An empirical approach to the assessment of the effectiveness of network-centric support tools for flood-emergency response: Results of a field exercise

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Abstract

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, the 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 research memorandum 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 organizational structures, institutional rules, norms, and in particular the human factor.

Keywords:

Flood-emergency response, network-centric information systems, information quality, system quality, case study.

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 historic data between 1980 and 2010, has observed a significant increase in terms of floods and their 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., 2008; 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 minimize 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., 2012a, 2014; Goodchild, 2010). 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., 2004). Conversely, poor information quality can be fatal for the emergency responders and the victims (Lee et al., 2011; Turoff et al., 2004; 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., 2012a, 2012b, 2014, 2015; 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 characterized 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., 2012b, 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 dimensions, 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 research memorandum is organized 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 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 utilized in order to achieve the objective of this research memorandum; the experimental protocol and finally the limitations and assumptions of the case study. Then in Section 4, the research memorandum proceeds by tabulating and qualitatively discussing the results of the exercise, i.e. the experts' judgment on selected IQ and SQ dimensions. The research memorandum 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 organizations.

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. In addition, 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.

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.*, 2008), pressing (Smithson and Hirschheim, 1998), uncertain (Longstaff, 2005), and dynamic environment of emergency response, several autonomous organizations 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 organizations (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 utilized 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., 2004; 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 also 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., 2012b, 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, proposes the categorization of 21 constructs in four categories. Strong et al. (1997) also groups 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. (2012b, 2015), by analyzing 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 1).

Table 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), personalization.

(Adapted from Steenbruggen et al., 2012b, 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. (2012b, 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 *personalization* and *context awareness* are two relatively new dimensions which are interrelated with the contextual IQ dimension *quantity* (Steenbruggen et al., 2012b, 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 emphasized 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 in Table 2.

Table 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.

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., 2012b, 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 organizational 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 3. Most of the selected SQ constructs reflect the more engineering-oriented performance attributes of the system under consideration.

Table 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 understand 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 it 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., 2012b, 2015)

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 detail (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) delineates 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-synchronization 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 characterized by limited adaptability.

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.

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 center, 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 organizational 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 minimize 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, 2010; 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).

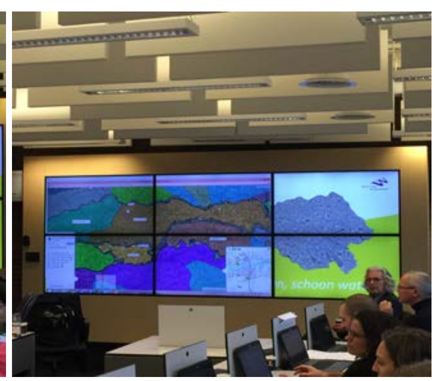
3.2 Set-up of the field exercise.

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 utilized in order to normalize 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 realized 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 10 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 1), in order to measure the added value of network-centric systems. The network-centric software tool used in this exercise is called 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 2 and 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 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 1: Stakeholders respond to the flood emergencies

Picture 2: Common Operational Picture in text form



Picture 3: Common Operational Picture in map form

3.3 Participants of the field exercise

The participants of the field exercise were emergency-response stakeholders (panel of experts). The following Table 4a, b shows their demographics, which have been extracted from their answers to the questionnaires, and include the number of participants, average age, gender, organization, 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 4a: 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 centre)	3
DCC-IenM Departmental Coordination Centre for Crisis management of the Dutch Ministry of Infrastructure and the Environment.	2

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

Table 4b: Demographics of the participants in the field exercise.

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 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

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 utilized, the operationalization 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 utilized 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 1). Instead, in a P2P network which underpins the logic of the network-centric approach, the safety organizations and stakeholders involved are considered as equal entities (peers or nodes), which serve both as a source and a recipient of information (see Figure 2). It is therefore apparent that in a P2P network, a distinction between clients and servers does not exist.

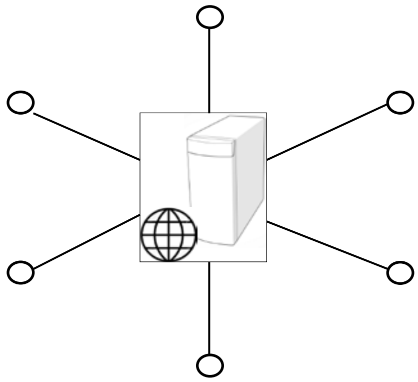


Figure 1: Client-server network (Hierarchical approach of information sharing – once with each)

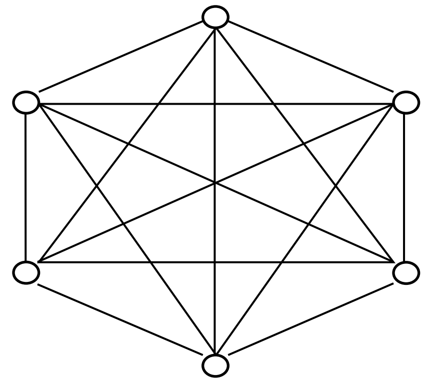


Figure 2: Peer-to-peer network (Network-centric approach of information sharing – once with all)

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 utilized 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 sit-reps-situation reports and sitplots-situation plots); it both facilitates and supports the decision makers.

Regarding the functionalities of the LCMS (see section 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, analyze, interpret and visualize 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 sit-reps 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 utilized for the visualization and communication of information is known as *sitplot* (situation plot). Basically, sitplot is a geographic interface which allows its users to create, edit, view, analyze 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 sit-plot 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 organizations and actors can have access to the shared picture at once. In addition, the different organizations 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 normalization of an emergency situation.

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 5a and 5b, a brief description of both the scenarios used during this exercise, along with their goals, is provided.

Table 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 organize 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 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 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 metres. 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 fieldworkers, 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, the 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 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 normalize the situation.

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 organizers (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 3 shows the layout of the field exercise.

Scenario Staff | Stakeholders (Expert panel)

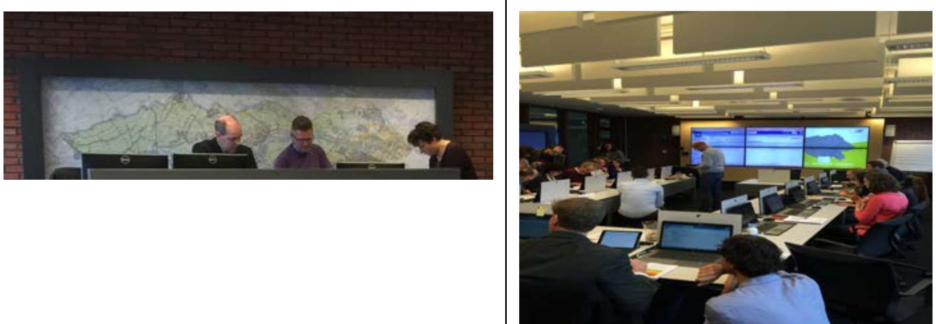


Figure 3: Field exercise's layout

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 organization. In addition, during the exercise, the organisers shadowed the participants using a pre-constructed form. Figure 4 below shows the experimental protocol along with its timelines.

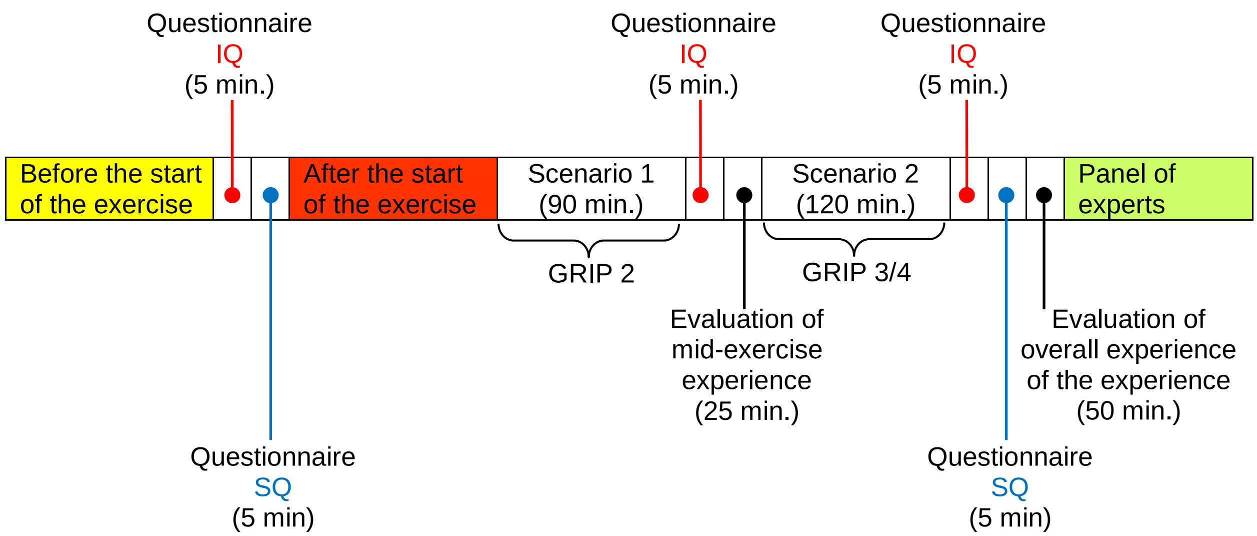


Figure 4: Schematic representation of the experimental protocol

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 organizations 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 organizations and stakeholders that should normally get involved in the response and normalization 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 practiced 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) organized 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.

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 utilized, and three statements (in Dutch) corresponding to each one were rated in order to validate them. However, these statements were placed in the questionnaires in random order. Furthermore, the statements were formulated in positive and negative forms in order to minimize 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 Appendix A. The stakeholders' perceptions of the same IQ dimensions but based on the experience gained during the two scenarios of this exercise, are provided in Appendices B and C. From the combination of the tabulated results, as well as from the organizers' 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 increase with regard to the IQ shared in such an environment. In this context, the stakeholders' judgment (answers) on IQ after considering Scenario 2 (see Appendix C) 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 Appendix A). Furthermore, as the complexity and the severity of the scenarios increases (Scenario 1 corresponds to a GRIP 2, while the 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.

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 normalization. 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 practicing the network-centric response operations during 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 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 personalization 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 Second 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 utilized and two, three or five statements (in Dutch) related to them were rated for their validation. The statements were placed in the questionnaires in random order and they were formulated in positive and negative forms in order to minimize 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 Appendix D. 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 Appendix E. From the organizers' observations, it can be seen that the participants (stakeholders) performed relatively better after the experience gained from working with the network-centric system (LCMS) utilized for the response operations during Scenario 1.

Furthermore, the stakeholders' judgment (answers) on SQ after participating in both the scenarios (see Appendix E) 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 utilize in their daily practice (see Appendix D).

For the system-related SQ attributes, three constructs were utilized: *accessibility*, *reliability*, and *response time*. Regarding the system-related SQ construct *accessibility*, while the stakeholders believe that the systems 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 utilized 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 organizations. 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 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 practiced 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 organized 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 organizers of the exercise, as the stakeholders, after gaining experience with the network-centric system in Scenario 1, performed better during the 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 utilized 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 recognized the added value of a network-centric system during the flood-emergency response.

5. Conclusions.

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., 2012b, 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 utilized 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 questionnaires 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 is 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 characterized by hierarchical (top-down) information flows that mainly lead to the development of static-oriented and organization-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 specialized structures, policies, and processes. This has traditionally contributed to the fragmented policy and organizational 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 organizations and individuals must provide what information to which organizations 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, organizational 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 organizations. Furthermore, central to the adoption strategy of such systems should be their gradual utilization in the management of emergencies, starting with the simplest incidents and proceeding to the more complex and chaotic situations.

Appendix A: Results of the questionnaire regarding the Quality of the Information (IQ) that the participants (stakeholders) experience in their daily practice (Statements are rated using 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
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

Appendix B: 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
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

Appendix C: 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, it 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
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

Appendix D: 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 organization.	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 a 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
Integration	1	It brings together information derived from different organizations.	1	2	3	2	0	0
	2	It has sufficiently supported me to share information within my own organization.	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 organizations.	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 of an emergency.	2	2	3	1	0	0
	2	It provides a comprehensive picture of handling 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

Appendix E: Results of the questionnaires regarding SQ that the participants (stakeholders) experienced during both Scenario 1 and 2. (Statements are rated using 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 organization.	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 a 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 organizations.	0	0	1	4	2	1
	2	It has sufficiently supported me to share information within my own organization.	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 organizations.	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 in the provision of 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

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