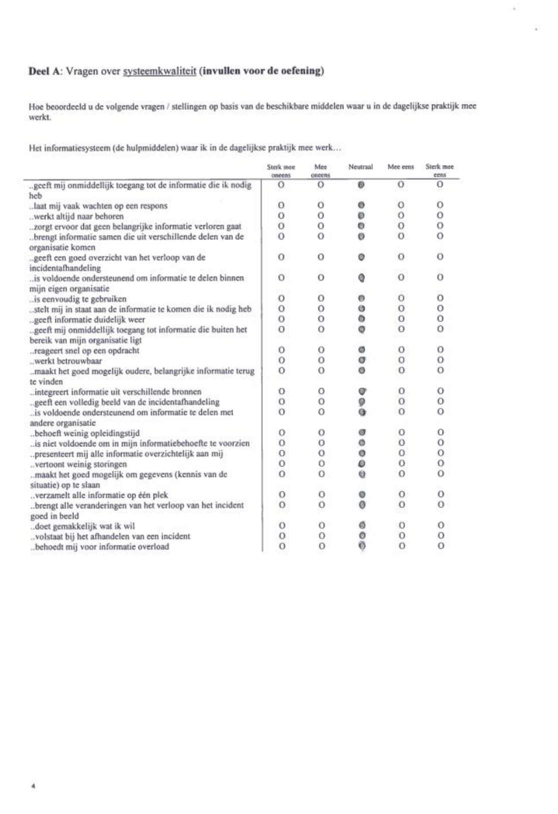
Wat is uw opleidingsniveau
Lager onderwijs (Basisschool)
LBO, LAVO, MAVO, MULO
MBO, VMBO, HAVO
MMS, HBS, [✓ Atheneum,] Gymnasium
[✓ HBO,] Universiteit
Anders nl: __________



**Deel A**: Vragen over informatiekwaliteit **(invullen voor de oefening)**

Hoe beoordeeld u de volgende vragen / stellingen op basis van de tools / systemen waar u in de dagelijkse praktijk mee werkt.

| | Sterk mee oneens | Mee oneens | Neutraal | Mee eens | Sterk mee eens |
|---|---|---|---|---|---|
| De informatie die met mij wordt gedeeld is up to date | ○ | ○ | ● | ○ | ○ |
| De informatie die met mij wordt gedeeld is correct | ○ | ○ | ● | ○ | ○ |
| De informatie die mij wordt aangeboden is compleet | ○ | ○ | ● | ○ | ○ |
| De informatie die ik krijg aangeboden van anderen is relevant (direct bruikbaar) | ○ | ○ | ● | ○ | ○ |
| De informatie die ik van anderen krijg is tegenstrijdig | ○ | ○ | ● | ○ | ○ |
| Over het algemeen is de informatie die mij wordt aangeboden teveel, vergeleken met wat ik nodig heb | ○ | ○ | ● | ○ | ○ |
| Het is voor mij onduidelijk of de informatie die ik van anderen krijg betrouwbaar is | ○ | ○ | ● | ○ | ○ |
| Ik krijg verouderde informatie aangeboden | ○ | ○ | ● | ○ | ○ |
| De informatie die mij wordt aangeboden bevat foutieve informatie | ○ | ○ | ● | ○ | ○ |
| De informatie die mij wordt aangeboden is onvolledig | ○ | ○ | ● | ○ | ○ |
| Ik ontvang veel informatie die niet nodig is voor het uitvoeren van mijn taken | ○ | ○ | ● | ○ | ○ |
| De informatie die ik krijg wijkt af van informatie die ik al had | ○ | ○ | ● | ○ | ○ |
| Ik kan alle informatie die ik krijg niet bijhouden | ○ | ○ | ● | ○ | ○ |
| Ik ben in staat om de informatie van de melding te verifiëren | ○ | ○ | ● | ○ | ○ |
| Ik word tijdig geïnformeerd over een incident | ○ | ○ | ● | ○ | ○ |
| De informatie die ik ontvang is onjuist | ○ | ○ | ● | ○ | ○ |
| Er ontbreekt detail in de informatie die anderen met mij delen | ○ | ○ | ● | ○ | ○ |
| Ik ontvang overbodige informatie | ○ | ○ | ● | ○ | ○ |
| Meldingen bevatten tegenstrijdige berichten | ○ | ○ | ● | ○ | ○ |
| De informatie die ik krijg is te summier | ○ | ○ | ● | ○ | ○ |
| Ik maak gebruik van eigen beschikbare informatie om meldingen te verifiëren | ○ | ○ | ● | ○ | ○ |



**Deel A**: Vragen over systeemkwaliteit **(invullen voor de oefening)**

Hoe beoordeeld u de volgende vragen / stellingen op basis van de beschikbare middelen waar u in de dagelijkse praktijk mee werkt.

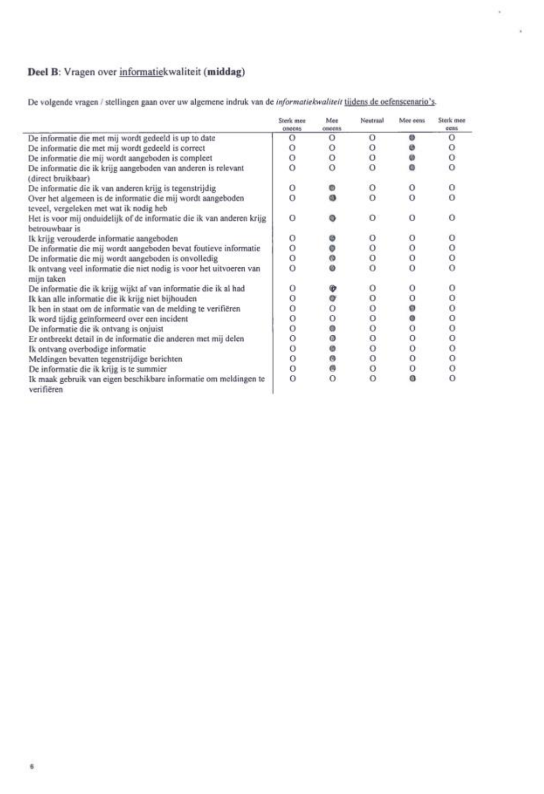
Het informatiesysteem (de hulpmiddelen) waar ik in de dagelijkse praktijk mee werk…

| | Sterk mee oneens | Mee oneens | Neutraal | Mee eens | Sterk mee eens |
|---|---|---|---|---|---|
| ..geeft mij onmiddellijk toegang tot de informatie die ik nodig heb | ○ | ○ | ● | ○ | ○ |
| ..laat mij vaak wachten op een respons | ○ | ○ | ● | ○ | ○ |
| ..werkt altijd naar behoren | ○ | ○ | ● | ○ | ○ |
| ..zorgt ervoor dat geen belangrijke informatie verloren gaat | ○ | ○ | ● | ○ | ○ |
| ..brengt informatie samen die uit verschillende delen van de organisatie komen | ○ | ○ | ● | ○ | ○ |
| ..geeft een goed overzicht van het verloop van de incidentafhandeling | ○ | ○ | ● | ○ | ○ |
| ..is voldoende ondersteunend om informatie te delen binnen mijn eigen organisatie | ○ | ○ | ● | ○ | ○ |
| ..is eenvoudig te gebruiken | ○ | ○ | ● | ○ | ○ |
| ..stelt mij in staat aan de informatie te komen die ik nodig heb | ○ | ○ | ● | ○ | ○ |
| ..geeft informatie duidelijk weer | ○ | ○ | ● | ○ | ○ |
| ..geeft mij onmiddellijk toegang tot informatie die buiten het bereik van mijn organisatie ligt | ○ | ○ | ● | ○ | ○ |
| ..reageert snel op een opdracht | ○ | ○ | ● | ○ | ○ |
| ..werkt betrouwbaar | ○ | ○ | ● | ○ | ○ |
| ..maakt het goed mogelijk oudere, belangrijke informatie terug te vinden | ○ | ○ | ● | ○ | ○ |
| ..integreert informatie uit verschillende bronnen | ○ | ○ | ● | ○ | ○ |
| ..geeft een volledig beeld van de incidentafhandeling | ○ | ○ | ● | ○ | ○ |
| ..is voldoende ondersteunend om informatie te delen met andere organisatie | ○ | ○ | ● | ○ | ○ |
| ..behoeft weinig opleidingstijd | ○ | ○ | ● | ○ | ○ |
| ..is niet voldoende om in mijn informatiebehoefte te voorzien | ○ | ○ | ● | ○ | ○ |
| ..presenteert mij alle informatie overzichtelijk aan mij | ○ | ○ | ● | ○ | ○ |
| ..vertoont weinig storingen | ○ | ○ | ● | ○ | ○ |
| ..maakt het goed mogelijk om gegevens (kennis van de situatie) op te slaan | ○ | ○ | ● | ○ | ○ |
| ..verzamelt alle informatie op één plek | ○ | ○ | ● | ○ | ○ |
| ..brengt alle veranderingen van het verloop van het incident goed in beeld | ○ | ○ | ● | ○ | ○ |
| ..doet gemakkelijk wat ik wil | ○ | ○ | ● | ○ | ○ |
| ..volstaat bij het afhandelen van een incident | ○ | ○ | ● | ○ | ○ |
| ..behoedt mij voor informatie overload | ○ | ○ | ● | ○ | ○ |

**Deel B**: Vragen over <u>informatie</u>kwaliteit (**einde ochtend**)

De volgende vragen / stellingen gaan over uw algemene indruk van de *informatiekwaliteit* tijdens de oefenscenario's.

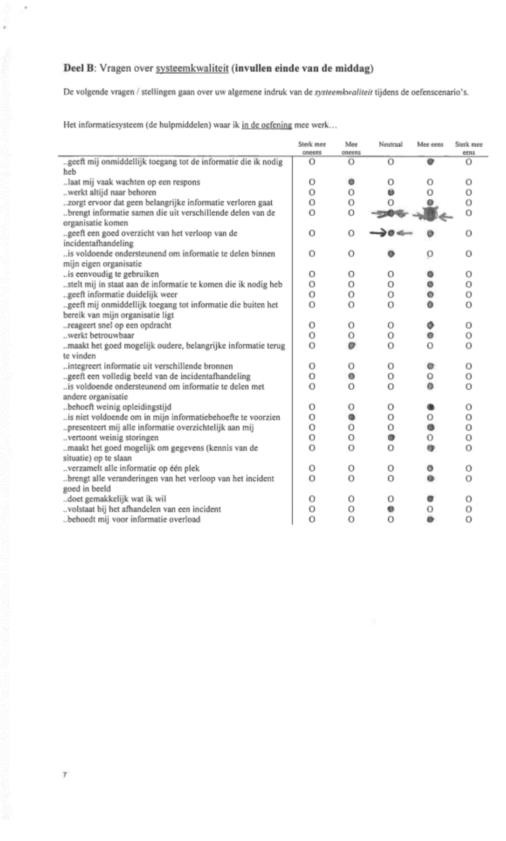
| | Sterk mee oneens | Mee oneens | Neutraal | Mee eens | Sterk mee eens |
|---|---|---|---|---|---|
| De informatie die met mij wordt gedeeld is up to date | ○ | ○ | ○ | ● | ○ |
| De informatie die met mij wordt gedeeld is correct | ○ | ○ | ○ | ● | ○ |
| De informatie die mij wordt aangeboden is compleet | ○ | ○ | ● | ○ | ○ |
| De informatie die ik krijg aangeboden van anderen is relevant (direct bruikbaar) | ○ | ○ | ○ | ● | ○ |
| De informatie die ik van anderen krijg is tegenstrijdig | ○ | ● | ○ | ○ | ○ |
| Over het algemeen is de informatie die mij wordt aangeboden teveel, vergeleken met wat ik nodig heb | ○ | ● | ○ | ○ | ○ |
| Het is voor mij onduidelijk of de informatie die ik van anderen krijg betrouwbaar is | ○ | ● | ○ | ○ | ○ |
| Ik krijg verouderde informatie aangeboden | ○ | ● | ○ | ○ | ○ |
| De informatie die mij wordt aangeboden bevat foutieve informatie | ○ | ● | ○ | ○ | ○ |
| De informatie die mij wordt aangeboden is onvolledig | ○ | ● | ○ | ○ | ○ |
| Ik ontvang veel informatie die niet nodig is voor het uitvoeren van mijn taken | ○ | ● | ○ | ○ | ○ |
| De informatie die ik krijg wijkt af van informatie die ik al had | ○ | ● | ○ | ○ | ○ |
| Ik kan alle informatie die ik krijg niet bijhouden | ○ | ● | ○ | ○ | ○ |
| Ik ben in staat om de informatie van de melding te verifiëren | ○ | ○ | ○ | ● | ○ |
| Ik word tijdig geïnformeerd over een incident | ○ | ○ | ○ | ● | ○ |
| De informatie die ik ontvang is onjuist | ○ | ● | ○ | ○ | ○ |
| Er ontbreekt detail in de informatie die anderen met mij delen | ○ | ● | ○ | ○ | ○ |
| Ik ontvang overbodige informatie | ○ | ● | ○ | ○ | ○ |
| Meldingen bevatten tegenstrijdige berichten | ○ | ● | ○ | ○ | ○ |
| De informatie die ik krijg is te summier | ○ | ● | ○ | ○ | ○ |
| Ik maak gebruik van eigen beschikbare informatie om meldingen te verifiëren | ○ | ○ | ○ | ● | ○ |



**Deel B**: Vragen over <u>informatie</u>kwaliteit (**middag**)

De volgende vragen / stellingen gaan over uw algemene indruk van de *informatiekwaliteit* tijdens de oefenscenario's.

| | Sterk mee oneens | Mee oneens | Neutraal | Mee eens | Sterk mee eens |
|---|---|---|---|---|---|
| De informatie die met mij wordt gedeeld is up to date | ○ | ○ | ○ | ● | ○ |
| De informatie die met mij wordt gedeeld is correct | ○ | ○ | ○ | ● | ○ |
| De informatie die mij wordt aangeboden is compleet | ○ | ○ | ○ | ● | ○ |
| De informatie die ik krijg aangeboden van anderen is relevant (direct bruikbaar) | ○ | ○ | ○ | ● | ○ |
| De informatie die ik van anderen krijg is tegenstrijdig | ○ | ● | ○ | ○ | ○ |
| Over het algemeen is de informatie die mij wordt aangeboden teveel, vergeleken met wat ik nodig heb | ○ | ● | ○ | ○ | ○ |
| Het is voor mij onduidelijk of de informatie die ik van anderen krijg betrouwbaar is | ○ | ● | ○ | ○ | ○ |
| Ik krijg verouderde informatie aangeboden | ○ | ● | ○ | ○ | ○ |
| De informatie die mij wordt aangeboden bevat foutieve informatie | ○ | ● | ○ | ○ | ○ |
| De informatie die mij wordt aangeboden is onvolledig | ○ | ● | ○ | ○ | ○ |
| Ik ontvang veel informatie die niet nodig is voor het uitvoeren van mijn taken | ○ | ● | ○ | ○ | ○ |
| De informatie die ik krijg wijkt af van informatie die ik al had | ○ | ● | ○ | ○ | ○ |
| Ik kan alle informatie die ik krijg niet bijhouden | ○ | ● | ○ | ○ | ○ |
| Ik ben in staat om de informatie van de melding te verifiëren | ○ | ○ | ○ | ● | ○ |
| Ik word tijdig geïnformeerd over een incident | ○ | ○ | ○ | ● | ○ |
| De informatie die ik ontvang is onjuist | ○ | ● | ○ | ○ | ○ |
| Er ontbreekt detail in de informatie die anderen met mij delen | ○ | ● | ○ | ○ | ○ |
| Ik ontvang overbodige informatie | ○ | ● | ○ | ○ | ○ |
| Meldingen bevatten tegenstrijdige berichten | ○ | ● | ○ | ○ | ○ |
| De informatie die ik krijg is te summier | ○ | ● | ○ | ○ | ○ |
| Ik maak gebruik van eigen beschikbare informatie om meldingen te verifiëren | ○ | ○ | ○ | ● | ○ |



**Deel B**: Vragen over <u>systeemkwaliteit</u> (**invullen einde van de middag**)

De volgende vragen / stellingen gaan over uw algemene indruk van de *systeemkwaliteit* tijdens de oefenscenario's.

Het informatiesysteem (de hulpmiddelen) waar ik <u>in de oefening</u> mee werk…

| | Sterk mee oneens | Mee oneens | Neutraal | Mee eens | Sterk mee eens |
|---|---|---|---|---|---|
| ..geeft mij onmiddellijk toegang tot de informatie die ik nodig heb | ○ | ○ | ○ | ● | ○ |
| ..laat mij vaak wachten op een respons | ○ | ● | ○ | ○ | ○ |
| ..werkt altijd naar behoren | ○ | ○ | ● | ○ | ○ |
| ..zorgt ervoor dat geen belangrijke informatie verloren gaat | ○ | ○ | ○ | ● | ○ |
| ..brengt informatie samen die uit verschillende delen van de organisatie komen | ○ | ○ | ● | ● | ○ |
| ..geeft een goed overzicht van het verloop van de incidentafhandeling | ○ | ○ | ● | ● | ○ |
| ..is voldoende ondersteunend om informatie te delen binnen mijn eigen organisatie | ○ | ○ | ● | ○ | ○ |
| ..is eenvoudig te gebruiken | ○ | ○ | ○ | ● | ○ |
| ..stelt mij in staat aan de informatie te komen die ik nodig heb | ○ | ○ | ○ | ● | ○ |
| ..geeft informatie duidelijk weer | ○ | ○ | ○ | ● | ○ |
| ..geeft mij onmiddellijk toegang tot informatie die buiten het bereik van mijn organisatie ligt | ○ | ○ | ○ | ● | ○ |
| ..reageert snel op een opdracht | ○ | ○ | ○ | ● | ○ |
| ..werkt betrouwbaar | ○ | ○ | ○ | ● | ○ |
| ..maakt het goed mogelijk oudere, belangrijke informatie terug te vinden | ○ | ● | ○ | ○ | ○ |
| ..integreert informatie uit verschillende bronnen | ○ | ○ | ○ | ● | ○ |
| ..geeft een volledig beeld van de incidentafhandeling | ○ | ● | ○ | ○ | ○ |
| ..is voldoende ondersteunend om informatie te delen met andere organisatie | ○ | ○ | ○ | ● | ○ |
| ..behoeft weinig opleidingstijd | ○ | ○ | ○ | ● | ○ |
| ..is niet voldoende om in mijn informatiebehoefte te voorzien | ○ | ● | ○ | ○ | ○ |
| ..presenteert mij alle informatie overzichtelijk aan mij | ○ | ○ | ○ | ● | ○ |
| ..vertoont weinig storingen | ○ | ○ | ● | ○ | ○ |
| ..maakt het goed mogelijk om gegevens (kennis van de situatie) op te slaan | ○ | ○ | ○ | ● | ○ |
| ..verzamelt alle informatie op één plek | ○ | ○ | ○ | ● | ○ |
| ..brengt alle veranderingen van het verloop van het incident goed in beeld | ○ | ○ | ○ | ● | ○ |
| ..doet gemakkelijk wat ik wil | ○ | ○ | ○ | ● | ○ |
| ..volstaat bij het afhandelen van een incident | ○ | ○ | ● | ○ | ○ |
| ..behoedt mij voor informatie overload | ○ | ○ | ○ | ● | ○ |

*Respondent 4:*

## Vragenlijst net-centrische oefening (10 December 2015)

Beste respondent,

Deze vragenlijst gaat over een onderzoek naar de informatie- en systeemkwaliteit van de crisisafhandeling. De resultaten van deze vragenlijst zullen worden gebruikt voor wetenschappelijk onderzoek naar de knelpunten rond de informatievoorziening van Crisis Management. Dit onderzoek wordt uitgevoerd door Rijkswaterstaat in samenwerking met de Vrije Universiteit Amsterdam.

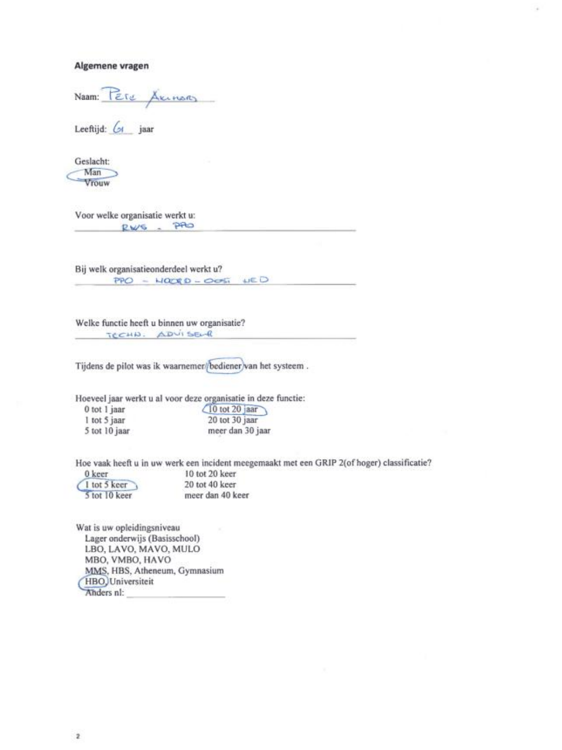
Uw bijdrage kan een belangrijke input leveren om de informatievoorziening verder te kunnen verbeteren waardoor betrokken organisaties in de toekomst nog beter kunnen samenwerken bij de dagelijkse afhandeling van de incidenten / crisissen.

In de oefening worden verschillende scenario's nagespeeld. Wij willen U vragen om deze vragenlijst zo zorgvuldig mogelijk in te vullen.

De vragenlijst bestaat uit twee delen:
Deel A: invullen voor de oefening
Deel B: invullen tijdens de oefening

Alvast bedankt voor de moeite!

1



**Algemene vragen**

Naam: Pete Akmans

Leeftijd: 61 jaar

Geslacht:
[✓ Man]
Vrouw

Voor welke organisatie werkt u:
RWS - PPO

Bij welk organisatieonderdeel werkt u?
PPO - NOORD-OOST NED

Welke functie heeft u binnen uw organisatie?
TECHN. ADVISEUR

Tijdens de pilot was ik waarnemer/ [✓ bediener] van het systeem .

Hoeveel jaar werkt u al voor deze organisatie in deze functie:

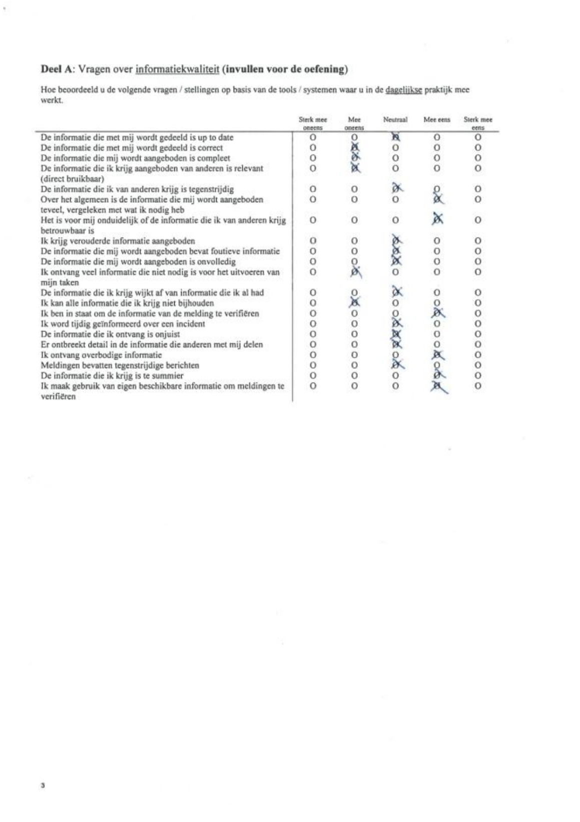
| | |
|---|---|
| 0 tot 1 jaar | [✓ 10 tot 20 jaar] |
| 1 tot 5 jaar | 20 tot 30 jaar |
| 5 tot 10 jaar | meer dan 30 jaar |

Hoe vaak heeft u in uw werk een incident meegemaakt met een GRIP 2(of hoger) classificatie?

| | |
|---|---|
| 0 keer | 10 tot 20 keer |
| [✓ 1 tot 5 keer] | 20 tot 40 keer |
| 5 tot 10 keer | meer dan 40 keer |

Wat is uw opleidingsniveau
Lager onderwijs (Basisschool)
LBO, LAVO, MAVO, MULO
MBO, VMBO, HAVO
MMS, HBS, Atheneum, Gymnasium
[✓ HBO], Universiteit
Anders nl: ____________

2

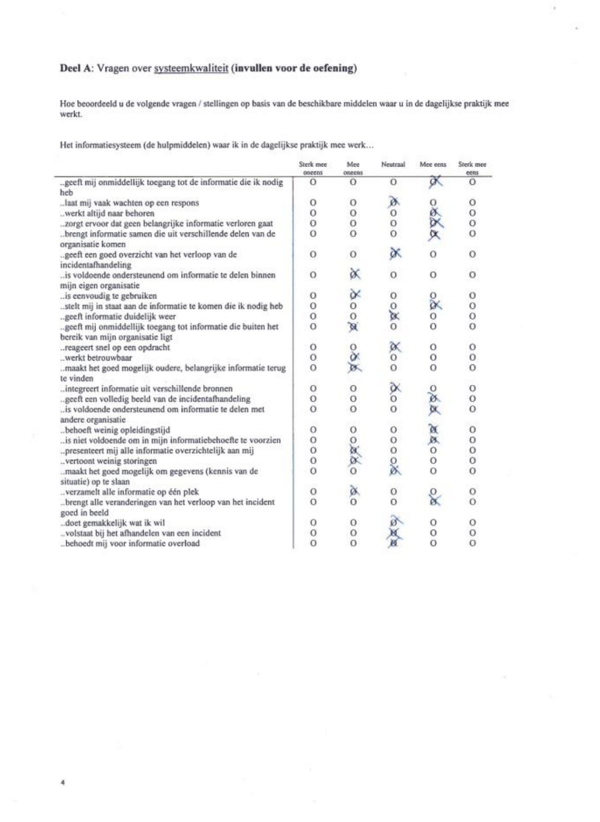


**Deel A**: Vragen over informatiekwaliteit **(invullen voor de oefening)**

Hoe beoordeeld u de volgende vragen / stellingen op basis van de tools / systemen waar u in de dagelijkse praktijk mee werkt.

| | Sterk mee oneens | Mee oneens | Neutraal | Mee eens | Sterk mee eens |
|---|---|---|---|---|---|
| De informatie die met mij wordt gedeeld is up to date | O | O | ☒ | O | O |
| De informatie die met mij wordt gedeeld is correct | O | ☒ | O | O | O |
| De informatie die mij wordt aangeboden is compleet | O | ☒ | O | O | O |
| De informatie die ik krijg aangeboden van anderen is relevant (direct bruikbaar) | O | ☒ | O | O | O |
| De informatie die ik van anderen krijg is tegenstrijdig | O | O | ☒ | O | O |
| Over het algemeen is de informatie die mij wordt aangeboden teveel, vergeleken met wat ik nodig heb | O | O | O | ☒ | O |
| Het is voor mij onduidelijk of de informatie die ik van anderen krijg betrouwbaar is | O | O | O | ☒ | O |
| Ik krijg verouderde informatie aangeboden | O | O | ☒ | O | O |
| De informatie die mij wordt aangeboden bevat foutieve informatie | O | O | ☒ | O | O |
| De informatie die mij wordt aangeboden is onvolledig | O | O | ☒ | O | O |
| Ik ontvang veel informatie die niet nodig is voor het uitvoeren van mijn taken | O | ☒ | O | O | O |
| De informatie die ik krijg wijkt af van informatie die ik al had | O | O | ☒ | O | O |
| Ik kan alle informatie die ik krijg niet bijhouden | O | ☒ | O | O | O |
| Ik ben in staat om de informatie van de melding te verifiëren | O | O | O | ☒ | O |
| Ik word tijdig geïnformeerd over een incident | O | O | ☒ | O | O |
| De informatie die ik ontvang is onjuist | O | O | ☒ | O | O |
| Er ontbreekt detail in de informatie die anderen met mij delen | O | O | ☒ | O | O |
| Ik ontvang overbodige informatie | O | O | O | ☒ | O |
| Meldingen bevatten tegenstrijdige berichten | O | O | ☒ | O | O |
| De informatie die ik krijg is te summier | O | O | O | ☒ | O |
| Ik maak gebruik van eigen beschikbare informatie om meldingen te verifiëren | O | O | O | ☒ | O |

3



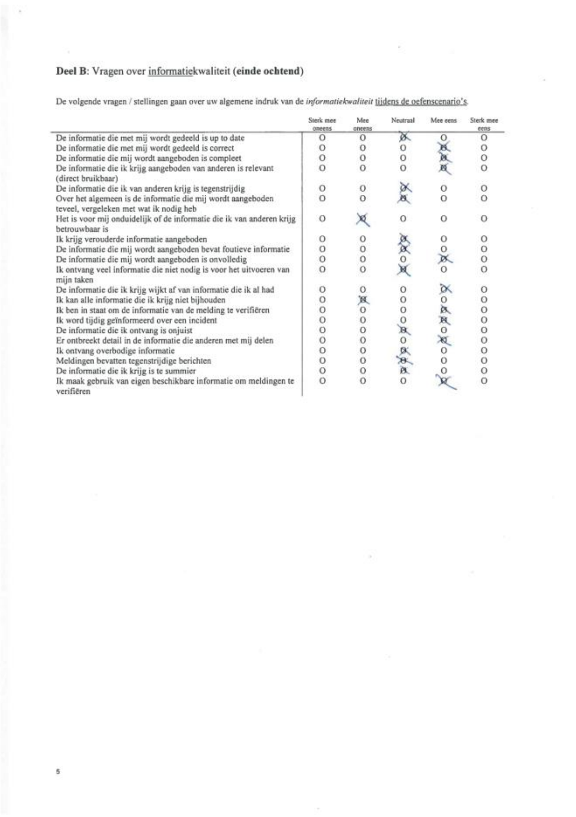
**Deel A**: Vragen over systeemkwaliteit **(invullen voor de oefening)**

Hoe beoordeeld u de volgende vragen / stellingen op basis van de beschikbare middelen waar u in de dagelijkse praktijk mee werkt.

Het informatiesysteem (de hulpmiddelen) waar ik in de dagelijkse praktijk mee werk…

| | Sterk mee oneens | Mee oneens | Neutraal | Mee eens | Sterk mee eens |
|---|---|---|---|---|---|
| ..geeft mij onmiddellijk toegang tot de informatie die ik nodig heb | O | O | O | ☒ | O |
| ..laat mij vaak wachten op een respons | O | O | ☒ | O | O |
| ..werkt altijd naar behoren | O | O | O | ☒ | O |
| ..zorgt ervoor dat geen belangrijke informatie verloren gaat | O | O | O | ☒ | O |
| ..brengt informatie samen die uit verschillende delen van de organisatie komen | O | O | O | ☒ | O |
| ..geeft een goed overzicht van het verloop van de incidentafhandeling | O | O | ☒ | O | O |
| ..is voldoende ondersteunend om informatie te delen binnen mijn eigen organisatie | O | ☒ | O | O | O |
| ..is eenvoudig te gebruiken | O | ☒ | O | O | O |
| ..stelt mij in staat aan de informatie te komen die ik nodig heb | O | O | O | ☒ | O |
| ..geeft informatie duidelijk weer | O | O | ☒ | O | O |
| ..geeft mij onmiddellijk toegang tot informatie die buiten het bereik van mijn organisatie ligt | O | ☒ | O | O | O |
| ..reageert snel op een opdracht | O | O | ☒ | O | O |
| ..werkt betrouwbaar | O | ☒ | O | O | O |
| ..maakt het goed mogelijk oudere, belangrijke informatie terug te vinden | O | ☒ | O | O | O |
| ..integreert informatie uit verschillende bronnen | O | O | ☒ | O | O |
| ..geeft een volledig beeld van de incidentafhandeling | O | O | O | ☒ | O |
| ..is voldoende ondersteunend om informatie te delen met andere organisatie | O | O | O | ☒ | O |
| ..behoeft weinig opleidingstijd | O | O | O | ☒ | O |
| ..is niet voldoende om in mijn informatiebehoefte te voorzien | O | O | O | ☒ | O |
| ..presenteert mij alle informatie overzichtelijk aan mij | O | ☒ | O | O | O |
| ..vertoont weinig storingen | O | ☒ | O | O | O |
| ..maakt het goed mogelijk om gegevens (kennis van de situatie) op te slaan | O | O | ☒ | O | O |
| ..verzamelt alle informatie op één plek | O | ☒ | O | O | O |
| ..brengt alle veranderingen van het verloop van het incident goed in beeld | O | O | O | ☒ | O |
| ..doet gemakkelijk wat ik wil | O | O | ☒ | O | O |
| ..volstaat bij het afhandelen van een incident | O | O | ☒ | O | O |
| ..behoedt mij voor informatie overload | O | O | ☒ | O | O |

4

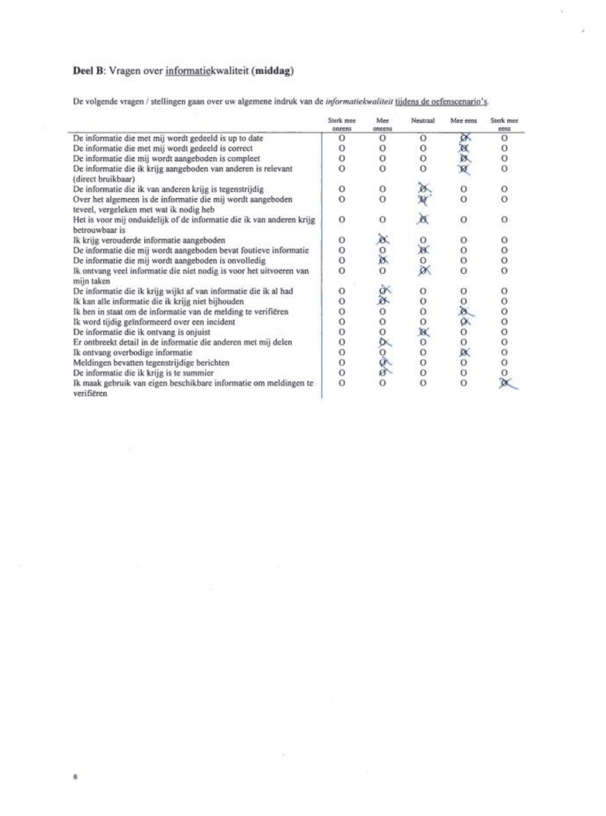


**Deel B**: Vragen over informatiekwaliteit (**einde ochtend**)

De volgende vragen / stellingen gaan over uw algemene indruk van de *informatiekwaliteit* tijdens de oefenscenario's.

| | Sterk mee oneens | Mee oneens | Neutraal | Mee eens | Sterk mee eens |
|---|---|---|---|---|---|
| De informatie die met mij wordt gedeeld is up to date | ○ | ○ | ☒ | ○ | ○ |
| De informatie die met mij wordt gedeeld is correct | ○ | ○ | ○ | ☒ | ○ |
| De informatie die mij wordt aangeboden is compleet | ○ | ○ | ○ | ☒ | ○ |
| De informatie die ik krijg aangeboden van anderen is relevant (direct bruikbaar) | ○ | ○ | ○ | ☒ | ○ |
| De informatie die ik van anderen krijg is tegenstrijdig | ○ | ○ | ☒ | ○ | ○ |
| Over het algemeen is de informatie die mij wordt aangeboden teveel, vergeleken met wat ik nodig heb | ○ | ○ | ☒ | ○ | ○ |
| Het is voor mij onduidelijk of de informatie die ik van anderen krijg betrouwbaar is | ○ | ☒ | ○ | ○ | ○ |
| Ik krijg verouderde informatie aangeboden | ○ | ○ | ☒ | ○ | ○ |
| De informatie die mij wordt aangeboden bevat foutieve informatie | ○ | ○ | ☒ | ○ | ○ |
| De informatie die mij wordt aangeboden is onvolledig | ○ | ○ | ○ | ☒ | ○ |
| Ik ontvang veel informatie die niet nodig is voor het uitvoeren van mijn taken | ○ | ○ | ☒ | ○ | ○ |
| De informatie die ik krijg wijkt af van informatie die ik al had | ○ | ○ | ○ | ☒ | ○ |
| Ik kan alle informatie die ik krijg niet bijhouden | ○ | ☒ | ○ | ○ | ○ |
| Ik ben in staat om de informatie van de melding te verifiëren | ○ | ○ | ○ | ☒ | ○ |
| Ik word tijdig geïnformeerd over een incident | ○ | ○ | ○ | ☒ | ○ |
| De informatie die ik ontvang is onjuist | ○ | ○ | ☒ | ○ | ○ |
| Er ontbreekt detail in de informatie die anderen met mij delen | ○ | ○ | ○ | ☒ | ○ |
| Ik ontvang overbodige informatie | ○ | ○ | ☒ | ○ | ○ |
| Meldingen bevatten tegenstrijdige berichten | ○ | ○ | ☒ | ○ | ○ |
| De informatie die ik krijg is te summier | ○ | ○ | ☒ | ○ | ○ |
| Ik maak gebruik van eigen beschikbare informatie om meldingen te verifiëren | ○ | ○ | ○ | ☒ | ○ |

5

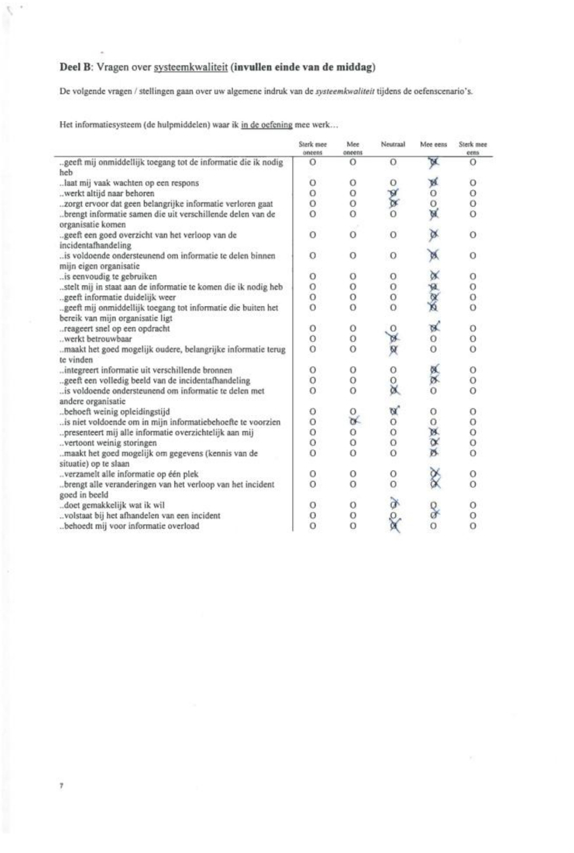


**Deel B**: Vragen over informatiekwaliteit (**middag**)

De volgende vragen / stellingen gaan over uw algemene indruk van de *informatiekwaliteit* tijdens de oefenscenario's.

| | Sterk mee oneens | Mee oneens | Neutraal | Mee eens | Sterk mee eens |
|---|---|---|---|---|---|
| De informatie die met mij wordt gedeeld is up to date | ○ | ○ | ○ | ☒ | ○ |
| De informatie die met mij wordt gedeeld is correct | ○ | ○ | ○ | ☒ | ○ |
| De informatie die mij wordt aangeboden is compleet | ○ | ○ | ○ | ☒ | ○ |
| De informatie die ik krijg aangeboden van anderen is relevant (direct bruikbaar) | ○ | ○ | ○ | ☒ | ○ |
| De informatie die ik van anderen krijg is tegenstrijdig | ○ | ○ | ☒ | ○ | ○ |
| Over het algemeen is de informatie die mij wordt aangeboden teveel, vergeleken met wat ik nodig heb | ○ | ○ | ☒ | ○ | ○ |
| Het is voor mij onduidelijk of de informatie die ik van anderen krijg betrouwbaar is | ○ | ○ | ☒ | ○ | ○ |
| Ik krijg verouderde informatie aangeboden | ○ | ☒ | ○ | ○ | ○ |
| De informatie die mij wordt aangeboden bevat foutieve informatie | ○ | ○ | ☒ | ○ | ○ |
| De informatie die mij wordt aangeboden is onvolledig | ○ | ☒ | ○ | ○ | ○ |
| Ik ontvang veel informatie die niet nodig is voor het uitvoeren van mijn taken | ○ | ○ | ☒ | ○ | ○ |
| De informatie die ik krijg wijkt af van informatie die ik al had | ○ | ☒ | ○ | ○ | ○ |
| Ik kan alle informatie die ik krijg niet bijhouden | ○ | ☒ | ○ | ○ | ○ |
| Ik ben in staat om de informatie van de melding te verifiëren | ○ | ○ | ○ | ☒ | ○ |
| Ik word tijdig geïnformeerd over een incident | ○ | ○ | ○ | ☒ | ○ |
| De informatie die ik ontvang is onjuist | ○ | ○ | ☒ | ○ | ○ |
| Er ontbreekt detail in de informatie die anderen met mij delen | ○ | ☒ | ○ | ○ | ○ |
| Ik ontvang overbodige informatie | ○ | ○ | ○ | ☒ | ○ |
| Meldingen bevatten tegenstrijdige berichten | ○ | ☒ | ○ | ○ | ○ |
| De informatie die ik krijg is te summier | ○ | ☒ | ○ | ○ | ○ |
| Ik maak gebruik van eigen beschikbare informatie om meldingen te verifiëren | ○ | ○ | ○ | ○ | ☒ |

6



**Deel B**: Vragen over systeemkwaliteit (**invullen einde van de middag**)

De volgende vragen / stellingen gaan over uw algemene indruk van de *systeemkwaliteit* tijdens de oefenscenario's.

Het informatiesysteem (de hulpmiddelen) waar ik in de oefening mee werk…

| | Sterk mee oneens | Mee oneens | Neutraal | Mee eens | Sterk mee eens |
|---|---|---|---|---|---|
| ..geeft mij onmiddellijk toegang tot de informatie die ik nodig heb | ○ | ○ | ○ | ☒ | ○ |
| ..laat mij vaak wachten op een respons | ○ | ○ | ○ | ☒ | ○ |
| ..werkt altijd naar behoren | ○ | ○ | ☒ | ○ | ○ |
| ..zorgt ervoor dat geen belangrijke informatie verloren gaat | ○ | ○ | ☒ | ○ | ○ |
| ..brengt informatie samen die uit verschillende delen van de organisatie komen | ○ | ○ | ○ | ☒ | ○ |
| ..geeft een goed overzicht van het verloop van de incidentafhandeling | ○ | ○ | ○ | ☒ | ○ |
| ..is voldoende ondersteunend om informatie te delen binnen mijn eigen organisatie | ○ | ○ | ○ | ☒ | ○ |
| ..is eenvoudig te gebruiken | ○ | ○ | ○ | ☒ | ○ |
| ..stelt mij in staat aan de informatie te komen die ik nodig heb | ○ | ○ | ○ | ☒ | ○ |
| ..geeft informatie duidelijk weer | ○ | ○ | ○ | ☒ | ○ |
| ..geeft mij onmiddellijk toegang tot informatie die buiten het bereik van mijn organisatie ligt | ○ | ○ | ○ | ☒ | ○ |
| ..reageert snel op een opdracht | ○ | ○ | ○ | ☒ | ○ |
| ..werkt betrouwbaar | ○ | ○ | ☒ | ○ | ○ |
| ..maakt het goed mogelijk oudere, belangrijke informatie terug te vinden | ○ | ○ | ☒ | ○ | ○ |
| ..integreert informatie uit verschillende bronnen | ○ | ○ | ○ | ☒ | ○ |
| ..geeft een volledig beeld van de incidentafhandeling | ○ | ○ | ○ | ☒ | ○ |
| ..is voldoende ondersteunend om informatie te delen met andere organisatie | ○ | ○ | ☒ | ○ | ○ |
| ..behoeft weinig opleidingstijd | ○ | ○ | ☒ | ○ | ○ |
| ..is niet voldoende om in mijn informatiebehoefte te voorzien | ○ | ☒ | ○ | ○ | ○ |
| ..presenteert mij alle informatie overzichtelijk aan mij | ○ | ○ | ○ | ☒ | ○ |
| ..vertoont weinig storingen | ○ | ○ | ○ | ☒ | ○ |
| ..maakt het goed mogelijk om gegevens (kennis van de situatie) op te slaan | ○ | ○ | ○ | ☒ | ○ |
| ..verzamelt alle informatie op één plek | ○ | ○ | ○ | ☒ | ○ |
| ..brengt alle veranderingen van het verloop van het incident goed in beeld | ○ | ○ | ○ | ☒ | ○ |
| ..doet gemakkelijk wat ik wil | ○ | ○ | ☒ | ○ | ○ |
| ..volstaat bij het afhandelen van een incident | ○ | ○ | ○ | ☒ | ○ |
| ..behoedt mij voor informatie overload | ○ | ○ | ☒ | ○ | ○ |

7

*Respondent 5:*

## Vragenlijst net-centrische oefening (10 December 2015)

Beste respondent,

Deze vragenlijst gaat over een onderzoek naar de informatie- en systeemkwaliteit van de crisisafhandeling. De resultaten van deze vragenlijst zullen worden gebruikt voor wetenschappelijk onderzoek naar de knelpunten rond de informatievoorziening van Crisis Management. Dit onderzoek wordt uitgevoerd door Rijkswaterstaat in samenwerking met de Vrije Universiteit Amsterdam.

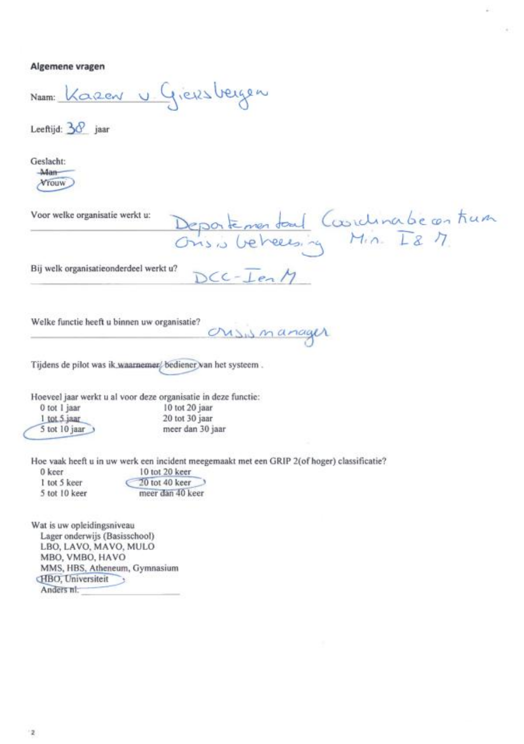
Uw bijdrage kan een belangrijke input leveren om de informatievoorziening verder te kunnen verbeteren waardoor betrokken organisaties in de toekomst nog beter kunnen samenwerken bij de dagelijkse afhandeling van de incidenten / crisissen.

In de oefening worden verschillende scenario's nagespeeld. Wij willen U vragen om deze vragenlijst zo zorgvuldig mogelijk in te vullen.

De vragenlijst bestaat uit twee delen:
Deel A: invullen voor de oefening
Deel B: invullen tijdens de oefening

Alvast bedankt voor de moeite!

1



**Algemene vragen**

Naam: Karen v Giersbergen

Leeftijd: 38 jaar

Geslacht:
~~Man~~
[✓ Vrouw]

Voor welke organisatie werkt u: Departementaal Coordinatiecentrum Crisisbeheersing Min. I & M

Bij welk organisatieonderdeel werkt u? DCC-I en M

Welke functie heeft u binnen uw organisatie? crisismanager

Tijdens de pilot was ik ~~waarnemer~~/ [✓ bediener] van het systeem .

Hoeveel jaar werkt u al voor deze organisatie in deze functie:

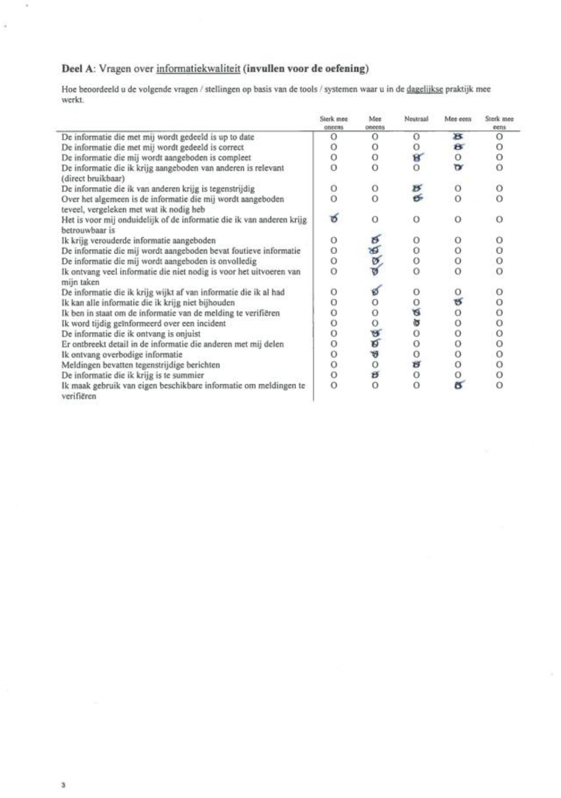
| | |
|---|---|
| 0 tot 1 jaar | 10 tot 20 jaar |
| 1 tot 5 jaar | 20 tot 30 jaar |
| [✓ 5 tot 10 jaar] | meer dan 30 jaar |

Hoe vaak heeft u in uw werk een incident meegemaakt met een GRIP 2(of hoger) classificatie?

| | |
|---|---|
| 0 keer | 10 tot 20 keer |
| 1 tot 5 keer | [✓ 20 tot 40 keer] |
| 5 tot 10 keer | meer dan 40 keer |

Wat is uw opleidingsniveau
- Lager onderwijs (Basisschool)
- LBO, LAVO, MAVO, MULO
- MBO, VMBO, HAVO
- MMS, HBS, Atheneum, Gymnasium
- [✓ HBO, Universiteit]
- Anders nl: ______

2

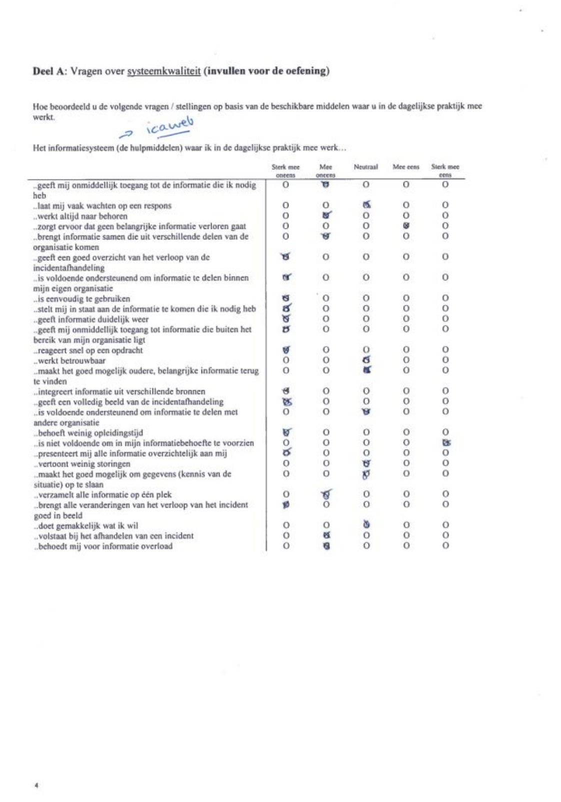


**Deel A**: Vragen over informatiekwaliteit **(invullen voor de oefening)**

Hoe beoordeeld u de volgende vragen / stellingen op basis van de tools / systemen waar u in de dagelijkse praktijk mee werkt.

| | Sterk mee oneens | Mee oneens | Neutraal | Mee eens | Sterk mee eens |
|---|---|---|---|---|---|
| De informatie die met mij wordt gedeeld is up to date | ○ | ○ | ○ | ☑ | ○ |
| De informatie die met mij wordt gedeeld is correct | ○ | ○ | ○ | ☑ | ○ |
| De informatie die mij wordt aangeboden is compleet | ○ | ○ | ☑ | ○ | ○ |
| De informatie die ik krijg aangeboden van anderen is relevant (direct bruikbaar) | ○ | ○ | ○ | ☑ | ○ |
| De informatie die ik van anderen krijg is tegenstrijdig | ○ | ○ | ☑ | ○ | ○ |
| Over het algemeen is de informatie die mij wordt aangeboden teveel, vergeleken met wat ik nodig heb | ○ | ○ | ☑ | ○ | ○ |
| Het is voor mij onduidelijk of de informatie die ik van anderen krijg betrouwbaar is | ☑ | ○ | ○ | ○ | ○ |
| Ik krijg verouderde informatie aangeboden | ○ | ☑ | ○ | ○ | ○ |
| De informatie die mij wordt aangeboden bevat foutieve informatie | ○ | ☑ | ○ | ○ | ○ |
| De informatie die mij wordt aangeboden is onvolledig | ○ | ☑ | ○ | ○ | ○ |
| Ik ontvang veel informatie die niet nodig is voor het uitvoeren van mijn taken | ○ | ☑ | ○ | ○ | ○ |
| De informatie die ik krijg wijkt af van informatie die ik al had | ○ | ☑ | ○ | ○ | ○ |
| Ik kan alle informatie die ik krijg niet bijhouden | ○ | ○ | ○ | ☑ | ○ |
| Ik ben in staat om de informatie van de melding te verifiëren | ○ | ○ | ☑ | ○ | ○ |
| Ik word tijdig geïnformeerd over een incident | ○ | ○ | ☑ | ○ | ○ |
| De informatie die ik ontvang is onjuist | ○ | ☑ | ○ | ○ | ○ |
| Er ontbreekt detail in de informatie die anderen met mij delen | ○ | ☑ | ○ | ○ | ○ |
| Ik ontvang overbodige informatie | ○ | ☑ | ○ | ○ | ○ |
| Meldingen bevatten tegenstrijdige berichten | ○ | ○ | ☑ | ○ | ○ |
| De informatie die ik krijg is te summier | ○ | ☑ | ○ | ○ | ○ |
| Ik maak gebruik van eigen beschikbare informatie om meldingen te verifiëren | ○ | ○ | ○ | ☑ | ○ |

3



**Deel A**: Vragen over systeemkwaliteit **(invullen voor de oefening)**

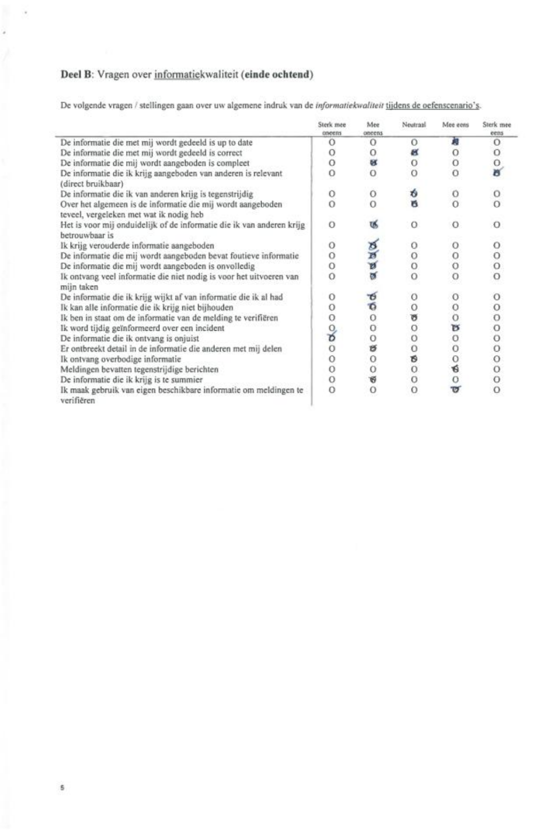
Hoe beoordeeld u de volgende vragen / stellingen op basis van de beschikbare middelen waar u in de dagelijkse praktijk mee werkt.

→ icaweb

Het informatiesysteem (de hulpmiddelen) waar ik in de dagelijkse praktijk mee werk…

| | Sterk mee oneens | Mee oneens | Neutraal | Mee eens | Sterk mee eens |
|---|---|---|---|---|---|
| ..geeft mij onmiddellijk toegang tot de informatie die ik nodig heb | ○ | ☑ | ○ | ○ | ○ |
| ..laat mij vaak wachten op een respons | ○ | ○ | ☑ | ○ | ○ |
| ..werkt altijd naar behoren | ○ | ☑ | ○ | ○ | ○ |
| ..zorgt ervoor dat geen belangrijke informatie verloren gaat | ○ | ○ | ○ | ☑ | ○ |
| ..brengt informatie samen die uit verschillende delen van de organisatie komen | ○ | ☑ | ○ | ○ | ○ |
| ..geeft een goed overzicht van het verloop van de incidentafhandeling | ☑ | ○ | ○ | ○ | ○ |
| ..is voldoende ondersteunend om informatie te delen binnen mijn eigen organisatie | ☑ | ○ | ○ | ○ | ○ |
| ..is eenvoudig te gebruiken | ☑ | ○ | ○ | ○ | ○ |
| ..stelt mij in staat aan de informatie te komen die ik nodig heb | ☑ | ○ | ○ | ○ | ○ |
| ..geeft informatie duidelijk weer | ☑ | ○ | ○ | ○ | ○ |
| ..geeft mij onmiddellijk toegang tot informatie die buiten het bereik van mijn organisatie ligt | ☑ | ○ | ○ | ○ | ○ |
| ..reageert snel op een opdracht | ☑ | ○ | ○ | ○ | ○ |
| ..werkt betrouwbaar | ○ | ○ | ☑ | ○ | ○ |
| ..maakt het goed mogelijk oudere, belangrijke informatie terug te vinden | ○ | ○ | ☑ | ○ | ○ |
| ..integreert informatie uit verschillende bronnen | ☑ | ○ | ○ | ○ | ○ |
| ..geeft een volledig beeld van de incidentafhandeling | ☑ | ○ | ○ | ○ | ○ |
| ..is voldoende ondersteunend om informatie te delen met andere organisatie | ○ | ○ | ☑ | ○ | ○ |
| ..behoeft weinig opleidingstijd | ☑ | ○ | ○ | ○ | ○ |
| ..is niet voldoende om in mijn informatiebehoefte te voorzien | ○ | ○ | ○ | ○ | ☑ |
| ..presenteert mij alle informatie overzichtelijk aan mij | ☑ | ○ | ○ | ○ | ○ |
| ..vertoont weinig storingen | ○ | ○ | ☑ | ○ | ○ |
| ..maakt het goed mogelijk om gegevens (kennis van de situatie) op te slaan | ○ | ○ | ☑ | ○ | ○ |
| ..verzamelt alle informatie op één plek | ○ | ☑ | ○ | ○ | ○ |
| ..brengt alle veranderingen van het verloop van het incident goed in beeld | ☑ | ○ | ○ | ○ | ○ |
| ..doet gemakkelijk wat ik wil | ○ | ○ | ☑ | ○ | ○ |
| ..volstaat bij het afhandelen van een incident | ○ | ☑ | ○ | ○ | ○ |
| ..behoedt mij voor informatie overload | ○ | ☑ | ○ | ○ | ○ |

4



**Deel B**: Vragen over informatiekwaliteit (**einde ochtend**)

De volgende vragen / stellingen gaan over uw algemene indruk van de *informatiekwaliteit* tijdens de oefenscenario's.

| | Sterk mee oneens | Mee oneens | Neutraal | Mee eens | Sterk mee eens |
|---|---|---|---|---|---|
| De informatie die met mij wordt gedeeld is up to date | O | O | O | [✓ O] | O |
| De informatie die met mij wordt gedeeld is correct | O | O | [✓ O] | O | O |
| De informatie die mij wordt aangeboden is compleet | O | [✓ O] | O | O | O |
| De informatie die ik krijg aangeboden van anderen is relevant (direct bruikbaar) | O | O | O | O | [✓ O] |
| De informatie die ik van anderen krijg is tegenstrijdig | O | O | [✓ O] | O | O |
| Over het algemeen is de informatie die mij wordt aangeboden teveel, vergeleken met wat ik nodig heb | O | O | [✓ O] | O | O |
| Het is voor mij onduidelijk of de informatie die ik van anderen krijg betrouwbaar is | O | [✓ O] | O | O | O |
| Ik krijg verouderde informatie aangeboden | O | [✓ O] | O | O | O |
| De informatie die mij wordt aangeboden bevat foutieve informatie | O | [✓ O] | O | O | O |
| De informatie die mij wordt aangeboden is onvolledig | O | [✓ O] | O | O | O |
| Ik ontvang veel informatie die niet nodig is voor het uitvoeren van mijn taken | O | [✓ O] | O | O | O |
| De informatie die ik krijg wijkt af van informatie die ik al had | O | [✓ O] | O | O | O |
| Ik kan alle informatie die ik krijg niet bijhouden | O | [✓ O] | O | O | O |
| Ik ben in staat om de informatie van de melding te verifiëren | O | O | [✓ O] | O | O |
| Ik word tijdig geïnformeerd over een incident | O | O | O | [✓ O] | O |
| De informatie die ik ontvang is onjuist | [✓ O] | O | O | O | O |
| Er ontbreekt detail in de informatie die anderen met mij delen | O | [✓ O] | O | O | O |
| Ik ontvang overbodige informatie | O | O | [✓ O] | O | O |
| Meldingen bevatten tegenstrijdige berichten | O | O | O | [✓ O] | O |
| De informatie die ik krijg is te summier | O | [✓ O] | O | O | O |
| Ik maak gebruik van eigen beschikbare informatie om meldingen te verifiëren | O | O | O | [✓ O] | O |

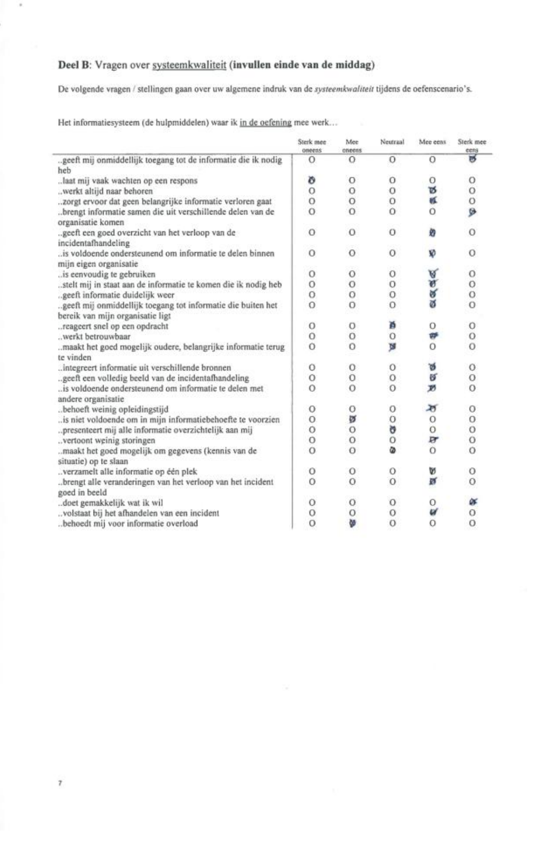
5

**Deel B**: Vragen over informatiekwaliteit (**middag**)

De volgende vragen / stellingen gaan over uw algemene indruk van de *informatiekwaliteit* tijdens de oefenscenario's.

| | Sterk mee oneens | Mee oneens | Neutraal | Mee eens | Sterk mee eens |
|---|---|---|---|---|---|
| De informatie die met mij wordt gedeeld is up to date | O | O | O | [✓ O] | O |
| De informatie die met mij wordt gedeeld is correct | O | O | O | [✓ O] | O |
| De informatie die mij wordt aangeboden is compleet | O | O | [✓ O] | O | O |
| De informatie die ik krijg aangeboden van anderen is relevant (direct bruikbaar) | O | O | O | [✓ O] | O |
| De informatie die ik van anderen krijg is tegenstrijdig | O | O | [✓ O] | O | O |
| Over het algemeen is de informatie die mij wordt aangeboden teveel, vergeleken met wat ik nodig heb | O | [✓ O] | O | O | O |
| Het is voor mij onduidelijk of de informatie die ik van anderen krijg betrouwbaar is | O | [✓ O] | O | O | O |
| Ik krijg verouderde informatie aangeboden | O | [✓ O] | O | O | O |
| De informatie die mij wordt aangeboden bevat foutieve informatie | O | [✓ O] | O | O | O |
| De informatie die mij wordt aangeboden is onvolledig | O | [✓ O] | O | O | O |
| Ik ontvang veel informatie die niet nodig is voor het uitvoeren van mijn taken | O | O | [✓ O] | O | O |
| De informatie die ik krijg wijkt af van informatie die ik al had | O | [✓ O] | O | O | O |
| Ik kan alle informatie die ik krijg niet bijhouden | O | [✓ O] | O | O | O |
| Ik ben in staat om de informatie van de melding te verifiëren | O | O | [✓ O] | O | O |
| Ik word tijdig geïnformeerd over een incident | O | O | O | [✓ O] | O |
| De informatie die ik ontvang is onjuist | O | [✓ O] | O | O | O |
| Er ontbreekt detail in de informatie die anderen met mij delen | O | [✓ O] | O | O | O |
| Ik ontvang overbodige informatie | O | [✓ O] | O | O | O |
| Meldingen bevatten tegenstrijdige berichten | O | O | [✓ O] | O | O |
| De informatie die ik krijg is te summier | O | [✓ O] | O | O | O |
| Ik maak gebruik van eigen beschikbare informatie om meldingen te verifiëren | O | O | [✓ O] | O | O |

6



**Deel B**: Vragen over systeemkwaliteit (**invullen einde van de middag**)

De volgende vragen / stellingen gaan over uw algemene indruk van de *systeemkwaliteit* tijdens de oefenscenario's.

Het informatiesysteem (de hulpmiddelen) waar ik in de oefening mee werk…

| | Sterk mee oneens | Mee oneens | Neutraal | Mee eens | Sterk mee eens |
|---|---|---|---|---|---|
| ..geeft mij onmiddellijk toegang tot de informatie die ik nodig heb | O | O | O | O | [✓ O] |
| ..laat mij vaak wachten op een respons | [✓ O] | O | O | O | O |
| ..werkt altijd naar behoren | O | O | O | [✓ O] | O |
| ..zorgt ervoor dat geen belangrijke informatie verloren gaat | O | O | O | [✓ O] | O |
| ..brengt informatie samen die uit verschillende delen van de organisatie komen | O | O | O | O | [✓ O] |
| ..geeft een goed overzicht van het verloop van de incidentafhandeling | O | O | O | [✓ O] | O |
| ..is voldoende ondersteunend om informatie te delen binnen mijn eigen organisatie | O | O | O | [✓ O] | O |
| ..is eenvoudig te gebruiken | O | O | O | [✓ O] | O |
| ..stelt mij in staat aan de informatie te komen die ik nodig heb | O | O | O | [✓ O] | O |
| ..geeft informatie duidelijk weer | O | O | O | [✓ O] | O |
| ..geeft mij onmiddellijk toegang tot informatie die buiten het bereik van mijn organisatie ligt | O | O | O | [✓ O] | O |
| ..reageert snel op een opdracht | O | O | [✓ O] | O | O |
| ..werkt betrouwbaar | O | O | O | [✓ O] | O |
| ..maakt het goed mogelijk oudere, belangrijke informatie terug te vinden | O | O | [✓ O] | O | O |
| ..integreert informatie uit verschillende bronnen | O | O | O | [✓ O] | O |
| ..geeft een volledig beeld van de incidentafhandeling | O | O | O | [✓ O] | O |
| ..is voldoende ondersteunend om informatie te delen met andere organisatie | O | O | O | [✓ O] | O |
| ..behoeft weinig opleidingstijd | O | O | O | [✓ O] | O |
| ..is niet voldoende om in mijn informatiebehoefte te voorzien | O | [✓ O] | O | O | O |
| ..presenteert mij alle informatie overzichtelijk aan mij | O | O | [✓ O] | O | O |
| ..vertoont weinig storingen | O | O | O | [✓ O] | O |
| ..maakt het goed mogelijk om gegevens (kennis van de situatie) op te slaan | O | O | [✓ O] | O | O |
| ..verzamelt alle informatie op één plek | O | O | O | [✓ O] | O |
| ..brengt alle veranderingen van het verloop van het incident goed in beeld | O | O | O | [✓ O] | O |
| ..doet gemakkelijk wat ik wil | O | O | O | O | [✓ O] |
| ..volstaat bij het afhandelen van een incident | O | O | O | [✓ O] | O |
| ..behoedt mij voor informatie overload | O | [✓ O] | O | O | O |

7

*Respondent 6:*

Vragenlijst net-centrische oefening (10 December 2015)

Beste respondent,

Deze vragenlijst gaat over een onderzoek naar de informatie- en systeemkwaliteit van de crisisafhandeling. De resultaten van deze vragenlijst zullen worden gebruikt voor wetenschappelijk onderzoek naar de knelpunten rond de informatievoorziening van Crisis Management. Dit onderzoek wordt uitgevoerd door Rijkswaterstaat in samenwerking met de Vrije Universiteit Amsterdam.

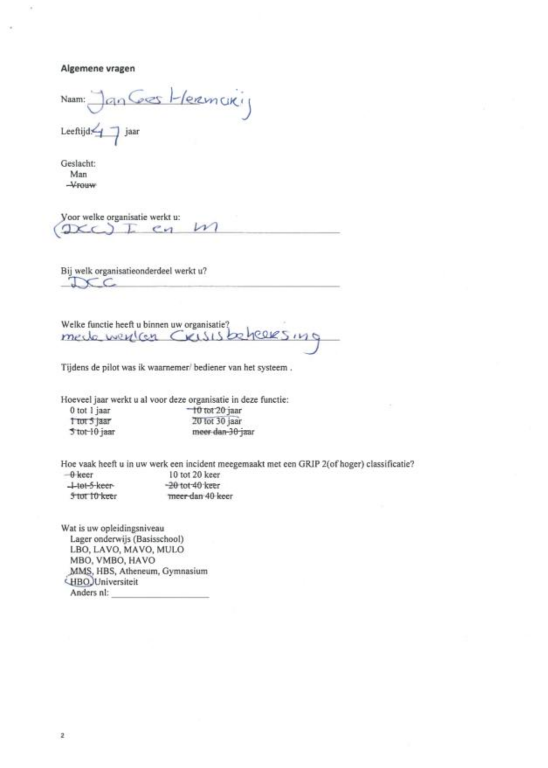
Uw bijdrage kan een belangrijke input leveren om de informatievoorziening verder te kunnen verbeteren waardoor betrokken organisaties in de toekomst nog beter kunnen samenwerken bij de dagelijkse afhandeling van de incidenten / crisissen.

In de oefening worden verschillende scenario's nagespeeld. Wij willen U vragen om deze vragenlijst zo zorgvuldig mogelijk in te vullen.

De vragenlijst bestaat uit twee delen:
Deel A: invullen voor de oefening
Deel B: invullen tijdens de oefening

Alvast bedankt voor de moeite!

1



**Algemene vragen**

Naam: Jan Cees Heemskij

Leeftijd: 47 jaar

Geslacht:
Man
~~Vrouw~~

Voor welke organisatie werkt u:
(DCC) I en M

Bij welk organisatieonderdeel werkt u?
DCC

Welke functie heeft u binnen uw organisatie?
medewerker Crisisbeheersing

Tijdens de pilot was ik waarnemer/ bediener van het systeem .

Hoeveel jaar werkt u al voor deze organisatie in deze functie:
0 tot 1 jaar
~~1 tot 5 jaar~~
~~5 tot 10 jaar~~
~~10 tot 20 jaar~~
20 tot 30 jaar
~~meer dan 30 jaar~~

Hoe vaak heeft u in uw werk een incident meegemaakt met een GRIP 2(of hoger) classificatie?
~~0 keer~~
~~1 tot 5 keer~~
~~5 tot 10 keer~~
10 tot 20 keer
~~20 tot 40 keer~~
~~meer dan 40 keer~~

Wat is uw opleidingsniveau
Lager onderwijs (Basisschool)
LBO, LAVO, MAVO, MULO
MBO, VMBO, HAVO
MMS, HBS, Atheneum, Gymnasium
[✓ HBO] Universiteit
Anders nl: ____________________

2

ICaweb

**Deel A**: Vragen over informatiekwaliteit **(invullen voor de oefening)**

Hoe beoordeeld u de volgende vragen / stellingen op basis van de tools / systemen waar u in de dagelijkse praktijk mee werkt.

| | Sterk mee oneens | Mee oneens | Neutraal | Mee eens | Sterk mee eens |
|---|---|---|---|---|---|
| De informatie die met mij wordt gedeeld is up to date | ○ | ○ | ● | ○ | ○ |
| De informatie die met mij wordt gedeeld is correct | ○ | ○ | ○ | ● | ○ |
| De informatie die mij wordt aangeboden is compleet | ○ | ○ | ● | ○ | ○ |
| De informatie die ik krijg aangeboden van anderen is relevant (direct bruikbaar) | ○ | ○ | ● | ○ | ○ |
| De informatie die ik van anderen krijg is tegenstrijdig | ○ | ○ | ● | ○ | ○ |
| Over het algemeen is de informatie die mij wordt aangeboden teveel, vergeleken met wat ik nodig heb | ○ | ● | ○ | ○ | ○ |
| Het is voor mij onduidelijk of de informatie die ik van anderen krijg betrouwbaar is | ○ | ● | ○ | ○ | ○ |
| Ik krijg verouderde informatie aangeboden | ○ | ○ | ● | ○ | ○ |
| De informatie die mij wordt aangeboden bevat foutieve informatie | ○ | ○ | ● | ○ | ○ |
| De informatie die mij wordt aangeboden is onvolledig | ○ | ○ | ○ | ● | ○ |
| Ik ontvang veel informatie die niet nodig is voor het uitvoeren van mijn taken | ○ | ○ | ● | ○ | ○ |
| De informatie die ik krijg wijkt af van informatie die ik al had | ○ | ○ | ● | ○ | ○ |
| Ik kan alle informatie die ik krijg niet bijhouden | ○ | ● | ○ | ○ | ○ |
| Ik ben in staat om de informatie van de melding te verifiëren | ○ | ○ | ● | ○ | ○ |
| Ik word tijdig geïnformeerd over een incident | ○ | ○ | ● | ○ | ○ |
| De informatie die ik ontvang is onjuist | ○ | ● | ○ | ○ | ○ |
| Er ontbreekt detail in de informatie die anderen met mij delen | ○ | ○ | ● | ○ | ○ |
| Ik ontvang overbodige informatie | ○ | ○ | ● | ○ | ○ |
| Meldingen bevatten tegenstrijdige berichten | ○ | ○ | ● | ○ | ○ |
| De informatie die ik krijg is te summier | ○ | ○ | ○ | ● | ○ |
| Ik maak gebruik van eigen beschikbare informatie om meldingen te verifiëren | ○ | ○ | ● | ○ | ○ |

3

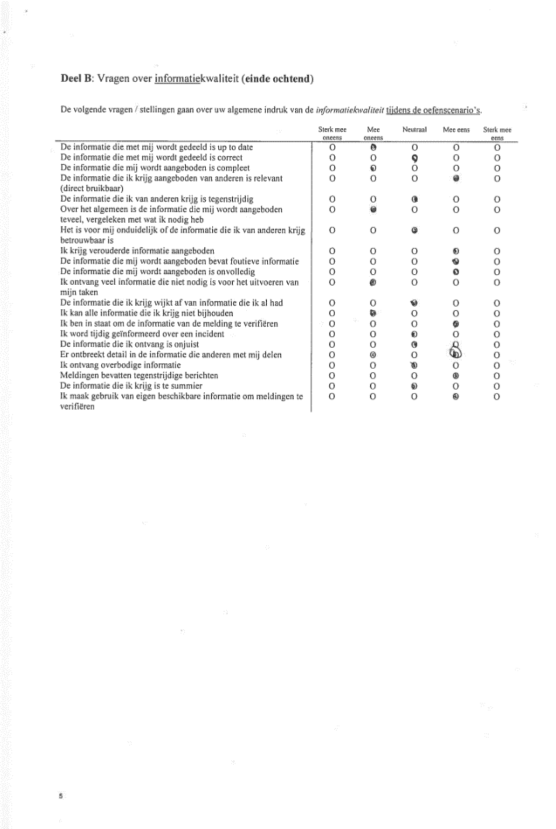
**Deel A**: Vragen over systeemkwaliteit **(invullen voor de oefening)**

Hoe beoordeeld u de volgende vragen / stellingen op basis van de beschikbare middelen waar u in de dagelijkse praktijk mee werkt.

Het informatiesysteem (de hulpmiddelen) waar ik in de dagelijkse praktijk mee werk…

| | Sterk mee oneens | Mee oneens | Neutraal | Mee eens | Sterk mee eens |
|---|---|---|---|---|---|
| ..geeft mij onmiddellijk toegang tot de informatie die ik nodig heb | ○ | ○ | ● | ○ | ○ |
| ..laat mij vaak wachten op een respons | ○ | ● | ○ | ○ | ○ |
| ..werkt altijd naar behoren | ○ | ● | ○ | ○ | ○ |
| ..zorgt ervoor dat geen belangrijke informatie verloren gaat | ○ | ○ | ● | ○ | ○ |
| ..brengt informatie samen die uit verschillende delen van de organisatie komen | ○ | ○ | ● | ○ | ○ |
| ..geeft een goed overzicht van het verloop van de incidentafhandeling | ○ | ○ | ● | ○ | ○ |
| ..is voldoende ondersteunend om informatie te delen binnen mijn eigen organisatie | ○ | ● | ○ | ○ | ○ |
| ..is eenvoudig te gebruiken | ○ | ● | ○ | ○ | ○ |
| ..stelt mij in staat aan de informatie te komen die ik nodig heb | ○ | ○ | ● | ○ | ○ |
| ..geeft informatie duidelijk weer | ○ | ○ | ● | ○ | ○ |
| ..geeft mij onmiddellijk toegang tot informatie die buiten het bereik van mijn organisatie ligt | ○ | ○ | ● | ○ | ○ |
| ..reageert snel op een opdracht | ○ | ○ | ● | ○ | ○ |
| ..werkt betrouwbaar | ○ | ○ | ● | ○ | ○ |
| ..maakt het goed mogelijk oudere, belangrijke informatie terug te vinden | ○ | ○ | ○ | ● | ○ |
| ..integreert informatie uit verschillende bronnen | ○ | ○ | ● | ○ | ○ |
| ..geeft een volledig beeld van de incidentafhandeling | ○ | ○ | ● | ○ | ○ |
| ..is voldoende ondersteunend om informatie te delen met andere organisatie | ○ | ○ | ● | ○ | ○ |
| ..behoeft weinig opleidingstijd | ○ | ● | ○ | ○ | ○ |
| ..is niet voldoende om in mijn informatiebehoefte te voorzien | ○ | ○ | ● | ○ | ○ |
| ..presenteert mij alle informatie overzichtelijk aan mij | ○ | ● | ○ | ○ | ○ |
| ..vertoont weinig storingen | ○ | ● | ○ | ○ | ○ |
| ..maakt het goed mogelijk om gegevens (kennis van de situatie) op te slaan | ○ | ○ | ● | ○ | ○ |
| ..verzamelt alle informatie op één plek | ○ | ○ | ● | ○ | ○ |
| ..brengt alle veranderingen van het verloop van het incident goed in beeld | ○ | ○ | ● | ○ | ○ |
| ..doet gemakkelijk wat ik wil | ○ | ○ | ● | ○ | ○ |
| ..volstaat bij het afhandelen van een incident | ○ | ○ | ● | ○ | ○ |
| ..behoedt mij voor informatie overload | ○ | ○ | ● | ○ | ○ |

4



**Deel B**: Vragen over <u>informatie</u>kwaliteit (**einde ochtend**)

De volgende vragen / stellingen gaan over uw algemene indruk van de *informatiekwaliteit* <u>tijdens de oefenscenario's</u>.

| | Sterk mee oneens | Mee oneens | Neutraal | Mee eens | Sterk mee eens |
|---|---|---|---|---|---|
| De informatie die met mij wordt gedeeld is up to date | ○ | ● | ○ | ○ | ○ |
| De informatie die met mij wordt gedeeld is correct | ○ | ○ | ● | ○ | ○ |
| De informatie die mij wordt aangeboden is compleet | ○ | ● | ○ | ○ | ○ |
| De informatie die ik krijg aangeboden van anderen is relevant (direct bruikbaar) | ○ | ○ | ○ | ● | ○ |
| De informatie die ik van anderen krijg is tegenstrijdig | ○ | ○ | ● | ○ | ○ |
| Over het algemeen is de informatie die mij wordt aangeboden teveel, vergeleken met wat ik nodig heb | ○ | ● | ○ | ○ | ○ |
| Het is voor mij onduidelijk of de informatie die ik van anderen krijg betrouwbaar is | ○ | ○ | ● | ○ | ○ |
| Ik krijg verouderde informatie aangeboden | ○ | ○ | ○ | ● | ○ |
| De informatie die mij wordt aangeboden bevat foutieve informatie | ○ | ○ | ○ | ● | ○ |
| De informatie die mij wordt aangeboden is onvolledig | ○ | ○ | ○ | ● | ○ |
| Ik ontvang veel informatie die niet nodig is voor het uitvoeren van mijn taken | ○ | ● | ○ | ○ | ○ |
| De informatie die ik krijg wijkt af van informatie die ik al had | ○ | ○ | ● | ○ | ○ |
| Ik kan alle informatie die ik krijg niet bijhouden | ○ | ● | ○ | ○ | ○ |
| Ik ben in staat om de informatie van de melding te verifiëren | ○ | ○ | ○ | ● | ○ |
| Ik word tijdig geïnformeerd over een incident | ○ | ○ | ● | ○ | ○ |
| De informatie die ik ontvang is onjuist | ○ | ○ | ● | ○ | ○ |
| Er ontbreekt detail in de informatie die anderen met mij delen | ○ | ○ | ○ | ● | ○ |
| Ik ontvang overbodige informatie | ○ | ○ | ● | ○ | ○ |
| Meldingen bevatten tegenstrijdige berichten | ○ | ○ | ○ | ● | ○ |
| De informatie die ik krijg is te summier | ○ | ○ | ● | ○ | ○ |
| Ik maak gebruik van eigen beschikbare informatie om meldingen te verifiëren | ○ | ○ | ○ | ● | ○ |

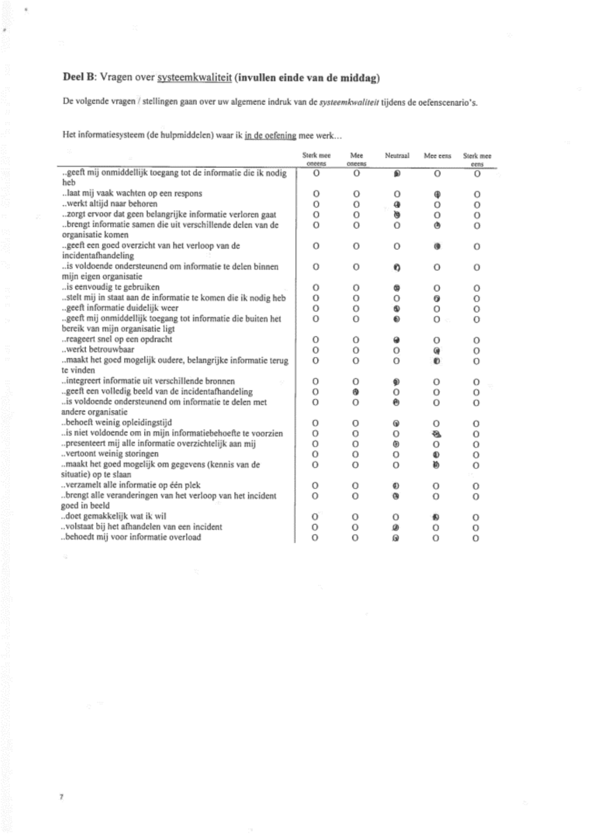
5

**Deel B**: Vragen over <u>informatie</u>kwaliteit (**middag**)

De volgende vragen / stellingen gaan over uw algemene indruk van de *informatiekwaliteit* <u>tijdens de oefenscenario's</u>.

| | Sterk mee oneens | Mee oneens | Neutraal | Mee eens | Sterk mee eens |
|---|---|---|---|---|---|
| De informatie die met mij wordt gedeeld is up to date | ○ | ○ | ● | ○ | ○ |
| De informatie die met mij wordt gedeeld is correct | ○ | ○ | ● | ○ | ○ |
| De informatie die mij wordt aangeboden is compleet | ○ | ● | ○ | ○ | ○ |
| De informatie die ik krijg aangeboden van anderen is relevant (direct bruikbaar) | ○ | ○ | ● | ○ | ○ |
| De informatie die ik van anderen krijg is tegenstrijdig | ○ | ○ | ○ | ● | ○ |
| Over het algemeen is de informatie die mij wordt aangeboden teveel, vergeleken met wat ik nodig heb | ○ | ● | ○ | ○ | ○ |
| Het is voor mij onduidelijk of de informatie die ik van anderen krijg betrouwbaar is | ○ | ● | ○ | ○ | ○ |
| Ik krijg verouderde informatie aangeboden | ○ | ○ | ○ | ● | ○ |
| De informatie die mij wordt aangeboden bevat foutieve informatie | ○ | ○ | ● | ○ | ○ |
| De informatie die mij wordt aangeboden is onvolledig | ○ | ● | ○ | ○ | ○ |
| Ik ontvang veel informatie die niet nodig is voor het uitvoeren van mijn taken | ○ | ● | ○ | ○ | ○ |
| De informatie die ik krijg wijkt af van informatie die ik al had | ○ | ○ | ● | ○ | ○ |
| Ik kan alle informatie die ik krijg niet bijhouden | ○ | ● | ○ | ○ | ○ |
| Ik ben in staat om de informatie van de melding te verifiëren | ○ | ○ | ● | ○ | ○ |
| Ik word tijdig geïnformeerd over een incident | ○ | ○ | ● | ○ | ○ |
| De informatie die ik ontvang is onjuist | ○ | ● | ○ | ○ | ○ |
| Er ontbreekt detail in de informatie die anderen met mij delen | ○ | ○ | ○ | ● | ○ |
| Ik ontvang overbodige informatie | ○ | ○ | ● | ○ | ○ |
| Meldingen bevatten tegenstrijdige berichten | ○ | ○ | ● | ○ | ○ |
| De informatie die ik krijg is te summier | ○ | ○ | ○ | ● | ○ |
| Ik maak gebruik van eigen beschikbare informatie om meldingen te verifiëren | ○ | ○ | ● | ○ | ○ |

6



**Deel B**: Vragen over <u>systeemkwaliteit</u> (**invullen einde van de middag**)

De volgende vragen / stellingen gaan over uw algemene indruk van de *systeemkwaliteit* tijdens de oefenscenario's.

Het informatiesysteem (de hulpmiddelen) waar ik <u>in de oefening</u> mee werk…

| | Sterk mee oneens | Mee oneens | Neutraal | Mee eens | Sterk mee eens |
|---|---|---|---|---|---|
| ..geeft mij onmiddellijk toegang tot de informatie die ik nodig heb | ○ | ○ | ● | ○ | ○ |
| ..laat mij vaak wachten op een respons | ○ | ○ | ○ | ● | ○ |
| ..werkt altijd naar behoren | ○ | ○ | ● | ○ | ○ |
| ..zorgt ervoor dat geen belangrijke informatie verloren gaat | ○ | ○ | ● | ○ | ○ |
| ..brengt informatie samen die uit verschillende delen van de organisatie komen | ○ | ○ | ○ | ● | ○ |
| ..geeft een goed overzicht van het verloop van de incidentafhandeling | ○ | ○ | ○ | ● | ○ |
| ..is voldoende ondersteunend om informatie te delen binnen mijn eigen organisatie | ○ | ○ | ● | ○ | ○ |
| ..is eenvoudig te gebruiken | ○ | ○ | ● | ○ | ○ |
| ..stelt mij in staat aan de informatie te komen die ik nodig heb | ○ | ○ | ○ | ● | ○ |
| ..geeft informatie duidelijk weer | ○ | ○ | ● | ○ | ○ |
| ..geeft mij onmiddellijk toegang tot informatie die buiten het bereik van mijn organisatie ligt | ○ | ○ | ● | ○ | ○ |
| ..reageert snel op een opdracht | ○ | ○ | ● | ○ | ○ |
| ..werkt betrouwbaar | ○ | ○ | ○ | ● | ○ |
| ..maakt het goed mogelijk oudere, belangrijke informatie terug te vinden | ○ | ○ | ○ | ● | ○ |
| ..integreert informatie uit verschillende bronnen | ○ | ○ | ● | ○ | ○ |
| ..geeft een volledig beeld van de incidentafhandeling | ○ | ● | ○ | ○ | ○ |
| ..is voldoende ondersteunend om informatie te delen met andere organisatie | ○ | ○ | ● | ○ | ○ |
| ..behoeft weinig opleidingstijd | ○ | ○ | ● | ○ | ○ |
| ..is niet voldoende om in mijn informatiebehoefte te voorzien | ○ | ○ | ○ | ● | ○ |
| ..presenteert mij alle informatie overzichtelijk aan mij | ○ | ○ | ● | ○ | ○ |
| ..vertoont weinig storingen | ○ | ○ | ○ | ● | ○ |
| ..maakt het goed mogelijk om gegevens (kennis van de situatie) op te slaan | ○ | ○ | ○ | ● | ○ |
| ..verzamelt alle informatie op één plek | ○ | ○ | ● | ○ | ○ |
| ..brengt alle veranderingen van het verloop van het incident goed in beeld | ○ | ○ | ● | ○ | ○ |
| ..doet gemakkelijk wat ik wil | ○ | ○ | ○ | ● | ○ |
| ..volstaat bij het afhandelen van een incident | ○ | ○ | ● | ○ | ○ |
| ..behoedt mij voor informatie overload | ○ | ○ | ● | ○ | ○ |

7

*Respondent 7:*

Vragenlijst net-centrische oefening (10 December 2015)

Beste respondent,

Deze vragenlijst gaat over een onderzoek naar de informatie- en systeemkwaliteit van de crisisafhandeling. De resultaten van deze vragenlijst zullen worden gebruikt voor wetenschappelijk onderzoek naar de knelpunten rond de informatievoorziening van Crisis Management. Dit onderzoek wordt uitgevoerd door Rijkswaterstaat in samenwerking met de Vrije Universiteit Amsterdam.

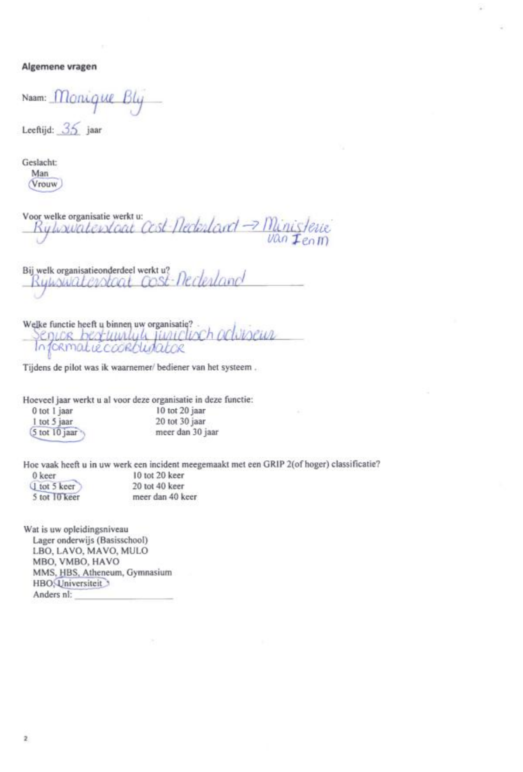
Uw bijdrage kan een belangrijke input leveren om de informatievoorziening verder te kunnen verbeteren waardoor betrokken organisaties in de toekomst nog beter kunnen samenwerken bij de dagelijkse afhandeling van de incidenten / crisissen.

In de oefening worden verschillende scenario's nagespeeld. Wij willen U vragen om deze vragenlijst zo zorgvuldig mogelijk in te vullen.

De vragenlijst bestaat uit <u>twee delen</u>:
Deel A: invullen voor de oefening
Deel B: invullen tijdens de oefening

Alvast bedankt voor de moeite!

1



**Algemene vragen**

Naam: Monique Blij

Leeftijd: 35 jaar

Geslacht:
Man
[✓ Vrouw]

Voor welke organisatie werkt u:
Rijkswaterstaat Oost-Nederland → Ministerie van I en M

Bij welk organisatieonderdeel werkt u?
Rijkswaterstaat Oost-Nederland

Welke functie heeft u binnen uw organisatie?
Senior bestuurlijk juridisch adviseur
Informatiecoordinator

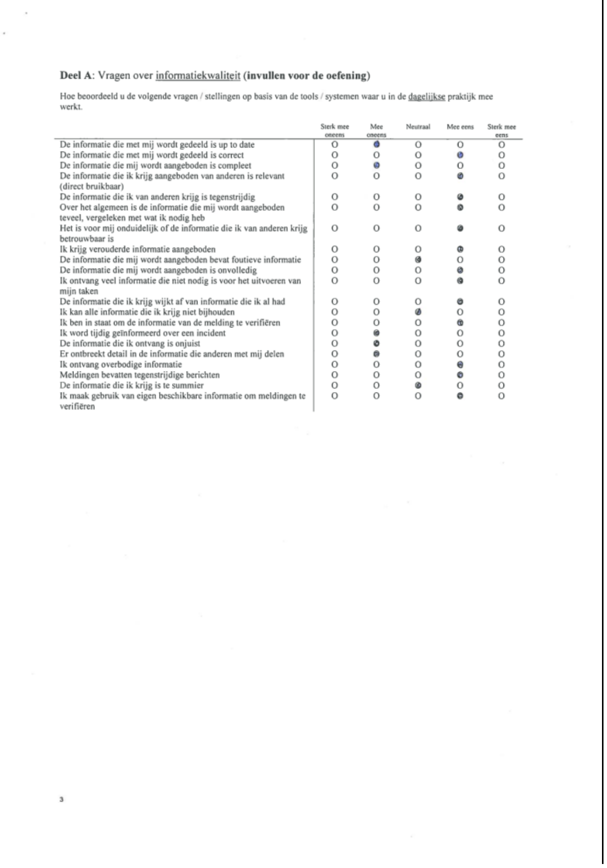
Tijdens de pilot was ik waarnemer/ bediener van het systeem .

Hoeveel jaar werkt u al voor deze organisatie in deze functie:
0 tot 1 jaar
1 tot 5 jaar
[✓ 5 tot 10 jaar]
10 tot 20 jaar
20 tot 30 jaar
meer dan 30 jaar

Hoe vaak heeft u in uw werk een incident meegemaakt met een GRIP 2(of hoger) classificatie?
0 keer
[✓ 1 tot 5 keer]
5 tot 10 keer
10 tot 20 keer
20 tot 40 keer
meer dan 40 keer

Wat is uw opleidingsniveau
Lager onderwijs (Basisschool)
LBO, LAVO, MAVO, MULO
MBO, VMBO, HAVO
MMS, HBS, Atheneum, Gymnasium
HBO, [✓ Universiteit]
Anders nl: ____________

2



**Deel A**: Vragen over <u>informatiekwaliteit</u> **(invullen voor de oefening)**

Hoe beoordeeld u de volgende vragen / stellingen op basis van de tools / systemen waar u in de <u>dagelijkse</u> praktijk mee werkt.

| | Sterk mee oneens | Mee oneens | Neutraal | Mee eens | Sterk mee eens |
|---|---|---|---|---|---|
| De informatie die met mij wordt gedeeld is up to date | ○ | ● | ○ | ○ | ○ |
| De informatie die met mij wordt gedeeld is correct | ○ | ○ | ○ | ● | ○ |
| De informatie die mij wordt aangeboden is compleet | ○ | ● | ○ | ○ | ○ |
| De informatie die ik krijg aangeboden van anderen is relevant (direct bruikbaar) | ○ | ○ | ○ | ● | ○ |
| De informatie die ik van anderen krijg is tegenstrijdig | ○ | ○ | ○ | ● | ○ |
| Over het algemeen is de informatie die mij wordt aangeboden teveel, vergeleken met wat ik nodig heb | ○ | ○ | ○ | ● | ○ |
| Het is voor mij onduidelijk of de informatie die ik van anderen krijg betrouwbaar is | ○ | ○ | ○ | ● | ○ |
| Ik krijg verouderde informatie aangeboden | ○ | ○ | ○ | ● | ○ |
| De informatie die mij wordt aangeboden bevat foutieve informatie | ○ | ○ | ● | ○ | ○ |
| De informatie die mij wordt aangeboden is onvolledig | ○ | ○ | ○ | ● | ○ |
| Ik ontvang veel informatie die niet nodig is voor het uitvoeren van mijn taken | ○ | ○ | ○ | ● | ○ |
| De informatie die ik krijg wijkt af van informatie die ik al had | ○ | ○ | ○ | ● | ○ |
| Ik kan alle informatie die ik krijg niet bijhouden | ○ | ○ | ● | ○ | ○ |
| Ik ben in staat om de informatie van de melding te verifiëren | ○ | ○ | ○ | ● | ○ |
| Ik word tijdig geïnformeerd over een incident | ○ | ● | ○ | ○ | ○ |
| De informatie die ik ontvang is onjuist | ○ | ● | ○ | ○ | ○ |
| Er ontbreekt detail in de informatie die anderen met mij delen | ○ | ● | ○ | ○ | ○ |
| Ik ontvang overbodige informatie | ○ | ○ | ○ | ● | ○ |
| Meldingen bevatten tegenstrijdige berichten | ○ | ○ | ○ | ● | ○ |
| De informatie die ik krijg is te summier | ○ | ○ | ● | ○ | ○ |
| Ik maak gebruik van eigen beschikbare informatie om meldingen te verifiëren | ○ | ○ | ○ | ● | ○ |

3

**Deel A**: Vragen over <u>systeemkwaliteit</u> **(invullen voor de oefening)**

Hoe beoordeeld u de volgende vragen / stellingen op basis van de beschikbare middelen waar u in de dagelijkse praktijk mee werkt.

Het informatiesysteem (de hulpmiddelen) waar ik in de dagelijkse praktijk mee werk…
Opm. ik werk hier alleen mee tijdens een crisis.

| | Sterk mee oneens | Mee oneens | Neutraal | Mee eens | Sterk mee eens |
|---|---|---|---|---|---|
| ..geeft mij onmiddellijk toegang tot de informatie die ik nodig heb | ○ | ● | ● | ○ | ○ |
| ..laat mij vaak wachten op een respons | ○ | ○ | ○ | ○ | ○ |
| ..werkt altijd naar behoren heb ik geen zicht op | ○ | ○ | ○ | ○ | ○ |
| ..zorgt ervoor dat geen belangrijke informatie verloren gaat | ○ | ○ | ○ | ○ | ○ |
| ..brengt informatie samen die uit verschillende delen van de organisatie komen | ○ | ○ | ○ | ● | ○ |
| ..geeft een goed overzicht van het verloop van de incidentafhandeling | ○ | ● | ● | ○ | ○ |
| ..is voldoende ondersteunend om informatie te delen binnen mijn eigen organisatie | ○ | ○ | ● | ○ | ○ |
| ..is eenvoudig te gebruiken | ○ | ○ | ○ | ● | ○ |
| ..stelt mij in staat aan de informatie te komen die ik nodig heb | ○ | ● | ○ | ○ | ○ |
| ..geeft informatie duidelijk weer | ○ | ● | ○ | ○ | ○ |
| ..geeft mij onmiddellijk toegang tot informatie die buiten het bereik van mijn organisatie ligt | ○ | ● | ○ | ○ | ○ |
| ..reageert snel op een opdracht | ○ | ○ | ○ | ● | ○ |
| ..werkt betrouwbaar heb ik geen zicht op | ○ | ○ | ○ | ○ | ○ |
| ..maakt het goed mogelijk oudere, belangrijke informatie terug te vinden | ○ | ○ | ○ | ● | ○ |
| ..integreert informatie uit verschillende bronnen | ○ | ● | ○ | ○ | ○ |
| ..geeft een volledig beeld van de incidentafhandeling | ○ | ● | ○ | ○ | ○ |
| ..is voldoende ondersteunend om informatie te delen met andere organisatie heb ik geen zicht op | ○ | ○ | ○ | ○ | ○ |
| ..behoeft weinig opleidingstijd | ○ | ○ | ○ | ● | ○ |
| ..is niet voldoende om in mijn informatiebehoefte te voorzien | ○ | ○ | ○ | ● | ○ |
| ..presenteert mij alle informatie overzichtelijk aan mij | ○ | ● | ○ | ○ | ○ |
| ..vertoont weinig storingen heb ik geen zicht op. | ○ | ○ | ○ | ○ | ○ |
| ..maakt het goed mogelijk om gegevens (kennis van de situatie) op te slaan | ○ | ○ | ● | ○ | ○ |
| ..verzamelt alle informatie op één plek | ○ | ○ | ○ | ● | ○ |
| ..brengt alle veranderingen van het verloop van het incident goed in beeld | ○ | ● | ○ | ○ | ○ |
| ..doet gemakkelijk wat ik wil | ○ | ○ | ● | ○ | ○ |
| ..volstaat bij het afhandelen van een incident | ○ | ● | ○ | ○ | ○ |
| ..behoedt mij voor informatie overload | ○ | ● | ○ | ○ | ○ |

4

**Deel B**: Vragen over informatiekwaliteit **(einde ochtend)**

De volgende vragen / stellingen gaan over uw algemene indruk van de *informatiekwaliteit* tijdens de oefenscenario's.

| | Sterk mee oneens | Mee oneens | Neutraal | Mee eens | Sterk mee eens |
|---|---|---|---|---|---|
| De informatie die met mij wordt gedeeld is up to date | ○ | ○ | ○ | ● | ○ |
| De informatie die met mij wordt gedeeld is correct | ○ | ○ | ● | ○ | ○ |
| De informatie die mij wordt aangeboden is compleet | ○ | ○ | ● | ○ | ○ |
| De informatie die ik krijg aangeboden van anderen is relevant (direct bruikbaar) | ○ | ○ | ○ | ● | ○ |
| De informatie die ik van anderen krijg is tegenstrijdig | ○ | ○ | ○ | ● | ○ |
| Over het algemeen is de informatie die mij wordt aangeboden teveel, vergeleken met wat ik nodig heb | ○ | ○ | ○ | ● | ○ |
| Het is voor mij onduidelijk of de informatie die ik van anderen krijg betrouwbaar is | ○ | ○ | ● | ○ | ○ |
| Ik krijg verouderde informatie aangeboden | ○ | ○ | ● | ○ | ○ |
| De informatie die mij wordt aangeboden bevat foutieve informatie | ○ | ○ | ● | ○ | ○ |
| De informatie die mij wordt aangeboden is onvolledig | ○ | ○ | ○ | ● | ○ |
| Ik ontvang veel informatie die niet nodig is voor het uitvoeren van mijn taken | ○ | ○ | ○ | ● | ○ |
| De informatie die ik krijg wijkt af van informatie die ik al had | ○ | ○ | ○ | ● | ○ |
| Ik kan alle informatie die ik krijg niet bijhouden | ○ | ● | ○ | ○ | ○ |
| Ik ben in staat om de informatie van de melding te verifiëren | ○ | ○ | ○ | ● | ○ |
| Ik word tijdig geïnformeerd over een incident | ○ | ○ | ● | ○ | ○ |
| De informatie die ik ontvang is onjuist | ○ | ○ | ● | ○ | ○ |
| Er ontbreekt detail in de informatie die anderen met mij delen | ○ | ○ | ○ | ● | ○ |
| Ik ontvang overbodige informatie | ○ | ○ | ○ | ● | ○ |
| Meldingen bevatten tegenstrijdige berichten | ○ | ○ | ● | ○ | ○ |
| De informatie die ik krijg is te summier | ○ | ● | ○ | ○ | ○ |
| Ik maak gebruik van eigen beschikbare informatie om meldingen te verifiëren | ○ | ○ | ○ | ● | ○ |

5

**Deel B**: Vragen over informatiekwaliteit (**middag**)

De volgende vragen / stellingen gaan over uw algemene indruk van de *informatiekwaliteit* tijdens de oefenscenario's.

| | Sterk mee oneens | Mee oneens | Neutraal | Mee eens | Sterk mee eens |
|---|---|---|---|---|---|
| De informatie die met mij wordt gedeeld is up to date | ○ | ○ | ○ | ● | ○ |
| De informatie die met mij wordt gedeeld is correct | ○ | ○ | ● | ○ | ○ |
| De informatie die mij wordt aangeboden is compleet | ○ | ○ | ● | ○ | ○ |
| De informatie die ik krijg aangeboden van anderen is relevant (direct bruikbaar) | ○ | ○ | ○ | ● | ○ |
| De informatie die ik van anderen krijg is tegenstrijdig | ○ | ○ | ○ | ● | ○ |
| Over het algemeen is de informatie die mij wordt aangeboden teveel, vergeleken met wat ik nodig heb | ○ | ○ | ○ | ● | ○ |
| Het is voor mij onduidelijk of de informatie die ik van anderen krijg betrouwbaar is | ○ | ○ | ● | ○ | ○ |
| Ik krijg verouderde informatie aangeboden | ○ | ● | ○ | ○ | ○ |
| De informatie die mij wordt aangeboden bevat foutieve informatie | ○ | ○ | ● | ○ | ○ |
| De informatie die mij wordt aangeboden is onvolledig | ○ | ● | ○ | ○ | ○ |
| Ik ontvang veel informatie die niet nodig is voor het uitvoeren van mijn taken | ○ | ○ | ○ | ● | ○ |
| De informatie die ik krijg wijkt af van informatie die ik al had | ○ | ○ | ● | ○ | ○ |
| Ik kan alle informatie die ik krijg niet bijhouden | ○ | ● | ○ | ○ | ○ |
| Ik ben in staat om de informatie van de melding te verifiëren | ○ | ○ | ○ | ● | ○ |
| Ik word tijdig geïnformeerd over een incident | ○ | ○ | ○ | ● | ○ |
| De informatie die ik ontvang is onjuist | ○ | ○ | ● | ○ | ○ |
| Er ontbreekt detail in de informatie die anderen met mij delen | ○ | ● | ○ | ○ | ○ |
| Ik ontvang overbodige informatie | ○ | ○ | ○ | ● | ○ |
| Meldingen bevatten tegenstrijdige berichten | ○ | ○ | ○ | ● | ○ |
| De informatie die ik krijg is te summier | ○ | ● | ○ | ○ | ○ |
| Ik maak gebruik van eigen beschikbare informatie om meldingen te verifiëren | ○ | ○ | ○ | ● | ○ |

6

**Deel B**: Vragen over systeemkwaliteit **(invullen einde van de middag)**

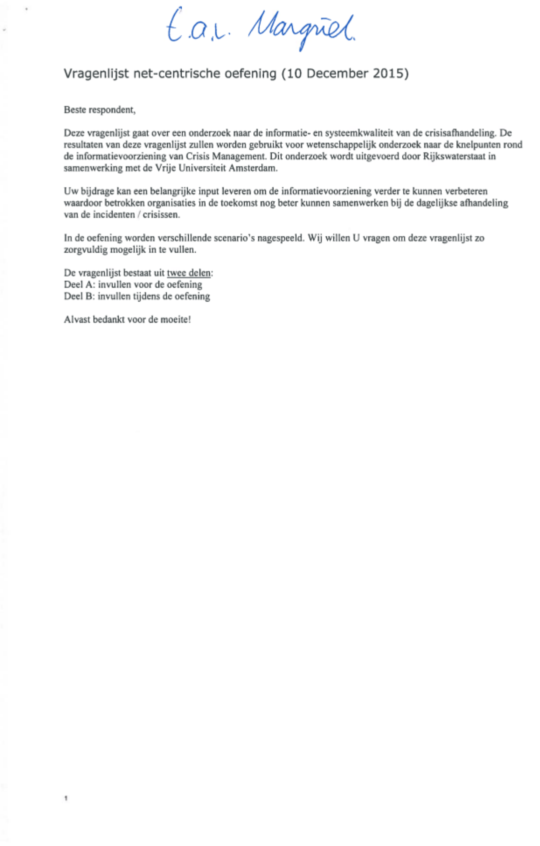
De volgende vragen / stellingen gaan over uw algemene indruk van de *systeemkwaliteit* tijdens de oefenscenario's.

Het informatiesysteem (de hulpmiddelen) waar ik in de oefening mee werk…

| | Sterk mee oneens | Mee oneens | Neutraal | Mee eens | Sterk mee eens |
|---|---|---|---|---|---|
| ..geeft mij onmiddellijk toegang tot de informatie die ik nodig heb | ○ | ○ | ○ | ● | ○ |
| ..laat mij vaak wachten op een respons | ○ | ● | ○ | ○ | ○ |
| ..werkt altijd naar behoren | ○ | ● | ○ | ○ | ○ |
| ..zorgt ervoor dat geen belangrijke informatie verloren gaat | ○ | ● | ○ | ○ | ○ |
| ..brengt informatie samen die uit verschillende delen van de organisatie komen | ○ | ○ | ○ | ● | ○ |
| ..geeft een goed overzicht van het verloop van de incidentafhandeling | ○ | ○ | ● | ○ | ○ |
| ..is voldoende ondersteunend om informatie te delen binnen mijn eigen organisatie | ○ | ○ | ○ | ● | ○ |
| ..is eenvoudig te gebruiken | ○ | ○ | ○ | ● | ○ |
| ..stelt mij in staat aan de informatie te komen die ik nodig heb | ○ | ○ | ○ | ● | ○ |
| ..geeft informatie duidelijk weer | ○ | ● | ○ | ○ | ○ |
| ..geeft mij onmiddellijk toegang tot informatie die buiten het bereik van mijn organisatie ligt | ○ | ○ | ○ | ● | ○ |
| ..reageert snel op een opdracht | ○ | ○ | ○ | ● | ○ |
| ..werkt betrouwbaar | ○ | ● | ○ | ○ | ○ |
| ..maakt het goed mogelijk oudere, belangrijke informatie terug te vinden | ○ | ● | ○ | ○ | ○ |
| ..integreert informatie uit verschillende bronnen | ○ | ○ | ○ | ● | ○ |
| ..geeft een volledig beeld van de incidentafhandeling | ○ | ○ | ● | ○ | ○ |
| ..is voldoende ondersteunend om informatie te delen met andere organisatie | ○ | ○ | ○ | ● | ○ |
| ..behoeft weinig opleidingstijd | ○ | ○ | ● | ○ | ○ |
| ..is niet voldoende om in mijn informatiebehoefte te voorzien | ○ | ● | ○ | ○ | ○ |
| ..presenteert mij alle informatie overzichtelijk aan mij | ○ | ● | ○ | ○ | ○ |
| ..vertoont weinig storingen | ○ | ● | ○ | ○ | ○ |
| ..maakt het goed mogelijk om gegevens (kennis van de situatie) op te slaan | ○ | ○ | ○ | ● | ○ |
| ..verzamelt alle informatie op één plek | ○ | ○ | ● | ○ | ○ |
| ..brengt alle veranderingen van het verloop van het incident goed in beeld | ○ | ○ | ○ | ● | ○ |
| ..doet gemakkelijk wat ik wil | ○ | ○ | ○ | ● | ○ |
| ..volstaat bij het afhandelen van een incident | ○ | ○ | ● | ○ | ○ |
| ..behoedt mij voor informatie overload | ○ | ● | ○ | ○ | ○ |

7

*Respondent 8:*



t.a.v. Margriet

## Vragenlijst net-centrische oefening (10 December 2015)

Beste respondent,

Deze vragenlijst gaat over een onderzoek naar de informatie- en systeemkwaliteit van de crisisafhandeling. De resultaten van deze vragenlijst zullen worden gebruikt voor wetenschappelijk onderzoek naar de knelpunten rond de informatievoorziening van Crisis Management. Dit onderzoek wordt uitgevoerd door Rijkswaterstaat in samenwerking met de Vrije Universiteit Amsterdam.

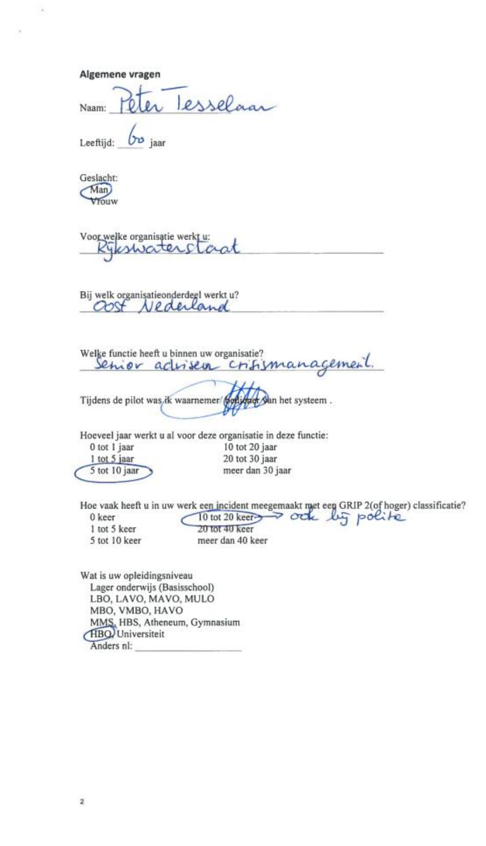
Uw bijdrage kan een belangrijke input leveren om de informatievoorziening verder te kunnen verbeteren waardoor betrokken organisaties in de toekomst nog beter kunnen samenwerken bij de dagelijkse afhandeling van de incidenten / crisissen.

In de oefening worden verschillende scenario's nagespeeld. Wij willen U vragen om deze vragenlijst zo zorgvuldig mogelijk in te vullen.

De vragenlijst bestaat uit twee delen:
Deel A: invullen voor de oefening
Deel B: invullen tijdens de oefening

Alvast bedankt voor de moeite!

1



**Algemene vragen**

Naam: Peter Tesselaar

Leeftijd: 60 jaar

Geslacht:
[✓ Man]
Vrouw

Voor welke organisatie werkt u:
Rijkswaterstaat

Bij welk organisatieonderdeel werkt u?
Oost Nederland

Welke functie heeft u binnen uw organisatie?
Senior adviseur crisismanagement.

Tijdens de pilot was [✓ ik waarnemer]/ ~~bediener~~ van het systeem .

Hoeveel jaar werkt u al voor deze organisatie in deze functie:

| | |
|---|---|
| 0 tot 1 jaar | 10 tot 20 jaar |
| 1 tot 5 jaar | 20 tot 30 jaar |
| [✓ 5 tot 10 jaar] | meer dan 30 jaar |

Hoe vaak heeft u in uw werk een incident meegemaakt met een GRIP 2(of hoger) classificatie?

| | |
|---|---|
| 0 keer | [✓ 10 tot 20 keer] → ook bij politie |
| 1 tot 5 keer | 20 tot 40 keer |
| 5 tot 10 keer | meer dan 40 keer |

Wat is uw opleidingsniveau
Lager onderwijs (Basisschool)
LBO, LAVO, MAVO, MULO
MBO, VMBO, HAVO
MMS, HBS, Atheneum, Gymnasium
[✓ HBO], Universiteit
Anders nl: ____________________

2

**Deel A**: Vragen over informatiekwaliteit **(invullen voor de oefening)**

Hoe beoordeeld u de volgende vragen / stellingen op basis van de tools / systemen waar u in de dagelijkse praktijk mee werkt.

| | Sterk mee oneens | Mee oneens | Neutraal | Mee eens | Sterk mee eens |
|---|---|---|---|---|---|
| De informatie die met mij wordt gedeeld is up to date | ○ | ● | ○ | ○ | ○ |
| De informatie die met mij wordt gedeeld is correct | ○ | ● | ○ | ○ | ○ |
| De informatie die mij wordt aangeboden is compleet | ○ | ○ | ○ | ● | ○ |
| De informatie die ik krijg aangeboden van anderen is relevant (direct bruikbaar) | ○ | ● | ○ | ○ | ○ |
| De informatie die ik van anderen krijg is tegenstrijdig | ○ | ● | ○ | ○ | ○ |
| Over het algemeen is de informatie die mij wordt aangeboden teveel, vergeleken met wat ik nodig heb | ○ | ○ | ○ | ○ | ● |
| Het is voor mij onduidelijk of de informatie die ik van anderen krijg betrouwbaar is | ○ | ● | ○ | ○ | ○ |
| Ik krijg verouderde informatie aangeboden | ○ | ● | ○ | ○ | ○ |
| De informatie die mij wordt aangeboden bevat foutieve informatie | ● | ○ | ○ | ○ | ○ |
| De informatie die mij wordt aangeboden is onvolledig | ○ | ● | ○ | ○ | ○ |
| Ik ontvang veel informatie die niet nodig is voor het uitvoeren van mijn taken | ○ | ○ | ○ | ● | ○ |
| De informatie die ik krijg wijkt af van informatie die ik al had | ○ | ○ | ● | ○ | ○ |
| Ik kan alle informatie die ik krijg niet bijhouden | ○ | ● | ○ | ○ | ○ |
| Ik ben in staat om de informatie van de melding te verifiëren | ○ | ○ | ○ | ● | ○ |
| Ik word tijdig geïnformeerd over een incident | ○ | ● | ○ | ○ | ○ |
| De informatie die ik ontvang is onjuist | ○ | ● | ○ | ○ | ○ |
| Er ontbreekt detail in de informatie die anderen met mij delen | ○ | ○ | ○ | ● | ○ |
| Ik ontvang overbodige informatie | ○ | ○ | ○ | ● | ○ |
| Meldingen bevatten tegenstrijdige berichten | ○ | ● | ○ | ○ | ○ |
| De informatie die ik krijg is te summier | ○ | ● | ○ | ○ | ○ |
| Ik maak gebruik van eigen beschikbare informatie om meldingen te verifiëren | ○ | ○ | ● | ○ | ○ |

3

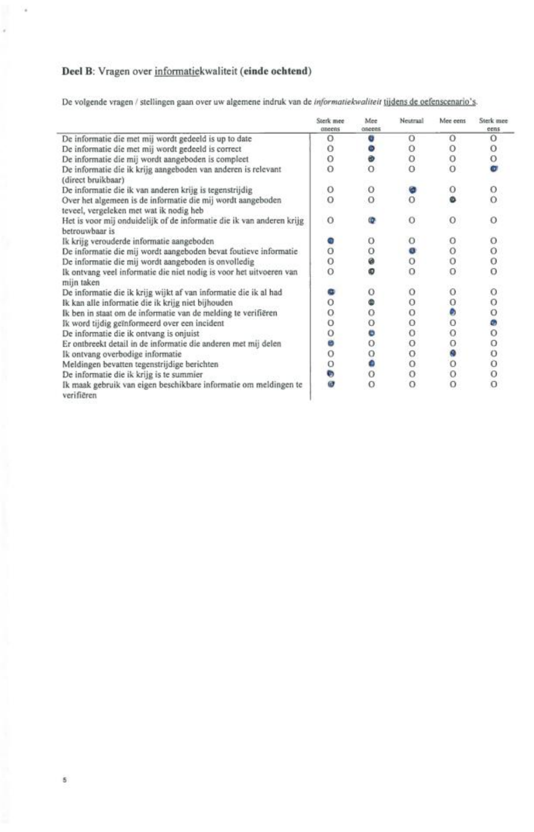
**Deel A**: Vragen over systeemkwaliteit **(invullen voor de oefening)**

Hoe beoordeeld u de volgende vragen / stellingen op basis van de beschikbare middelen waar u in de dagelijkse praktijk mee werkt.

Het informatiesysteem (de hulpmiddelen) waar ik in de dagelijkse praktijk mee werk…

| | Sterk mee oneens | Mee oneens | Neutraal | Mee eens | Sterk mee eens |
|---|---|---|---|---|---|
| ..geeft mij onmiddellijk toegang tot de informatie die ik nodig heb | ○ | ● | ○ | ○ | ○ |
| ..laat mij vaak wachten op een respons | ○ | ○ | ○ | ● | ○ |
| ..werkt altijd naar behoren | ○ | ○ | ● | ○ | ○ |
| ..zorgt ervoor dat geen belangrijke informatie verloren gaat | ○ | ○ | ● | ○ | ○ |
| ..brengt informatie samen die uit verschillende delen van de organisatie komen | ● | ○ | ○ | ○ | ○ |
| ..geeft een goed overzicht van het verloop van de incidentafhandeling | ● | ○ | ○ | ○ | ○ |
| ..is voldoende ondersteunend om informatie te delen binnen mijn eigen organisatie | ○ | ○ | ● | ○ | ○ |
| ..is eenvoudig te gebruiken | ○ | ● | ○ | ○ | ○ |
| ..stelt mij in staat aan de informatie te komen die ik nodig heb | ○ | ○ | ○ | ● | ○ |
| ..geeft informatie duidelijk weer | ○ | ● | ○ | ○ | ○ |
| ..geeft mij onmiddellijk toegang tot informatie die buiten het bereik van mijn organisatie ligt | ○ | ● | ○ | ○ | ○ |
| ..reageert snel op een opdracht | ○ | ○ | ○ | ● | ○ |
| ..werkt betrouwbaar | ○ | ○ | ● | ○ | ○ |
| ..maakt het goed mogelijk oudere, belangrijke informatie terug te vinden | ○ | ○ | ● | ○ | ○ |
| ..integreert informatie uit verschillende bronnen | ● | ○ | ○ | ○ | ○ |
| ..geeft een volledig beeld van de incidentafhandeling | ● | ○ | ○ | ○ | ○ |
| ..is voldoende ondersteunend om informatie te delen met andere organisatie | ● | ○ | ○ | ○ | ○ |
| ..behoeft weinig opleidingstijd | ○ | ○ | ○ | ● | ○ |
| ..is niet voldoende om in mijn informatiebehoefte te voorzien | ○ | ○ | ○ | ● | ○ |
| ..presenteert mij alle informatie overzichtelijk aan mij | ○ | ○ | ● | ○ | ○ |
| ..vertoont weinig storingen | ○ | ○ | ○ | ● | ○ |
| ..maakt het goed mogelijk om gegevens (kennis van de situatie) op te slaan | ○ | ○ | ● | ○ | ○ |
| ..verzamelt alle informatie op één plek | ○ | ● | ○ | ○ | ○ |
| ..brengt alle veranderingen van het verloop van het incident goed in beeld | ● | ○ | ○ | ○ | ○ |
| ..doet gemakkelijk wat ik wil | ○ | ○ | ○ | ● | ○ |
| ..volstaat bij het afhandelen van een incident | ● | ○ | ○ | ○ | ○ |
| ..behoedt mij voor informatie overload | ○ | ○ | ● | ○ | ○ |

4

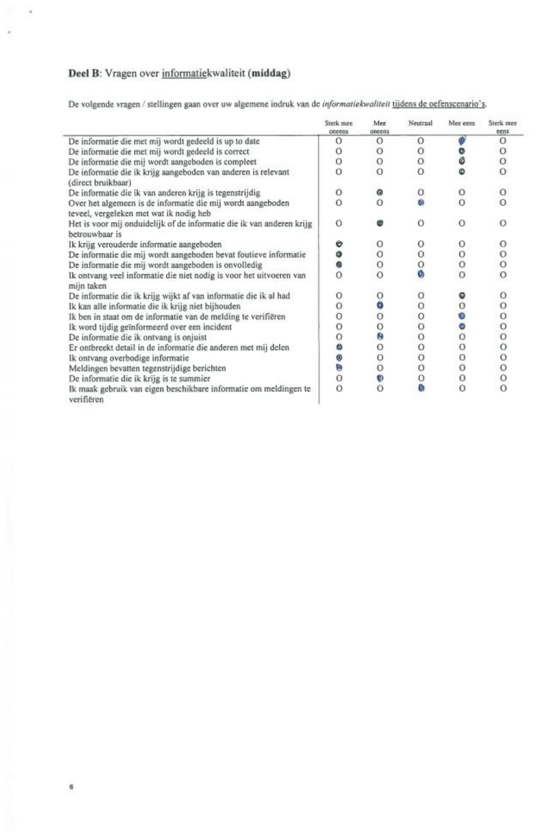


**Deel B**: Vragen over <u>informatie</u>kwaliteit (**einde ochtend**)

De volgende vragen / stellingen gaan over uw algemene indruk van de *informatiekwaliteit* <u>tijdens de oefenscenario's</u>.

| | Sterk mee oneens | Mee oneens | Neutraal | Mee eens | Sterk mee eens |
|---|---|---|---|---|---|
| De informatie die met mij wordt gedeeld is up to date | ○ | ● | ○ | ○ | ○ |
| De informatie die met mij wordt gedeeld is correct | ○ | ● | ○ | ○ | ○ |
| De informatie die mij wordt aangeboden is compleet | ○ | ● | ○ | ○ | ○ |
| De informatie die ik krijg aangeboden van anderen is relevant (direct bruikbaar) | ○ | ○ | ○ | ○ | ● |
| De informatie die ik van anderen krijg is tegenstrijdig | ○ | ○ | ● | ○ | ○ |
| Over het algemeen is de informatie die mij wordt aangeboden teveel, vergeleken met wat ik nodig heb | ○ | ○ | ○ | ● | ○ |
| Het is voor mij onduidelijk of de informatie die ik van anderen krijg betrouwbaar is | ○ | ● | ○ | ○ | ○ |
| Ik krijg verouderde informatie aangeboden | ● | ○ | ○ | ○ | ○ |
| De informatie die mij wordt aangeboden bevat foutieve informatie | ○ | ○ | ● | ○ | ○ |
| De informatie die mij wordt aangeboden is onvolledig | ○ | ● | ○ | ○ | ○ |
| Ik ontvang veel informatie die niet nodig is voor het uitvoeren van mijn taken | ○ | ● | ○ | ○ | ○ |
| De informatie die ik krijg wijkt af van informatie die ik al had | ● | ○ | ○ | ○ | ○ |
| Ik kan alle informatie die ik krijg niet bijhouden | ○ | ● | ○ | ○ | ○ |
| Ik ben in staat om de informatie van de melding te verifiëren | ○ | ○ | ○ | ● | ○ |
| Ik word tijdig geïnformeerd over een incident | ○ | ○ | ○ | ○ | ● |
| De informatie die ik ontvang is onjuist | ○ | ● | ○ | ○ | ○ |
| Er ontbreekt detail in de informatie die anderen met mij delen | ● | ○ | ○ | ○ | ○ |
| Ik ontvang overbodige informatie | ○ | ○ | ○ | ● | ○ |
| Meldingen bevatten tegenstrijdige berichten | ○ | ● | ○ | ○ | ○ |
| De informatie die ik krijg is te summier | ● | ○ | ○ | ○ | ○ |
| Ik maak gebruik van eigen beschikbare informatie om meldingen te verifiëren | ● | ○ | ○ | ○ | ○ |

5

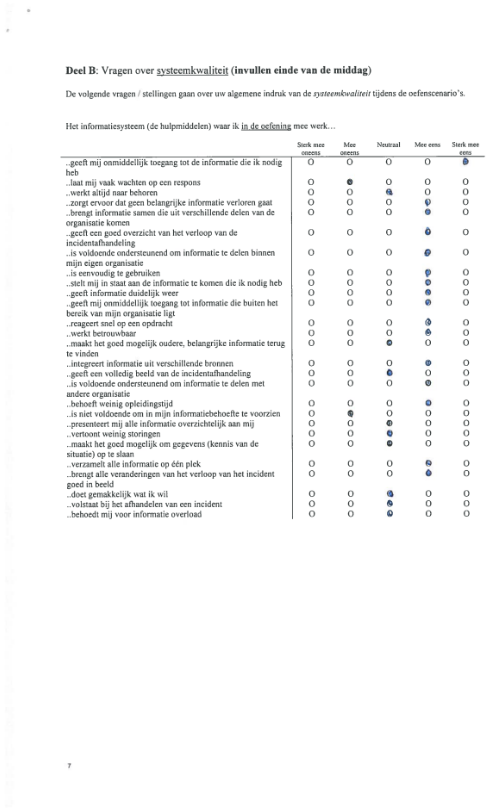


**Deel B**: Vragen over <u>informatie</u>kwaliteit (**middag**)

De volgende vragen / stellingen gaan over uw algemene indruk van de *informatiekwaliteit* <u>tijdens de oefenscenario's</u>.

| | Sterk mee oneens | Mee oneens | Neutraal | Mee eens | Sterk mee eens |
|---|---|---|---|---|---|
| De informatie die met mij wordt gedeeld is up to date | ○ | ○ | ○ | ● | ○ |
| De informatie die met mij wordt gedeeld is correct | ○ | ○ | ○ | ● | ○ |
| De informatie die mij wordt aangeboden is compleet | ○ | ○ | ○ | ● | ○ |
| De informatie die ik krijg aangeboden van anderen is relevant (direct bruikbaar) | ○ | ○ | ○ | ● | ○ |
| De informatie die ik van anderen krijg is tegenstrijdig | ○ | ● | ○ | ○ | ○ |
| Over het algemeen is de informatie die mij wordt aangeboden teveel, vergeleken met wat ik nodig heb | ○ | ○ | ● | ○ | ○ |
| Het is voor mij onduidelijk of de informatie die ik van anderen krijg betrouwbaar is | ○ | ● | ○ | ○ | ○ |
| Ik krijg verouderde informatie aangeboden | ● | ○ | ○ | ○ | ○ |
| De informatie die mij wordt aangeboden bevat foutieve informatie | ● | ○ | ○ | ○ | ○ |
| De informatie die mij wordt aangeboden is onvolledig | ● | ○ | ○ | ○ | ○ |
| Ik ontvang veel informatie die niet nodig is voor het uitvoeren van mijn taken | ○ | ○ | ● | ○ | ○ |
| De informatie die ik krijg wijkt af van informatie die ik al had | ○ | ○ | ○ | ● | ○ |
| Ik kan alle informatie die ik krijg niet bijhouden | ○ | ● | ○ | ○ | ○ |
| Ik ben in staat om de informatie van de melding te verifiëren | ○ | ○ | ○ | ● | ○ |
| Ik word tijdig geïnformeerd over een incident | ○ | ○ | ○ | ● | ○ |
| De informatie die ik ontvang is onjuist | ○ | ● | ○ | ○ | ○ |
| Er ontbreekt detail in de informatie die anderen met mij delen | ● | ○ | ○ | ○ | ○ |
| Ik ontvang overbodige informatie | ● | ○ | ○ | ○ | ○ |
| Meldingen bevatten tegenstrijdige berichten | ● | ○ | ○ | ○ | ○ |
| De informatie die ik krijg is te summier | ○ | ● | ○ | ○ | ○ |
| Ik maak gebruik van eigen beschikbare informatie om meldingen te verifiëren | ○ | ○ | ● | ○ | ○ |

6



**Deel B**: Vragen over <u>systeemkwaliteit</u> (**invullen einde van de middag**)

De volgende vragen / stellingen gaan over uw algemene indruk van de *systeemkwaliteit* tijdens de oefenscenario's.

Het informatiesysteem (de hulpmiddelen) waar ik <u>in de oefening</u> mee werk…

| | Sterk mee oneens | Mee oneens | Neutraal | Mee eens | Sterk mee eens |
|---|---|---|---|---|---|
| ..geeft mij onmiddellijk toegang tot de informatie die ik nodig heb | ○ | ○ | ○ | ○ | ● |
| ..laat mij vaak wachten op een respons | ○ | ● | ○ | ○ | ○ |
| ..werkt altijd naar behoren | ○ | ○ | ● | ○ | ○ |
| ..zorgt ervoor dat geen belangrijke informatie verloren gaat | ○ | ○ | ○ | ● | ○ |
| ..brengt informatie samen die uit verschillende delen van de organisatie komen | ○ | ○ | ○ | ● | ○ |
| ..geeft een goed overzicht van het verloop van de incidentafhandeling | ○ | ○ | ○ | ● | ○ |
| ..is voldoende ondersteunend om informatie te delen binnen mijn eigen organisatie | ○ | ○ | ○ | ● | ○ |
| ..is eenvoudig te gebruiken | ○ | ○ | ○ | ● | ○ |
| ..stelt mij in staat aan de informatie te komen die ik nodig heb | ○ | ○ | ○ | ● | ○ |
| ..geeft informatie duidelijk weer | ○ | ○ | ○ | ● | ○ |
| ..geeft mij onmiddellijk toegang tot informatie die buiten het bereik van mijn organisatie ligt | ○ | ○ | ○ | ● | ○ |
| ..reageert snel op een opdracht | ○ | ○ | ○ | ● | ○ |
| ..werkt betrouwbaar | ○ | ○ | ○ | ● | ○ |
| ..maakt het goed mogelijk oudere, belangrijke informatie terug te vinden | ○ | ○ | ● | ○ | ○ |
| ..integreert informatie uit verschillende bronnen | ○ | ○ | ○ | ● | ○ |
| ..geeft een volledig beeld van de incidentafhandeling | ○ | ○ | ● | ○ | ○ |
| ..is voldoende ondersteunend om informatie te delen met andere organisatie | ○ | ○ | ○ | ● | ○ |
| ..behoeft weinig opleidingstijd | ○ | ○ | ○ | ● | ○ |
| ..is niet voldoende om in mijn informatiebehoefte te voorzien | ○ | ● | ○ | ○ | ○ |
| ..presenteert mij alle informatie overzichtelijk aan mij | ○ | ○ | ● | ○ | ○ |
| ..vertoont weinig storingen | ○ | ○ | ● | ○ | ○ |
| ..maakt het goed mogelijk om gegevens (kennis van de situatie) op te slaan | ○ | ○ | ● | ○ | ○ |
| ..verzamelt alle informatie op één plek | ○ | ○ | ○ | ● | ○ |
| ..brengt alle veranderingen van het verloop van het incident goed in beeld | ○ | ○ | ○ | ● | ○ |
| ..doet gemakkelijk wat ik wil | ○ | ○ | ● | ○ | ○ |
| ..volstaat bij het afhandelen van een incident | ○ | ○ | ● | ○ | ○ |
| ..behoedt mij voor informatie overload | ○ | ○ | ● | ○ | ○ |

7

# ΠΕΡΙΛΗΨΗ – SUMMARY IN GREEK.

Η διδακτορική διατριβή με τίτλο «Συστήματα Στήριξης Αποφάσεων για Συμμετοχική Διαχείριση της Πλημμυρικής Διακινδύνευσης και των Πλημμυρικών Καταστροφών», έχει ως στόχο να διερευνήσει κριτικά την υφιστάμενη γνώση και να εξεύρει και να προτείνει λύσεις προς την κατεύθυνση βελτίωσης της επίγνωσης μιας κατάστασης προκειμένου οι διαδικασίες λήψης αποφάσεων για διαχείριση της πλημμυρικής διακινδύνευσης και των πλημμυρικών καταστροφών να υποστηρίζονται με τρόπο αποτελεσματικό. Προς επίτευξη τούτου, η διατριβή πραγματοποιεί δύο θεωρητικές καθώς και δύο εμπειρικές μελέτες.

## ***Γεωσχεδιάζοντας ένα πολυεπίπεδο σύστημα προστασίας από πλημμύρες.***

Η πρώτη θεωρητική μελέτη (κεφάλαιο 2) περιλαμβάνει βιβλιογραφική ανασκόπηση όσον αφορά στο σχέδιο πολυεπίπεδης ασφάλειας από πλημμύρες. Αυτό το σχέδιο έχει υιοθετηθεί από την Ολλανδία κατόπιν της ευρωπαϊκής οδηγίας (2007/60/EC) και αποτελεί μια ολοκληρωμένη προσέγγιση στη διαχείριση της πλημμυρικής διακινδύνευσης η οποία αποτελείται από τρία επίπεδα: 1. Ελαχιστοποίηση της πιθανότητας πλημμυρών μέσω προληπτικών μέτρων; 2. Ελαχιστοποίση των επιπτώσεων στην περίπτωση ενός πλημμυρικού γεγονότος μέσω χωρικών λύσεων και 3. Προετοιμασία για απόκριση σε περίπτωση εκδήλωσης πλημμύρας. Ένα τέτοιο πολυεπίπεδο σύστημα προστασίας από τις πλημμύρες είναι περισσότερο παράλληλο παρά σειριακό. Αυτό αιτιολογείται από το γεγονός ότι σε περίπτωση αστοχίας των μέτρων προστασίας που αντιστοιχούν σε ένα επίπεδο δε συνεπάγεται αστοχία ολόκληρου του συστήματος. Ωστόσο το σύστημα δεν είναι ακριβώς παράλληλο καθώς σε περίπτωση αστοχίας των προληπτικών μέτρων που αντιστοιχούν στο επίπεδο 1, τα μέτρα που αντιστοιχούν στα επίπεδα 2 και 3 δύνανται να μειώσουν τις συνέπεις μιας πλημμύρας αλλά όχι να τις εξαλείψουν. Επομένως, τί θεωρείται αστοχία όσον αφορά στα επίπεδα 2 και 3 πρέπει να συμφωνηθεί σε επίπεδο πολιτικής. Μια τέτοια απόφαση θα βοηθήσει στη βέλτιστη κατανομή βαρών μεταξύ των τριών επιπέδων του πολυεπίπεδου συστήματος προστασίας από πλημμύρες. Όμως, τα βέλτιστα μέτρα ασφαλείας για πλημμύρες δεν πρέπει να βασίζονται μόνο στην οικονομική τους αποδοτικότητα αλλά και στην κοινωνική τους αποδοχή. Η ποιοτική ανάλυση του πολυεπίπεδου αυτού συστήματος προστασίας από πλημμύρες κατέδειξε την ανάγκη ενός μεθοδολογικού πλαισίου το οποίο θα παροτρύνει τη συμμετοχή των ενδιαφερόμενων μερών, την ενεργό συμμετοχή των πολιτών, τον πειραματισμό και την εκτίμηση των επιπτώσεων προς την κατεύθυνση επίτευξης του βέλτιστου συνδυασμού μέτρων ασφαλείας τα οποία θα ανταποκρίνονται στα ιδιαίτερα χαρακτηριστικά και στις συνθήκες μιας περιοχής μελέτης.

Στο πλαίσια αυτό, το κεφάλαιο εισάγει την έννοια, τη μεθοδολογία καθώς και τα μοντέλα του γεωσχεδιασμού. Το συγκριτικό πλεονέκτημα αυτής της μελέτης σε σχέση με τις προηγούμενες, είναι ότι ενορχηστρώνει θεωρητικά και συστηματοποιεί το πολυεπίπεδο σύστημα προστασίας από τις πλημμύρες σε ένα μεθολογικό πλαίσιο προσανατολισμένο στο γεωσχεδιασμό που παρακινεί τη συμμετοχή και αλληλεπίδραση, επιτρέπει τη διεπιστημονική συνεργασία, προσδιορίζει τους ρόλους των διαφόρων φορέων, αξιοποιεί όλη την γεωγραφική πληροφορία και γνώση, προωθεί την επικοινωνία της υπό εξέταση κατάστασης, διευκολύνει την κατανόηση και αξιολόγηση προτάσεων και υποστηρίζει την ανάδραση των συμμετοχόντων όποτε αυτή χρειάζεται.

Πολύ σημαντική για το πολυεπίπεδο σύστημα προστασίας από πλημμύρες είναι η καταγραφή όλης της χρειώδους πληροφορίας. Κατά τη διάρκεια αυτής της θεωρητικής μελέτης, πραγματοποιήθηκε απόπειρα περιεκτικής ανασκόπησης της ζητούμενης πληροφορίας, παρόλο που έρευνα βασισμένη σε ερωτηματολόγια δύναται να φωτίσει περισσότερο τις απαιτήσεις σε πληροφορία που αφορούν στο κάθε επίπεδο πλημμυρικής ασφάλειας ξεχωριστά. Με αυτό τον τρόπο, είναι δυνατόν να εξευρεθεί και κατά πόσον η ίδια πληροφορία ανταποκρίνεται στις ανάγκες περισσότερων του ενός επιπέδων ασφαλείας. Γενικά, η απαιτούμενη πληροφορία είναι χωρικά συσχετισμένη και διακρίνεται σε ημι-στατική καθώς και σε εξαγόμενη από μοντέλα. Ωστόσο, η εφαρμογή μέτρων που αφορούν σε προληπτική οργανωμένη εκκένωση χώρου στα πλαίσια προετοιμασίας για απόκριση σε μια πλημμυρική κατάσταση, απαιτεί δυναμική πληροφορία.

Εν κατακλείδι, η συστηματοποίηση του πολυεπίπεδου συστήματος προστασίας από πλημμύρες σε ένα πλαίσιο γεωσχεδιασμού έχει τη δυνατότητα αποτελεσματικής υποστήριξης της διαδκασίας λήψης αποφάσεων μέσα από τις διάφορες κυκλικές διαδικασίες της που καθοδηγούνται απο την ανατροφοδότηση των συμμετεχόντων, δημιουργώντας προστιθέμενη αξία για την τοπική κοινωνία, οικονομία και περιβάλλον. Επίσης, υποστηρίζει μια λογική δοκιμής και λάθους έτσι ώστε όλα τα ενδιαφερόμενα μέρη να δύνανται να αξιολογήσουν τις επιπτώσεις των μέτρων ασφαλείας από τη δική τους οπτική γωνία. Έτσι, οι εμπλεκόμενοι είναι εφικτό να δημιουργήσουν επίγνωση της κατάστασης σχετικά με το επίπεδο ασφάλειας από πλημμύρες σε μια περιοχή ενδιαφέροντος ενώ τους δίνεται η ευκαιρία να διερευνήσουν και να αναγνωρίσουν όμοιες προτάσεις τους όσον αφορά σε πλημμυρικά μέτρα προστασίας, με αποτέλεσμα να είναι κατορθωτή η επίτευξη μέγιστης δυνατής συναίνεσης μεταξύ τους. Ως εκ τούτου, η επιλογή των πιο επιθυμητών και ισορροπημένων πλημμυρικών μέτρων ασφαλείας σε διαφορετικές χωρικές και χρονικές κλίμακες τα οποία λαμβάνουν υπόψη το κόστος τους, τις επιπτώσεις τους στο περιβάλλον καθώς και τις αξίες και απόψεις της τοπικής κοινωνίας είναι δυνητικά εφικτή.

### ***Μια κοινή επιχειρησιακή εικόνα για υποστήριξη της επίγνωσης μιας κατάστασης προς την κατεύθυνση αποτελεσματικής απόκρισης σε περίπτωση έκτατης ανάγκης.***

Η δεύτερη θεωρητική μελέτη αυτής της διατριβής (κεφάλαιο 4), μέσα από μια εκτεταμένη βιβλιογραφική έρευνα παραθέτει επισκόπηση καινοφανών πληροφοριακών εννοιών και διερευνά πώς αυτές μπορούν να αξιοποιηθούν σε περίπτωση απόκρισης σε έκτακτη ανάγκη. Συγκεκριμένα, ένα δικτυοκεντρικό σύστημα που έχει τις ρίζες του στο στρατιωτικό τομέα μπορεί να αποτελέσει όχημα προς την κατεύθυνση καλύτερης ανταλλαγής πληροφοριών που με τη σειρά τους δύνανται να βελτιώσουν τη διαδικασία λήψης αποφάσεων και να υποστηρίξουν καλύτερη χωροχρονική οργάνωση πόρων και ανθρώπων στο περίπλοκο και δυναμικό περιβάλλον των επιχειρήσεων απόκρισης σε έκτακτη ανάγκη. Ένα δικτυοκεντρικό πληροφοριακό σύστημα ουσιαστικά δικτυώνει όλους τους εμπλεκόμενους στη διαχείριση μιας κρίσης ώστε να ενσωματώνονται νέες πληροφορίες και γνώση από διάφορες πηγές και να επιτυγχάνεται επιχειρησιακή αποτελεσματικότητα. Επιπλέον, ένα τέτοιο σύστημα επιτρέπει ανεμπόδιστη ροή πληροφοριών και γνώσης σε όλα τα διοικητικά στρώματα απόκρισης σε μια έκτακτη ανάγκη. Αντί οι πληροφορίες να διαχέονται κάθετα ακολουθώντας τα επίπεδα της διοικητικής δομής σε μια ιεραρχική λογική, αυτές διανέμονται ελεύθερα μεταξύ όλων των εμπλεκομένων στην αντιμετώπιση μιας κατάστασης έκτακτης ανάγκης με μια οριζόντια λογική. Ωστόσο, στο ολοένα αυξανόμενα ρευστό και πλούσιο σε πληροφορίες περιβάλλον της απόκρισης σε έκτακτη ανάγκη, τα δικτυοκεντρικά συστήματα πρέπει να υποστηρίζουν όχι μόνο τις απαιτήσεις σε πληροφορίες των υπηρεσιών ασφαλείας αλλά και τις γνωστικές και ψυχολογικές ικανότητες των εμπλεκομένων λαμβάνοντας υπόψη ότι οι άνθρωποι διαθέτουν περιορισμένες δυνατότητες μνήμης και προσοχής. Επιπλέον, έμφαση πρέπει να δίνεται προς την κατεύθυνση αποφυγής υπερφόρτωσης πληροφοριών δεδομένου ότι αυτές δεν είναι όλες σχετικές με τα καθήκοντα των διαφόρων οργανισμών ασφαλείας.

Μέσω ενός δικτυοκεντρικού συστήματος, η ίδια πληροφορία είναι δυνατό να καθίσταται διαθέσιμη την ίδια στιγμή σε όλους. Μια κοινή επιχειρησιακή εικόνα παρέχει πληροφορίες και γνώση σχετικά με το τί συμβαίνει γύρω από τους εμπλεκόμενους σε μία και μόνο απεικόνιση. Σύμφωνα με τον ορισμό του Endsley (1988) σχετικά με την επίγνωση μιας κατάστασης, αυτή διακρίνεται σε τρία επίπεδα: Κατά πρώτον, επίγνωση μιας κατάστασης αποτελεί την αντίληψη κρίσιμων παραμέτρων όπως είναι η εξέλιξη, οι ιδιότητες και η δυναμική σχετικών στοιχείων στο περιβάλλον. Κατά δεύτερον, είναι η κατανόηση της σημασίας αυτών των στοιχείων μετά τη σύνθεσή τους υπό το πρίσμα του στόχου των φορέων λήψης αποφάσεων. Κατά τρίτον, στο υψηλότερο επίπεδο, επίγνωση μιας κατάστασης αφορά στην πρόβλεψη σχετικά με το τί θα συμβεί στο σύστημα στο εγγύς μέλλον. Επιπλέον, τρία συστατικά συνθέτουν μία κατάσταση: 1. Πληροφορίες σχετικά με την κατάσταση έκτακτης ανάγκης; 2. Πληροφορίες σχετικά με το περιβάλλον της κατάστασης έκτακτης ανάγκης (επίγνωση του χώρου) και 3. Πληροφορίες σχετικά με τις εμπλεκόμενες επιχειρησιακά υπηρεσίες διαχείρισης έκτακτης ανάγκης.

Οι διαδικασίες επικοινωνίας μπορούν να διαιρεθούν σε τρεις σχετιζόμενους τομείς: τον πληροφοριακό τομέα που αφορά σε σχετικά δεδομένα, τον γνωστικό τομέα που συνδέεται με τις ανθρώπινες διανοητικές διεργασίες και το φυσικό τομέα που εστιάζει σε δραστηριότητες στον πραγματικό κόσμο. Τα δικτυοκετνρικά συστήματα δύνανται να επιτρέψουν καλύτερη ανταλλαγή πληροφοριών μέσα από την ανάπτυξη μιας κοινής επιχειρησιακής εικόνας στον πληροφοριακό τομέα που με τη σειρά της μπορεί να υποστηρίξει όλες τις μονάδες απόκρισης να επιτύχουν την ίδια κατανόηση (κοινή επίγνωση μιας κατάστασης) των πληροφοριών και της εξέλιξης μιας κατάστασης έκτακτης ανάγκης όταν διενεργούν τις επιχειρήσεις τους. Επομένως, ένα δικτυοκεντρικό σύστημα μπορεί να θεωρηθεί σαν ένα εργαλείο απόκρισης σε καταστάσεις έκτακτης ανάγκης με προστιθέμενη αξία όχι μόνο στην αποτελεσματική ανταλλαγή πληροφοριών αλλά και στην κατανόηση του πραγματικού νοήματος και της χρονικής αξίας της μεταχειρισμένης αλλά και απαιτούμενης πληροφορίας για διενέργεια επιχειρήσεων, επικοινωνία και συντονισμό των υπηρεσιών διαχείρισης κρίσεων. Επιπλέον, τα δικτυοκεντρικά συστήματα καθώς και η κοινή επιχειρησιακή εικόνα αποτελούν βασικά συστατικά για την επίτευξη βελτιωμένης επίγνωσης μιας κατάστασης. Στο γνωστικό τομέα, οργανισμοί, διαδικασίες και εμπλεκόμενοι στηριγμένοι σε καλύτερη κοινή επίγνωση μιας κατάστασης και υποβοηθούμενοι από την τεχνολογία μπορούν να επιδείξουν καλύτερες συμπεριφορές προς την κατεύθυνση αποτελεσματικής λήψης αποφάσεων με αποτέλεσμα να εξάγονται καλύτερες δράσεις και ενέργειες με καλύτερες επιδράσεις στο φυσικό τομέα.

Εν συντομία, ένα δικτυοκεντρικό σύστημα προσασμοσμένο στις ιδιαίτερες συνθήκες των καταστάσεων έκτακτης ανάγκης δύναται να εφαρμοστεί με επιτυχία δημιουργώντας προστιθέμενη αξία για τις επιχειρήσεις απόκρισης. Επιπρόσθετα, μπορεί να προσφέρει την ευελιξία και τα χαρακτηριστικά της προσαρμοζόμενης διαχείρισης κρίσεων που αποτελεί μια από τις πιο αποτελεσματικές προσεγγίσεις για απόκριση σε δυνητικές φυσικές καταστροφές. Ωστόσο, η επιτυχής υιοθέτηση ενός δικτυοκεντρικού πληροφοριακού συστήματος απαιτεί την προσεκτική εισαγωγή του σε διαφορετικά στάδια βασισμένη σε ένα μοντέλο ωριμότητας και λαμβάνοντας υπόψη ότι βραχυπρόσθεσμες στρατηγικές που υποθέτουν ότι η κοινή επίγνωση μιας κατάστασης μπορεί να επιτευχθεί εύκολα είναι καταδικασμένες να αποτύχουν. Επιπλέον, η εισαγωγή ενός τέτοιου συστήματος στους εμπλεκόμενους φορείς αντιμετώπισης καταστάσεων έκτακτης ανάγκης απαιτεί εκπαίδευση του προσωπικού τους προκειμένου να υπερπηδηθούν τυχόν προβλήματα δυνητικής έλλειψης γνώσης.

### ***Τρισδιάστατες πληροφοριακές έννοιες για διαχείριση και επικοινωνία της διακινδύνευσης στο σύνθετο αστικό χώρο.***

Η πρώτη εμπειρική μελέτη αυτής της διατριβής (κεφάλαιο 3), διενεργεί μια μελέτη περίπτωσης προκειμένου να διερευνήσει τη χρησιμότητα των τρισδιάστατων εικονικών μοντέλων πόλης στην επικοινωνία και διαχείριση της πλημμυρικής διακινδύνευσης. Επίσης, εννοιολογικοποιεί ένα τρισδιάστατο πληροφοριακό σύστημα βασισμένο στα τρισδιάστατα εικονικά μοντέλα πόλης ως βήμα προς την κατεύθυνση προσδιορισμού ενός πλαισίου για συστήματα διαχείρισης της πλημμυρικής διακινδύνευσης και προετοιμασίας για απόκριση σε έκτακτες ανάγκες.

Για την διερεύνηση της προστιθέμενης αξίας των τρισδιάστατων εικονικών μοντέλων πόλης, έχει επιλεχθεί ως μελέτη περίπτωσης, η πόλη Heerhugowaard στην Ολλανδία. Τα τρισδιάστατα εικονικά μοντέλα που έχουν αναπτυχθεί για αυτή την πόλη βασίζονται σε κανόνες και εντολές και περιγράφουν τα γεωμετρικά και εμφανισιακά χαρακτηριστικά των αντικειμένων της πόλης προσφέροντας δυναμικές τρισδιάστατες απεικονίσεις των συστατικών της πλημμυρικής διακινδύνευσης στη βάση ενός σχετικού μοντέλου πηγής - διόδου - υποδοχέα. Τα τρισδιάστατα αυτά εικονικά μοντέλα παρέχουν γραφικές και μη γραφικές πληροφορίες επιτρέποντας οπτική εξόρυξη δεδομένων, ανάλυση και πλοήγηση. Επίσης, διευκολύνουν την αλληλεπίδραση των ενδιαφερόμενων μερών παροτρύνοντάς τους να διαδραματίσουν ένα ενεργό ρόλο στη διαδικασία λήψης αποφάσεων για διαχείριση της πλημμυρικής διακινδύνευσης. Επιπλέον, τα μοντέλα πόλης που αναπτύσσονται σε αυτό το κεφάλαιο προσφέρουν δυναμικές τρισδιάστατες επιχειρησιακές εικόνες ή τετραδιάστατες επιχειρησιακές εικόνες λαμβάνοντας υπόψη τη χρονική μεταβλητή και στοχεύουν στη βελτίωση της επίγνωσης της κατάστασης μεταξύ των εμπλεκόμενων φορέων όσον αφορά στην πλημμυρική διακινδύνευση της περιοχής ενδιαφέροντος. Επιπρόσθετα, τα τρισδιάστατα αυτά μοντέλα επιτρέπουν στους εμπλεκόμενους να εξετάσουν και να κρίνουν τις εναλλακτικές τους προτάσεις καθώς και να αξιολογήσουν οπτικώς τις επιπτώσεις τους σε πραγματικό χρόνο, κατόπιν τροποποίησης των παραμέτρων των μοντέλων της πόλης με την επικουρία καθορισμένων διαδικαστικών κανόνων και εντολών. Έτσι, υποστηρίζεται η διαφάνεια, ενισχύεται η εμπιστοσύνη και διευκολύνεται η συνεργασία μεταξύ των εμπλεκομένων. Επίσης, ενισχύονται οι γνωστικές ικανότητες των συμμετεχόντων ούτως ώστε να δύνανται να ασκούν αποτελεσματικά την επιρροή που απορρέι από τη θέση τους κατά τη διαδικασία λήψης αποφάσεων. Ωστόσο, η ποιότητα της αναπαράστασης των τρισδιάστατων αντικειμένων της πόλης είναι άμεσα συνδεδμένη με τη διαθεσιμότητα και ακρίβεια των δεδομένων.

Τα εικονικά τρισδιάστατα μοντέλα πόλης μπορούν να θεωρηθούν ως εξαιρετικά μέσα για ενσωμάτωση, συντήρηση, παρουσίαση, διάχυση και επικοινωνία με κατανοητό κι εύληπτο τρόπο, πιο κοντά στον πραγματικό τρισδιάστατο κόσμο, των γεω-πληροφοριών που σχετίζονται με τη διακινδύνευση. Αυτό επιβεβαιώνεται μέσα από την εκτεταμένη βιβλιογραφική έρευνα που έχει πραγματοποιηθεί σε αυτό το κεφάλαιο. Ωστόσο, στο στάδιο προετοιμασίας για απόκριση σε καταστάσεις έκτακτης ανάγκης όπου οι εμπλεκόμενοι φορείς πρέπει να αναπτύξουν σχέδια που περιλαμβάνουν για παράδειγμα εσωτερικές ή/και εξωτερικές διαδρομές εκκένωσης, απαιτούνται επιπρόσθετα, τοπολογικές και σημασιολογικές πληροφορίες όσον αφορά στα τρισδιάστατα αντικείμενα της πόλης και των συστατικών τους. Αυτές οι πληροφορίες μπορούν δυνητικά να ικανοποιήσουν την ανάγκη των διαφόρων οργανισμών ασφαλείας για αναζήτηση και ανάλυση των τρισδιάστατων μοντέλων πόλης. Επιπλέον, μια βασική παράμετρος για την αποτελεσματική διαχείριση της διακινδύνευσης και την ετοιμασία για απόκριση σε έκτακτες ανάγκες είναι η ικανότητα των εμπλεκομένων να διαλειτουργούν (να λειτουργούν μαζί). Καθώς τα απαιτούμενα δεδομένα προέρχονται από πολλαπλές πηγές και συνήθως έχουν ποικίλες μορφές, είναι αναγκαίο να υιοθετηθεί μια «κοινή γλώσσα» μεταξύ των διαφόρων υπηρεσιών ασφαλείας η οποία εν δυνάμει να μπορεί να επικουρήσει στην υπερπήδηση αυτού του καταρκεματισμού των δεδομένων. Σε αυτό το πλαίσιο, ένα τρισδιάστατο πληροφοριακό σύστημα που βασίζεται στα εικονικά τρισδιάστα μοντέλα πόλης και επεκτείνεται με υφιστάμενα ανοικτά διεθνή πρότυπα δεδομένων από τους τομείς των Συστημάτων Γεωγραφικών Πληροφοριών και των Μοντέλων

Κτιριακών Πληροφοριών όπως είναι η γεωγραφική γλώσσα σήμανσης δεδομένων πόλης (CityGML) και οι θεμελιακές κλάσεις της βιομηχανίας (IFC) αντίστοιχα, έχει αναπτυχθεί και παρουσιάζεται εννοιολογικά στοχεύοντας να κάνει ένα βήμα προς την κατεύθυνση προσδιορισμού ενός πλαισίου για συστήματα διαχείρισης της πλημμυρικής διακινδύνευσης και ετοιμασίας για απόκριση σε έκτακτες ανάγκες.

Το τρισδιάστατο σύστημα που έχει εννοιολογικοποιηθεί σε αυτό το κεφάλαιο, δύναται να ξεπεράσει τους περιορισμούς των εικονικών τρισδιάστατων μοντέλων που έχουν αναπτυχθεί για την περιοχή της Heerhugowaard σκοπεύοντας να επιτρέψει σημασιολογική διαλειτουργικότητα κατά τη διάρκεια της διαχείρισης της διακινδύνευσης και της προετοιμασίας για έκτακτες ανάγκες. Επιπλέον, στοχεύει να προσφέρει στους εμπλεκομένους όχι μόνο λειτουργίες πλοήγησης αλλά και εύχρηστες δυνατότητες αναζήτησης και ανάλυσης των τρισδιάστατων μοντέλων μέσω των υιοθετημένων προτύπων του εννοιολογικού συστήματος. Συγκεκριμένα, αυτά τα πρότυπα προσφέρουν, σημασιολογικές, τοπολογικές και θεματικές πληροφορίες εκτός από τα γεωμετρικά και εμφανιακά χαρακτηριστικά των τρισδιάστατων μοντέλων πόλης. Επιπρόσθετα, το τρισδιάστατο αυτό σύστημα πληροφοριών μέσα από τη λεπτομερή περιγραφή των φυσικών και λειτουργικών χαρακτηριστικών αλλά και σχέσεων των αντικειμένων της πόλης στη μακροκλίμακα (πόλη) καθώς και στη μικροκλίμακα (εγκατάσταση), φιλοδοξεί να επιτρέψει την ανάπτυξη εναλλακτικών εξωτερικών και εσωτερικών διαδρομών εκκένωσης κτιρίων για διαχείριση της εναπομείνουσας διακινδύνευσης και ετοιμασία για καταστάσεις έκτακτης ανάγκης. Το προτεινόμενο τρισδιάστατο πληροφοριακό σύστημα επιλέγει το πρότυπο δεδομένων CityGML από τον τομέα των Συστημάτων Γεωγραφικών Πληροφοριών ως μοντέλο για την αναπαράσταση του πολύπλοκου αστικού χώρου καθώς είναι περισσότερο ικανό στη μοντελοποίηση αντικειμένων στη μακροκλίμακα χρησιμοποιώντας πέντε διακριτά επίπεδα λεπτομέρειας ενώ τα Μοντέλα Κτιριακών Πληροφοριών σε μορφή κλάσεων IFC είναι σχεδιασμένα να αναπαριστούν την πληροφορία με μεγάλη λεπτομέρεια στη μικροκλίμακα με αποτέλεσμα να αποτελούν μια πολύτιμη πηγή ενημερωμένων πληροφοριών όσον αφορά στις εγκαταστάσεις μιας πόλης, τις κατασκευές της και την κατάστασή τους. Κατά τη διάρκεια αυτού του κεφαλαίου, η βιβλιογραφική έρευνα κατέδειξε ότι υπάρχουν παραδείγματα μετατροπής των δεδομένων από μορφή IFC των Μοντέλων Κτιριακών Πληροφοριών σε μορφή CityGML των Συστημάτων Γεωγραφικών Πληροφοριών. Όμως, το επίπεδο λεπτομέρειας της τελικής αναπαράστασης των αντικειμένων της πόλης σε CityGML, εξαρτάται από την ακρίβεια και τη διαθεσιμότητα των απαιτούμενων δεδομένων. Επίσης, η κατασκευή των διαφορετικών επιπέδων λεπτομέρειας της CityGML αποτελεί δύσκολο έργο ενώ η συλλογή της σημασιολογίας καθώς και ο έλεγχος της εγκυρότητας των γεωμετριών των αντικειμένων της πόλης είναι απαιτητικά τόσο σε χρόνο όσο και σε προσπάθεια.

Οι κυβερνήσεις καθώς και οι οργανισμοί ασφαλείας πρέπει να εξετάσουν την υιοθέτηση και αξιοποίηση τρισδιάστατων πληροφοριακών συστημάτων βασισμένων σε εικονικά τρισδιάστατα μοντέλα πόλης μιας και αυτά φιλοδοξούν να υποστηρίξουν αποτελεσματικά διαδικασίες διάχυσης πληροφοριών και επικοινωνίας, δημιουργώντας προϋποθέσεις για συμμετοχική διαχείριση της πλημμυρικής διακινδύνευσης και ετοιμασία για απόκριση σε καταστάσεις έκτακτης ανάγκης. Ένα τέτοιο τρισδιάστατο σύστημα δύναται να παρέχει στα ενδιαφερόμενα μέρη ίσες ευκαιρίες πρόσβασης στις απαιτούμενες πληροφορίες προς την κατεύθυνση διευκόλυνσης της δημιουργίας επίγνωσης όσον αφορά σε καταστάσεις διακινδύνευσης, ενισχύοντας τη διαφάνεια, την εμπιστοσύνη και τη διεπιστημονική συνεργασία για καλύτερες αποφάσεις με καλύτερα αποτελέσματα στον πραγματικό κόσμο. Τα επικαλυπτόμενα πεδία των Μοντέλων Κτιριακής Πληροφορίας δεινκύουν μια ευκαιρία για συνεργασία, μεταφορά γνώσης και ενσωμάτωσης των ρόλων όλων των εμπλεκόμενων φορέων στη μικροκλίμακα. Ωστόσο, η συνεργασία ούτε μπορεί να επιβληθεί, ούτε επίσης να επιτευχθεί όντας έννοια ενός θεσμικού πλαισίου που αφορά στη διαχείριση της διακινδύνευσης. Τα πληροφοριακά συστήματα βασισμένα σε εικονικά τρισδιάστατα μοντέλα πόλης, μπορούν δυνητικά να διευκολύνουν τη συνεργασία, αλλά για την εφαρφμογή της στην πράξη απαιτούνται μεταβολές σε θεσμικές συμπεριφορές.

### ***Μια εμπειρική προσέγγιση στην αξιολόγηση της αποτελεσματικότητας των δικτυοκεντρικών εργαλείων υποστήριξης της απόκρισης σε πλημμυρικές καταστάσεις έκτακτης ανάγκης: Αποτελέσματα άσκησης πεδίου.***

Η δεύτερη εμπειρική μελέτη αυτής της διατριβής (κεφάλαιο 5) μέσα από μια σειρά βημάτων τα οποία περιλαμβάνουν βιβλιογραφική ανασκόπηση, οργάνωση άσκησης πεδίου με ρεαλιστικά πλημμυρικά σενάρια και ερωτηματολόγια για καταγραφή της κρίσης των εμπειρογνωμόνων αξιολογεί και παραθέτει τα αποτελέσματα μιας εμπειρικής ανάλυσης όσον αφορά στην προστιθέμενη αξία των δικτυοκεντρικών συστημάτων σε πλημμυρικές καταστάσεις έκτακτης ανάγκης. Στα πλαίσια αυτού του κεφαλαίου, η εκτίμηση της αποτελεσματικότητας των δικτυοκεντρικών συστημάτων βασίζεται στη λήψη και ποιοτική σύγκριση της κρίσης και άποψης των εμπειρογνωμόνων αναφορικά με το σύστημα που χρησιμοποιούν στην καθημερινή τους πρακτική και το οποίο εδράζεται σε μια ιεραρχική λογική σε σχέση με ένα δικτυοκεντρικό σύστημα το οποίο χρησιμοποιείται κατά τη διάρκεια αυτής της άσκησης. Τα τρέχοντα συστήματα στον τομέα των επιχειρήσεων απόκρισης σε καταστάσεις έκτακτης ανάγκης χαρακτηρίζονται παραδοσιακά ως μονοεπιστημονικά και επιτρέπουν τη ροή των πληροφοριών από πάνω προς τα κάτω καθώς και από κάτω προς τα πάνω δημιουργώντας επιχειρησιακές εικόνες στατικές και εξειδικευμένες για συγκεκριμένες υπηρεσίες ασφαλείας. Αντιθέτως, η αρχιτεκτονική του δικτυοκεντρικού συστήματος αυτής της άσκησης πεδίου, εστιάζει στη διευκόλυνση της οριζόντιας ανταλλαγής πληροφοριών και επικοινωνίας μεταξύ των εμπλεκομένων. Το σύστημα είναι σχεδιασμένο με γνώμονα την αξιοποίηση των δικτυοκεντρικά ενεργοποιημένων ικανοτήτων οι οποίες αντανακλώνται στην αλυσίδα αξίας τους με βάση την οποία καλύτερα δίκτυα μπορούν να βελτιώσουν την ανταλλαγή πληροφοριών στον πληροφοριακό τομέα που με τη σειρά τους μπορούν να οδηγήσουν σε καλύτερη κατανόηση μιας κατάστασης καθώς και σε καλύτερες αποφάσεις στο γνωστικό τομέα οδηγώντας σε βέλτιστες ενέργειες με υπέρτερες επιδράσεις στο φυσικό τομέα.

Στην άσκηση πεδίου που έχει οργανωθεί σε αυτή τη διατριβή, οι συμμετέχοντες ήταν πραγματικοί και καλά καταρτισμένοι επαγγελματίες για απόκριση σε καταστάσεις έκτακτης ανάγκης. Παρόλο που οι συμμετέχοντες ήταν λίγοι λόγω μη διαθεσιμότητάς τους σε συνδυασμό με το απαιτητικό επιχειρησιακό περιβάλλον της διαχείρισης κρίσεων, οι απόψεις τους ως εμπειρογνώμονες, που ελήφθησαν κατά τη διάρκεια αυτής της άσκησης κρίνονται ως εξαιρετικά σημαντικές και πολύτιμες δεδομένου του πολύ περιορισμένου αριθμού τέτοιων δεδομένων στον τομέα της απόκρισης σε έκτακτες ανάγκες. Το πλαίσιο αξιολόγησης αυτής της άσκησης βασίζεται σε δομές όσον αφορά στην ποιότητα των πληροφοριών καθώς και στην ποιότητα των συστημάτων που έχουν εξευρεθεί μέσα από εκτεταμένη βιβλιογραφική επισκόπηση. Οι δομές που αφορούν στην ποιότητα των πληροφοριών έχουν χρησιμοποιηθεί για τη διερεύνηση της συμβολής μιας κοινής επιχειρησιακής εικόνας στην επίτευξη καλύτερης κοινής επίγνωση μιας κατάστασης, ενώ οι δομές που σχετίζονται με την ποιότητα των συστημάτων έχουν αξιοποιηθεί για την αξιολόγηση της συμβολής ενός δικτυοκεντρικού συστήματος στην καλύτερη ανταλλαγή πληροφοριών και στην ανάπτυξη μιας κοινής επιχειρησιακής εικόνας. Η ποιότητα των πληροφοριών σχετίζεται με τα χαρακτηριστικά τους καθώς επίσης και με το βαθμό στον οποίο αυτές δύνανται να ικανοποιήσουν τις ανάγκες των τελικών χρηστών τους. Η ποιότητα των συστημάτων εστιάζει σε διαστάσεις που αφορούν στα συστήματα αυτά καθαυτά, στην εκπλήρωση των καθηκόντων των εμπλεκομένων καθώς και στην αντιληπτή λειτουργική τους ικανοποίηση. Τόσο η ποιότητα των πληροφοριών όσο και η ποιότητα των συστημάτων αποτελούν προϋποθέσεις για την ανάπτυξη μιας κοινής επιχειρησιακής εικόνας καθώς και για την αξιοποίηση στο μέγιστο βαθμό της δυναμικής της επίτευξης κοινής επίγνωσης μιας κατάστασης.

Οι διαστάσεις της ποιότητας των πληροφοριών για τις οποίες έχει επιδειχθεί αύξηση της εκτίμησής τους από μέρους των επαγγελματιών μετά από την εμπειρία τους με το δικτυοκεντρικό σύστημα σε αυτή την άσκηση πεδίου, είναι η επικαιρότητα καθώς και η αξιοπιστία της πληροφορίας. Αυτό αιτιολογείται από τη φύση της ίσου προς ίσον (peer-to-peer) τεχνολογίας που υποστηρίζει ένα δικτυοκεντρικό σύστημα το οποίο επιτρέπει στους τελικούς του χρήστες να λαμβάνουν άμεσα έγκαιρες πληροφορίες. Επιπλέον, η ταχύτητα στην ανταλλαγή πληροφοριών που προσφέρεται από ένα τέτοιο σύστημα, επιτρέπει στους χρήστες του να ανακαλύπτουν γρήγορα το βαθμό στον οποίο η πληροφορία που ανταλλάσσεται είναι ορθή και έμπιστη. Αντίθετα, το σύστημα που χρησιμοποιούν οι επαγγελματίες στις καθημερινές τους λειτουργίες, συχνά τους αφήνει να περιμένουν μέχρι να λάβουν τις χρειώδεις πληροφορίες. Συγκεκριμένα, το τρέχον σύστημα που μεταχειρίζονται οι εμπλεκόμενοι βασίζεται σε μια ιεραρχική λογική και υποστηρίζεται από μια παραδοσιακή αρχιτεκτονική διακομιστή-πελάτη (client-server) που επιτρέπει ανταλλαγή πληροφοριών στη βάση του ένας προς έναν. Κατά τη διάρκεια της άσκησης πεδίου, έχει επίσης παρατηρηθεί μαθησιακή επίδραση ένεκα του γεγονότος ότι οι συμμετέχοντες μετά την εμπειρία που απέκτησαν κατά τη διάρκεια του πρώτου ρεαλιστικού πλημμυρικού σεναρίου όπου οι επιχειρήσεις απόκρισης έλαβαν χώρα σε ένα δικτυοκεντρικό περιβάλλον, λειτούργησαν καλύτερα κατά τη διάρκεια του δεύτερου και πιο σύνθετου πλημμυρικού σεναρίου. Από τις κρίσεις των εμπειρογνωμόνων που αντανακλώνται στα αποτελέσματα των ερωτηματολογίων αυτής της άσκησης, μπορεί να εξαχθεί ότι όσο η πολυπλοκότητα και η κρισιμότητα των σεναρίων αυξάνει και η ανάγκη για περισσότερες πληροφορίες μεγαλώνει, τόσο περισσότερο οι επαγγελματίες τείνουν να εκτιμούν την ποιότητα των ανταλλασσόμενων πληροφοριών σε ένα δικτυοκεντρικό περιβάλλον.

Οι διαστάσεις της ποιότητας των συστημάτων για τις οποίες έχει επιδειχθεί μια αύξηση στην εκτίμησή τους από τους ειδικούς μετά την εμπειρία τους με το δικτυοκεντρικό σύστημα αυτής της άσκησης πεδίου, είναι η σχετιζόμενη με το σύστημα αυτό καθαυτό προσβασιμότητα, οι σχετιζόμενες με τα καθήκοντα των επαγγελματιών, ενσωμάτωση και επίγνωση μιας κατάστασης και οι σχετιζόμενες με την αντιληπτή λειτουργική ικανοποίηση των τελικών χρηστών, χρηστικότητα και ευκολία στη χρήση. Αυτές οι διαστάσεις της ποιότητας των συστημάτων μπορούν να θεωρηθούν και ως οι αρχές σχεδιασμού ενός πλαισίου για προσαρμοζόμενα συστήματα απόκρισης σε καταστάσεις έκτακτης ανάγκης που με βάση την κρίση των εμπειρογνωμόνων υποστηρίζονται καλύτερα από δικτυοκεντρικά εργαλεία. Τα αποτελέσματα που αφορούν στις διαστάσεις της ποιότητας των συστημάτων δεικνύουν ότι οι εμπειρογνώμονες αντιλαμβάνονται ένα δικτυοκεντρικό σύστημα ως κατάλληλο για αποτελεσματική διευκόλυνση της προσβασιμότητας σε όλες τις απαιτούμενες πληροφορίες. Επιπλέον, τα αποτελέσματα υποδηλώνουν ότι οι εμπειρογνώμονες φαίνεται να αναγνωρίζουν ότι ένα δικτυοκεντρικό σύστημα μπορεί να τους επιτρέψει να ενσωματώσουν πληροφορίες προερχόμενες από διάφορες πηγές προς την κατεύθυνση δημιουργίας μια κοινής επιχειρησιακής εικόνας ικανής να τους υποστηρίξει στην ανάπτυξη επίγνωσης σχετικά με μια συγκεκριμένη πλημμυρική κατάσταση. Επιπρόσθετα, τα αποτελέσματα δεικνύουν ότι οι εμπειρογνώμονες τείνουν να θεωρήσουν ένα δικτυοκεντρικό σύστημα εύκολο στη χρήση του πιθανόν λόγω των εκπαιδευτικών σεμιναρίων που προηγήθηκαν και είχαν στόχο την εξοικείωσή τους με το σύστημα που χρησιμοποιήθηκε σε αυτή την άσκηση. Συνολικά, οι εμπλεκόμενοι επαγγελματίες φαίνεται να εκτιμούν τη χρησιμότητα και τις ικανότητες ενός δικτυοκεντρικού συστήματος στις επιχειρήσεις απόκρισης σε έκτακτες ανάγκες.

Με βάση την κρίση των εμπειρογνωμόνων που συμμετείχαν στο πείραμα πεδίου αυτής της διατριβής, συμπεραίνεται ότι τα δικτυοκεντρικά συστήματα έχουν τη δυνατότητα να επιτρέψουν καλύτερη ανταλλαγή πληροφοριών προς την κατεύθυνση ανάπτυξης μιας κοινής επιχειρησιακής εικόνας και βελτίωσης της επίγνωσης μιας κατάστασης από τους εμπλεκομένους, υποστηρίζοντας αποτελεσματικά τη λήψη αποφάσεων για απόκριση σε πλημμυρικές καταστάσεις έκτακτης ανάγκης. Ωστόσο, η εισαγωγή ενός δικτυοκεντρικού συστήματος στις υπηρεσίες αντιμετώπισης κρίσεων, σίγουρα δεν είναι εύκολη υπόθεση καθώς στις επιχειρήσεις απόκρισης εμπλέκονται πολλές και διάφορες υπηρεσίες ασφαλείας. Αυτές οι υπηρεσίες είναι συνήθως αυτόνομες και ετερογενείς στην καθημερινή τους λειτουργία και έχουν εξειδικευμένες δομές, διαδικασίες και στόχους που συντείνουν τόσο στην κατακερματισμένη πολιτική όσο και στο κατακερματισμένο οργανωτικό περιβάλλον της ανταλλαγής πληροφοριών και συντονισμού μεταξύ των υπηρεσιών εκτάκτων αναγκών. Η υιοθέτηση καθώς και η εφαρμογή ενός δικτυοκεντρικού συστήματος από τους οργανισμούς αρωγής ίσως να απαιτούν σημαντικές θεσμικές μεταρρυθμίσεις. Τα υφιστάμενα συστήματα πληροφοριών πρέπει να επανασχεδιαστούν με κριτικό πνεύμα και στη βάση καινοφανών αρχιτεκτονικών συντονισμού των πληροφοριών (δικτυοκεντρικών αντί ιεραρχικών). Επίσης, η διαχείριση δεδομένων καθώς και οι τρέχουσες μέθοδοι εργασίας που είναι βασισμένες στη διανομή πληροφοριών σε πραγματικό χρόνο πρέπει να αναθεωρηθούν προς την κατεύθυνση επίτευξης συλλογικής νοημοσύνης μεταξύ των υπηρεσιών ασφαλείας. Επιπρόσθετα, πρέπει να προσδιοριστεί ποιοί οργανισμοί και ποιά μέλη τους πρέπει να προσφέρουν συγκεκριμένες πληροφορίες σε συγκεκριμένους οργανισμούς και μέλη τους κατά τη διάρκεια των επιχειρήσεων απόκρισης σε έκτακτες ανάγκες. Το τελευταίο, αποτέλεσε ένα κρίσιμο ζήτημα στην αφετηρία της άσκησης πεδίου αυτής της διατριβής αποκαλύπτοντας ότι οι εμπλεκόμενοι στη διαχείριση κρίσεων υποφέρουν από έλλειψη επίγνωσης όσον αφορά στη διαθεσιμότητα των πληροφοριών. Πιο συγκεκριμένα, οι επαγγελματίες δεν γνώριζαν ποιοί διέθεταν τις πληροφορίες που χρειάζονταν γεγονός που οδήγησε σε περιττή έρευνα, χαμηλό ποσοστό επαναχρησιμοποίησης πληροφοριών καθώς και σε χάσιμο πολύτιμου χρόνου για τις επιχειρήσεις απόκρισης. Αυτό επιβεβαιώνει ότι οι ρόλοι και οι δυνατότητες ανταλλαγής πληροφοριών και συντονισμού στις επιχειρήσεις απόκρισης σε έκτακτες ανάγκες είναι επί του παρόντος ρυθμισμένες στη βάση ιεραρχικής λογικής και δεν προσαρμόζονται εύκολα στις απαιτήσεις μιας κατάστασης.

### ***Καταληκτικά.***

Τα ευρήματα αυτής της διατριβής αποτελούν βήμα προς την κατεύθυνση ανάπτυξης και υιοθέτησης καινοτόμων πληροφοριακών συστημάτων που υποστηρίζουν αποτελεσματικά την ανταλλαγή πληροφοριών, την επικοινωνία και τη συνεργασία μεταξύ των υπηρεσιών ασφαλείας και των επαγγελματιών τους, οι οποίοι βασισμένοι σε βελτιωμένη επίγνωση μιας κατάστασης δύνανται να διαχειριστούν αποδοτικότερα τη πλημμυρική διακινδύνευση σε μια περιοχή μελέτης ή να αντιμετωπίσουν τελέσφορα ένα περιστατικό πλημμύρας μικρής κλίμακας ή μια πλημμυρική κατάσταση μεγάλης κλίμακας. Ωστόσο ένα σύστημα από μόνο του δεν αρκεί για να λύσει όλα τα εν δυνάμει οργανωτικά προβλήματα των υπηρεσιών ασφαλείας ενός κράτους. Επιπλέον, η δημιουργία επίγνωσης όσον αφορά σε μια κατάσταση δεν αναπτύσσεται από ένα σύστημα με λογική μαύρου κουτιού. Η δημιουργία επίγνωσης μιας κατάστασης σχετίζεται με τη ψυχολογική, νοητική και γνωσιακή κατάσταση του τελικού χρήστη ενός συστήματος. Επιπρόσθετα, η επίτευξη επίγνωσης μιας κατάστασης μπορεί να επηρεαστεί από διάφορους παράγοντες όπως οι προηγούμενες εμπειρίες, το εκπαιδευτικό υπόβαθρο, η οργανωσιακή κουλτούρα, οι στόχοι καθώς και οι προσδοκίες των διαφόρων φορέων ασφαλείας. Προκειμένου η εισαγωγή και χρήση καινοτόμων πληροφοριακών συστημάτων από τους διάφορους φορείς ασφαλείας να στεφθεί με επιτυχία, πρέπει να γίνεται προσεκτικά και σε διαφορετικά στάδια με ενεργό συμμετοχή της διεύθυνσής τους, λαμβάνοντας υπόψη το θεσμικό πλαίσιο, τις οργανωτικές δομές, πρότυπα και κανόνες και κυρίως τον ανθρώπινο παράγοντα.