# DIOS: Disaster Interagency Orchestration System

*Developing and Evaluating a Network-Centric Crisis Information Management System for ensuring Information and System Quality in Crisis Situations*


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# Acknowledgments

This thesis report focuses on developing and evaluating a network-centric CIMS. I started this thesis in mid October 2009 with asking my current first supervisor Nitesh Bharosa whether he had a master thesis assignment for me. Consequently, this thesis contributes to the ongoing PhD-research of my first supervisor Nitesh Bharosa.

I was very fortunate that I could host the gaming simulation session at the Police Academy of the Netherlands. For this opportunity, I would like to thank all the officers of the Police Academy who made this possible. Also, I would like to thank all participants of the Master of Disaster Game, hosted on March 12, 2010.

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I hope that every reader will read this thesis with pleasure and I hope that everyone who reads this thesis gains more insight into crisis management and the important role of information in crisis situations.

Satiesh Bajnath
Den Haag, July 2010

# Summary


**Background and problem description**

This thesis investigates the extent to which a network-centric based crisis information management system ensures information quality (IQ) and system quality (SQ) in crisis situations. Repressing a crisis often has to be done by several heterogeneous actors (e.g. police, paramedics and firefighters), which makes crisis management often a complex task to fulfill. In crisis situations, information plays a key role in achieving effective crisis management. To elaborate on the role of information: two constructs are of high importance for assessing information as given in literature: information quality (IQ) and system quality (SQ). IQ is often characterized as a set of dimensions concerned with the quality of information (e.g. timeliness, correctness and consistency of information). On the other hand, SQ dimensions, such as flexibility, interoperability and response time, are concerned with the quality of the information system itself. Many evaluation reports on crisis response efforts have reported poor IQ and SQ, often hampering relief workers in their work. Moreover, crisis management processes are information-intensive and as a result they rely heavily on information of high quality and high-quality information management systems. For instance, in case incorrect information is delivered to relief workers about the number of victims (an IQ problem) or the information system is not available for 10 minutes (an SQ problem), the consequences of a disaster may be enormous. Thus, ensuring IQ and SQ during crisis situations has become an increasingly important topic on the agenda of both researchers and practitioners.

An important aspect in ensuring IQ and SQ dimensions is the architecture of a crisis information management system (CIMS), as this architecture often forms the basis for information provision and sharing during a crisis. Traditionally, CIMS were designed to accommodate information sharing in a hierarchical command-and-control structure. Important characteristics of a hierarchical structure are centralized decision-making and authorized (sequential) information sharing. However, in literature it has become evident that hierarchically coordinated CIMS often fail in ensuring IQ and SQ dimensions during crisis situations. Hierarchical CIMS were also criticized particularly because they are rigid, inefficient with respect to information sharing and have limited flexibility.

As a response, the alternative of network-centric coordinated CIMS is gaining more popularity. The network-centric approach originates from the field of military operations and is mainly focused on decentralized decision-making and allowing information sharing amongst all users of the information system in order to increase the shared situational awareness. Network-centric CIMS have been promoted for use in crisis situations, also in the Netherlands. Yet, despite the promotion of these network-centric CIMS in the Netherlands, little is known in current literature about their actual implementation and whether a network-centric CIMS design really ensures IQ and SQ dimensions in crisis situations. Furthermore, relief workers in the Netherlands also have little experience with utilizing a network-centric CIMS. With these described problems in mind, the following research question was formulated:

***To what extent does a network-centric CIMS design ensure IQ and SQ dimensions for relief workers during crisis situations?***

**Research approach**

This research question requires both designing a network-centric CIMS prototype and evaluating this system to determine whether the IQ and SQ dimensions are indeed ensured. As such, we followed a design science strategy which consisted of the following phases: (1) Awareness of the problem, (2) Suggestions for Design, (3) Development, (4) Evaluation and (5) Conclusion. The first step was to get aware of the problem and to

formulate the research objectives. For this purpose, we conducted desk research on IQ and SQ problems during crisis response. Additionally, we performed desk research to clarify the tasks and responsibilities of each relief agency during a crisis. Desk research was also performed to determine which IQ and SQ dimensions are relevant for a crisis situation.

Next, suggestions for a design were made in the second phase of this research. In this phase, we employed the principles behind network-centric warfare to design a network-centric CIMS. To our knowledge, network-centric CIMS are ill-studied in existing literature. As such, the network centric CIMS design is already a contribution to existing literature. In phase 3, a software development methodology was pursued for developing the network-centric CIMS prototype design, called DIOS (Disaster Interagency Orchestration System).

In the fourth phase of this research we evaluated DIOS using a gaming simulation with relief agency professionals at the Police Academy of the Netherlands. The heterogeneous group of participants consisted of several policemen, paramedics and firefighters. The gaming simulation replicated a crisis situation in which several agencies needed to work together in order to manage the crisis. We simulated two rounds of crisis response. In the first round, a CIMS with a conventional (hierarchical) approach was simulated by using predefined situation reports and distributing envelopes as communication method Information sharing was only done by commanders of each team and decisions were only made by commanders. In round 2, DIOS was used as the network-centric CIMS. Additionally, everyone could post and read information and make decisions. After each round, we requested the participants to fill out a questionnaire. Finally, an evaluation session was held in which the experiences of all participants were discussed.

**Results and conclusions**

Using a 7-point scale, the data analysis on the collected questionnaire data (N=22) revealed that DIOS, as a network-centric CIMS design, can ensure the following IQ and SQ dimensions for a crisis situation (the scores for round 1 and round 2 are given in brackets): the data indicates significant improvements on the correctness of information (R1: 4.33; R2: 5.00), the timeliness of information (R1: 3.80; R2: 4.29) and the accessibility of the information system (R1: 2.57; R2: 4.53) during a crisis situation.

Yet, our dataset did not show statistically significant improvements on other IQ or SQ dimensions when DIOS was used. Interestingly, the data reveals that the dimensions IQ-Overload and IQ-Consistency deteriorated in particular. With respect to information overload, it was already predicted in literature that this would be a major issue in using a network-centric CIMS. One explanation for the low score on IQ-Consistency is that in a network-centric CIMS, relatively more information becomes available for everyone, which may lead to the discovery of more inconsistent information on the average.

Apart from the results on IQ and SQ dimensions, we also discovered some interesting findings with respect to the attitude and experiences of the relief workers during the session. We observed that several relief workers had a somewhat negative stance towards using a network-centric CIMS, even before the gaming simulation session. This may be the result of the active imposition and promotion of network-centric systems by the Ministry of Internal Affairs of the Netherlands. This also means that there is a danger that relief workers are not entirely willing to accept a network-centric system because it requires major changes in their way of working. Furthermore, as we conducted the gaming simulation with a heterogeneous group of relief workers, a lot of relief workers also were of opinion that they experienced difficulties in collaborating effectively. The use of a network-centric CIMS caused some confusion and misalignment on which tasks are the most important and who needs to take responsibility for which action. Another point in this matter was that we were not able to completely satisfy the expectations of all participants. Some relief workers expected a learning workshop instead of only a gaming-simulation after which they could tell their experiences. We also found that relief workers experienced a mismatch between the network-centric CIMS and the hierarchical process structure they are acquainted with. Based on these results, we might conclude that the emergency response community in the Netherlands is not fully prepared to work with a network-centric CIMS as of yet.

If we consider the results of this research, we can conclude that the solution for ensuring IQ and SQ dimensions in crisis situations may lie in combining a hierarchical and network-centric approach for designing a CIMS. Further research needs to investigate CIMS designs that leverage both the advantages of a network-centric approach (e.g. timely and correct information) and of a hierarchical approach (e.g. alignment with the process structure and prevalence of the authority structure).

This study contributes to previous research in the field of crisis management because this research provides more clarity on the use of network-centric information systems in crisis situations to ensure IQ and SQ dimensions. In addition, this research contributes to the critical evaluation of network-centric CIMS in the Netherlands by giving users (i.e. relief workers) the opportunity to state their own opinion on possible future usage of a network-centric CIMS.

The conclusions formulated in this study are obviously limited by the boundaries of this research. The main limitation was that only one gaming simulation session was held. More gaming simulations are necessary to improve the reliability of our findings. Furthermore, we only observed crisis management processes as they are carried out in the Netherlands.

The following recommendations are meant for the practitioners in the Netherlands:

1. We recommend the Ministry of Internal Affairs of the Netherlands involve relief workers actively in developing and pre-testing a CIMS. Also, the ministry should take criticism and experiences of relief workers more into account by hosting feedback sessions in which the network-centric approach towards crisis management is discussed and evaluated. The Ministry must take into account that for implementing a network-centric CIMS that is effective, one needs the acceptance of all users.
2. We also recommend the Ministry of Internal Affairs involve all relief agencies in developing a CIMS that is interoperable. As these agencies are heterogeneous with respect to their information systems, procedures and authority structures, the development of a CIMS needs to happen in collaboration with every relief agency. The Ministry can, for instance, host collaboration sessions with representatives of all relief agencies for formulating acceptable requirements. In this way, each agency can give its preferences and the result may be more effective and acceptable for all agencies.

For researchers concerned with improving information management in crisis situations, we pose the following recommendations for further research:

1. Investigate further development of a fitting CIMS for crisis situations. Further research needs to be performed that leverages the advantages of both the network-centric and hierarchical approach. This can for instance be done by extending this research and trying to collaborate with other groups and organizations to come up with more requirements and design principles (e.g. collaborate with TNO, Ministry of Internal Affairs, Safety Regions and Municipalities).
2. Utilize more gaming simulation sessions with relief workers as an evaluation tool, as we only had a sample size of 22 relief workers. As relief workers have the opportunity to use a CIMS in a simulated crisis situation, the CIMS can be improved based on relevant feedback from the actual users. Also, a gaming simulation session gives the participants the chance to experience what it is like to use such a system. Furthermore, generalizing results of all sessions becomes easier and has more power as several groups of relief workers are asked to participate.

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# 1 Introduction

Repressing a crisis often has to be done by several heterogeneous actors (e.g. police, paramedics and firefighters), which make crisis management a complex task to fulfill. In the event that crisis management fails, the consequences can have a tremendous impact on society. The failure of crisis management was clearly visible during the events of 9/11. Miscommunication and insufficient information sharing put several firefighters inside one of the towers when it was collapsing, while policemen had the information concerning the collapsing danger (De Bruijn 2006).

Effective crisis management has become an increasingly important issue after this man-made disaster, not only on the political agenda but also as a significant topic in science. Reflecting back on the 9/11 event, the importance of information became evident as the lack of information sharing caused several firefighters to perish. Previous contributions in this field of science also state that in crisis situations crucial information is often lacking, not available, not shared adequately, or delivered too late (Quarantelli 1988; Fisher 1998; Dawes, Creswell et al. 2004; Horan and Schooley 2007).

As such, in state-of-the-art literature many scholars suggest that for making the right decisions in crisis situations, the access to the right information on the right level of detail at the right time is essential (Turoff 2002; Dawes, Creswell et al. 2004; Horan and Schooley 2007). These requirements are considered to be dimensions of the constructs of Information Quality (IQ) and System Quality (SQ) by Bharosa et al. (Bharosa and Janssen 2008).

IQ is often characterized as a set of dimensions concerned with the quality of information (e.g. timeliness, correctness and consistency of information) (Strong, Lee et al. 1997; Ballou, Madnick et al. 2004). On the other hand, SQ dimensions, such as flexibility, interoperability and response time, are concerned with the quality of the information system itself (Nelson, Todd et al. 2005; Bharosa, Janssen et al. 2009). Many evaluation reports on crisis response efforts have reported poor IQ and SQ, often hampering relief workers in their work (Dawes, Creswell et al. 2004; Helsloot 2005; Horan 2005). Moreover, crisis management processes are information-intensive and as a result they rely heavily on information of high quality and high-quality information management systems (De Bruijn 2006). For instance, in case incorrect information is delivered to relief workers about the number of victims (an IQ problem) or the information system is not available for 10 minutes (an SQ problem), the consequences of a disaster may be enormous. Thus, ensuring IQ and SQ during crisis situations has become an increasingly important topic on the agenda of both researchers and practitioners.

An important aspect in ensuring IQ and SQ dimensions is the architecture of a crisis information management system (CIMS), as this architecture often forms the basis for information provision and sharing during a crisis. Traditionally, CIMS were designed to accommodate information sharing in a hierarchical command-and-control structure (Bigley and Roberts 2001). Important characteristics of a hierarchical structure are centralized decision-making and authorized (sequential) information sharing (Schraagen, Huis in 't Veld et al. 2010). However, in literature it has become evident that hierarchically coordinated CIMS often fail in ensuring IQ and SQ dimensions during crisis situations. Hierarchical CIMS are also criticized particularly because they are rigid, inefficient with respect to information sharing and have limited flexibility (Drabek and McEntire 2003).

As a response, the alternative of network-centric coordinated CIMS is gaining more popularity. The network-centric approach originates from the field of military operations and is mainly focused on decentralized decision-making and allowing information sharing amongst all users of the information system in order to increase the shared situational awareness (Fewell and Hazen 2003; Stanovich 2006). Network-centric CIMS have been promoted for use in crisis situations, also in the Netherlands (Crisisplein.nl 2010). Yet, despite the promotion of these network-centric CIMS in the Netherlands, little is known in current literature about their actual implementation and about whether a network-centric CIMS design actually ensures IQ and SQ dimensions in crisis situations.

## 1.1 Research Objective

It is interesting to see that the popularity of network-centric systems and the concept of net-centricity are gaining vast popularity in the Netherlands. Moreover, the goal of the Ministry of Internal Affairs is to implement one nation-wide, network-centric information system. Yet, the question arises whether a network-centric system will actually contribute to a more effective crisis management in the Netherlands.

Proponents of a network-centric approach state that current ways of information management are too rigid, inflexible and inefficient due to the strict and hierarchical command-and-control structure. They advocate that a network-centric approach leads to better situational awareness of a crisis as everyone has immediate access to all information shared by a crisis response network.

On the other hand, opponents of a network-centric approach think that such an approach does not fit the current way of working and has the danger of information overload for each relief worker. The potential threat of information overload is also mentioned in the network-centric warfare approach of the military paradigm (Stanovich 2006).

We want to contribute to this academic discussion by performing this research. Therefore, the objective of this research is to find out whether a network-centric CIMS design actually improves information management in crisis situations. This is measured by assessing the extent to which IQ and SQ dimensions are ensured in crisis situations. This objective leads to the main research question in this thesis:

***To what extent does a network-centric CIMS design ensure IQ and SQ dimensions for relief workers during crisis situations?***

Because little research has been done on using a network-centric information system in crisis situations, we opted to design such a system. This system will be a proof of principle: we will design a network-centric CIMS to primarily test its feasibility and applicability in crisis management.

## 1.2 Thesis Structure

To ultimately answer my main research question, the structure of this thesis report is as follows:

- *Chapter 2 - Research Problem:* in this chapter, the research problem will be formulated alongside several demarcations and research questions.
- *Chapter 3 - Research Methodology:* the research methodology will stand central in this chapter. This methodology consists of 5 phases and is based on a design science methodology, as we are planning to design a network-centric CIMS.
- *Chapter 4 - Theoretical Background:* several desk researches are performed to create a theoretical background chapter. We will elaborate on the definition of crisis management, which IQ and SQ dimensions can be distinguished, what type of coordination mechanisms are defined for information management and which state-of-the-art CIMS solutions are already in place.
- *Chapter 5 - DIOS: Requirements and Principles:* requirements and design principles are formulated for the network-centric CIMS design.
- *Chapter 6 - DIOS: Functional Design:* based on the requirements and principles of the previous chapter, a functional design is made for the network-centric CIMS.
- *Chapter 7 - DIOS: Technical Design:* following the functional design, the technical design of the CIMS is shown in this chapter.

- *Chapter 8 - Evaluation of DIOS: 'Master of Disaster' Gaming Simulation:* to evaluate the network-centric CIMS on IQ and SQ dimensions, a quasi-experiment is held in the form of a gaming simulation. The design of the experiment, gaming simulation and the questionnaires is given in this chapter.
- *Chapter 9 - Results:* the results of the gaming simulation session are given. These results indicate whether the network-centric CIMS design indeed ensures IQ and SQ dimensions during a crisis situation.
- *Chapter 10 – Conclusions and Recommendations:* in the final chapter, the conclusions of this research are formulated and the main question is answered. Limitations of this research are also given and several recommendations are formulated for academics and practitioners.

# 2 Research Problem

An important part of this thesis is sharply formulating the research problem in order to come up with a feasible and relevant problem definition for this thesis. To this end, an in-depth exploration of the problem is conducted in paragraph 2.1, where after several problem demarcations are made to come up with a feasible and doable research subject. In paragraph 2.3 a formal problem statement is given and finally the research questions are formulated in paragraph 2.4.

## 2.1 Problem Exploration

Effectively managing a crisis has become an increasingly important issue, not only on the political agenda but also as a significant topic in science. Guaranteeing effective crisis management is however a difficult promise to fulfill, because crisis situations are characterized as dynamic, unpredictable and time-pressuring situations for decision-makers (Hermann 1972; Rosenthal 1997; Falkheimer and Heide 2006). Moreover, several relief agencies need to work together in order to effectively repress a crisis (De Bruijn 2006). Managing crisis situations can therefore be seen as a very complex process for all relief agencies (Bigley and Roberts 2001). As such, effective crisis management is a difficult, but still a very important goal to fulfill for relief agencies. An emerging concept in modern literature that assists in achieving effective crisis management is the use of Crisis/Disaster Information Management Systems (CIMS/DIMS). Several examples of CIMS can be found in (Fahland, Glässer et al. 2007; Iannella and Henricksen 2007; Iannella, Robinson et al. 2007; Ye, Song et al. 2008), even though many scholars use their own terminology to describe their CIMS. Yet, to understand CIMS and the use of it in crisis situations, a definition of information management is given first. Choo considers information management to be a set of six distinct processes within a given situation (Choo 1995):

1. Identifying information needs
2. Acquiring information
3. Organizing and storing information
4. Developing information products and services
5. Distributing information
6. Using information

These processes form a good starting point for explaining information management in crisis situations. However, as a crisis is characterized as a complex and dynamic process with a lot of unforeseeable events, additional information management processes are proposed by (Bharosa and Janssen 2008) and are already utilized by the Police Academy in the Netherlands:

1. *Validating information:* checking whether the information provided is the right information.
2. *Enriching information:* in case information is incomplete or inaccurate, agencies should search for additional information.

These information management processes play a prominent role in achieving effective crisis management. Ryoo and Choi confirm the importance of information management in crisis situations as they state that 'at the core of disaster management lie the monumental tasks of collecting, distributing, processing and presenting disaster-related data' (Ryoo and Choi 2006). In this context, the purpose of a CIMS is to provide support for the given information management processes above in crisis circumstances. Additionally, Iannella et al. consider a CIMS to be a complete suite of ICT functions addressing the many requirements from the emergency or crisis management community (Iannella, Robinson et al. 2007). Therefore, a CIMS can help relief agencies in making the right decisions under crisis circumstances.

Nonetheless, a CIMS needs to work with high-quality information in order to assist relief agencies adequately. As Iannella et al. also mention, 'the mantra for a CIMS is to deliver the right information to the right people in the right format in the right place at the right time' (Iannella and Henricksen 2007). Moreover, in state-of-the-art literature, many scholars suggest that for making the right decisions in crisis situations, the access to the right information on the right level of detail at the right time is essential (Turoff 2002; Dawes, Creswell et al. 2004; Horan and Schooley 2007). These information requirements are considered to be dimensions of the constructs of Information Quality (IQ) and System Quality (SQ) by Bharosa et al (Bharosa and Janssen 2008). As high-quality information and high-quality information systems are of importance in crisis situations, the constructs IQ and SQ are explained in the next paragraphs.

Given that information plays a crucial part in crisis management, the quality of information in crisis situations is of high relevance. In previous contributions on crisis management, scholars state that in crisis situations crucial information is lacking, not available, not shared adequately or delivered too late (Quarantelli 1988; Fisher 1998; Dawes, Creswell et al. 2004; Horan and Schooley 2007). As Fisher and Kingsma also suggest, the quality of information is crucial for an effective response on crises (Fisher and Kingma 2001). Information Quality is a construct widely discussed in literature that can be expressed in multiple dimensions, varying from completeness and timeliness of information to the correctness and understandability of information (Lee, Strong et al. 2002; Nelson, Todd et al. 2005; Bharosa and Janssen 2008). Knight and Burn present a list of 20 most common dimensions for IQ (Knight and Burn 2005). The five dimensions that can be distinguished in the mantra for a CIMS (‘the right information to the right people in the right format in the right place at the right time’) are correctness, accuracy, timeliness, format and relevancy of information.

Apart from the importance of IQ requirements in crisis situations, the concept of System Quality (SQ) also plays a significant role in crisis circumstances. SQ is a construct that assesses the quality of the information systems that process and provide information (Nelson, Todd et al. 2005). Response time, accessibility and interoperability are typically SQ dimensions or requirements (Bharosa, van Zanten et al. 2009), thereby focusing on the quality of the information systems. With respect to achieving a more effective crisis management, guaranteeing a high information and system quality within crisis information management processes is necessary.

As previously mentioned in this section, CIMS need to work with the right information in order to assist relief agencies accordingly. The requirements for information and information systems derived from IQ and SQ dimensions could provide a useful checklist a CIMS need to comply with in order to promise a more effective crisis management. However, designing and evaluating a CIMS that provides a high IQ and SQ during a crisis can prove to be a complicated job as different agencies with different information systems need to share the correct information with each other in a timely and accurate fashion. Moreover, not every IQ or SQ dimension is relevant in guaranteeing an effective crisis management (Bharosa, van Zanten et al. 2009). In addition, emergency or crisis management is still in its infancy when it comes to utilizing ICT solutions (Iannella, Robinson et al. 2007). On top of that, information management in crisis situations is seen as a problematic balancing act: agencies need to gather just enough information to effectively deal with the crisis, but they also need to reduce the amount of information to avoid sluggish communication and information overload (Turoff 2002).

As said before, an important aspect in ensuring IQ and SQ dimensions is the architecture of a crisis information management system (CIMS) (Ianella, Robinson et al. 2007) as this architecture often forms the basis for information provision and sharing during a crisis. Traditionally, CIMS are designed to accommodate information sharing in a hierarchical command-and-control structure (Bigley and Roberts 2001). Important characteristics of a hierarchical structure are centralized decision-making and authorized (sequential) information sharing. However, in literature it has become evident that hierarchically coordinated CIMS often fail in ensuring IQ and SQ dimensions during crisis situations (Bharosa, Janssen et al. 2009). Hierarchical CIMS are also condemned particularly because they are rigid, inefficient with respect to information sharing and have limited flexibility (Drabek and McEntire 2003).

As a response, the alternative of network-centric coordinated CIMS is gaining more popularity (Stanovich 2006). The network-centric approach originates from the field of military operations and is mainly focused on decentralized decision-making and allowing information sharing amongst all users of the information system in order to increase the shared situational awareness (Fewell and Hazen 2003). Network-centric CIMS have been promoted for use in crisis situations, also in the Netherlands (Crisisplein.nl 2010). Yet, despite the promotion of these network-centric CIMS in the Netherlands, little is known in current literature about their actual implementation and whether a network-centric CIMS design really ensures IQ and SQ dimensions in crisis situations. Furthermore, relief workers in the Netherlands also have little experience with utilizing a network-centric CIMS.

The figure below gives an overview of the problem exploration given in the previous paragraphs. It shows that we will focus on information management processes in crisis management. More specifically, we will elaborate on the use of network-centric CIMS that assist information management processes. A network-centric CIMS can be used by several heterogeneous relief agencies and all users will receive a shared situational overview of the crisis. The goal of this research is to determine whether a network-centric CIMS ensures IQ and SQ in crisis situations.

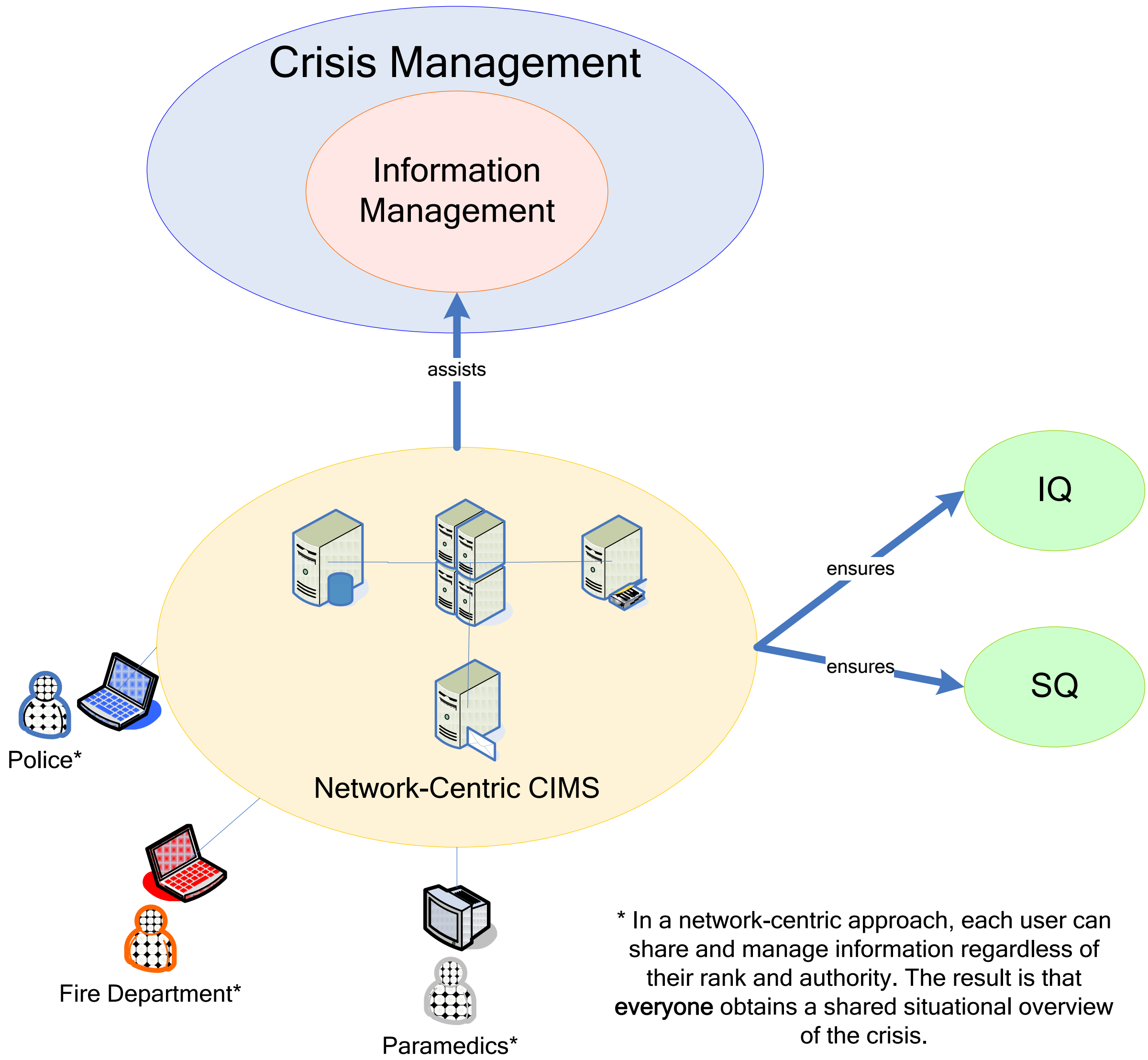



Figure 1: Overview of the Problem Exploration

## 2.2 Problem Demarcations

The previous section explained the lack of knowledge on using a network-centric CIMS in crisis situations and the lack of evaluation of these CIMS on relevant IQ and SQ dimensions. Since the field of crisis management is rather broad, the following demarcations are made to come up with a feasible research proposal for the given time span of this master thesis:

- There are several domains that pose solutions for improving crisis management, for instance reducing leadership stress (Weisaeth, Knudsen et al. 2002) and improving communication between parties by using new communication technologies (Auf der Heide 1989). In this research, only the role of *information management systems* in crisis situations will be examined.
- Information Management covers several information processes (Choo 1995), also in crisis situations. The emphasis will lie on the following processes: acquiring information, organizing and storing information, developing information products and services, distributing information, validating and enriching information.
- CIMS can be evaluated using a lot of performance criteria, such as IQ dimensions, SQ dimensions, time constraints and budget constraints. As we have seen a lack of evaluation on IQ and SQ dimensions, we will only look at those dimensions as performance criteria.
- The research will take place in the Netherlands, so we only take crisis management processes into account as carried out by Dutch relief agencies for our evaluation of the CIMS.

## 2.3 Problem Statement

The exploration and demarcation of the problem have led to the following problem statement in this research:

*'Information management during crisis situations is seen as one of the greatest challenges for crisis management, moreover because several heterogeneous relief agencies need to collaborate effectively. In this matter, an important prerequisite for effective crisis management is ensuring high information quality (IQ) and system quality (SQ) in crisis situations. To help ensure high IQ and SQ in crisis situations, the use of network-centric Crisis Information Management Systems (CIMS) is gaining popularity in the Netherlands. However, it is unknown whether network-centric CIMS ensure information quality and system quality dimensions in crisis situations.'*

## 2.4 Research Questions

Based on the problem statement in the previous chapter, the following research question is formulated:

***To what extent does a network-centric CIMS design ensure IQ and SQ dimensions for relief workers during crisis situations?***

The question stated above is unfortunately not all-inclusive. For each different crisis, different IQ and SQ dimensions can be deemed more relevant. Therefore, a first conclusion is that a very generic list of relevant information and system quality dimensions cannot be defined. Yet, an attempt will still be made by coming up with a number of IQ and SQ dimensions that are generally accepted as important in each type of crisis.

The following sub-questions are part of this research in order to answer the main question:

- RQ1: What is the state-of-the-art in CIMS solutions and upon which foundations do they rely?
- RQ2: What are the functional and non-functional requirements for a network-centric CIMS?
- RQ3: What are the principles of design for a network-centric CIMS?
- RQ4: What is the functional design of a network-centric CIMS?
- RQ5: What is the technical design of a network-centric CIMS?
- RQ6: What is the effect of the network-centric CIMS design on ensuring IQ and SQ dimensions?

The main research question stated above will be answered in the conclusion of this thesis report. In line with the research objective, the network-centric CIMS we design will be a proof of principle to test its feasibility and applicability in crisis management. To answer the main research question, a research methodology is formulated in the next chapter in which all sub-questions are resolved by following a specific combination of research methods.

# 3 Research Methodology

This chapter will elaborate on the methodology followed in this research in order to answer the sub-questions and ultimately the main research question of this thesis. The methodology consists of several methods used for answering the sub-questions. As the objective of this research is to design and evaluate an artifact (a network-centric CIMS), a design science methodology as explained by Vaishnavi and Kuechler is pursued (Vaishnavi and Kuechler Jr. 2007). The figure below shows which phases this methodology encompasses, which outputs are expected for each phase and which knowledge flows can be distinguished in providing each phase with additional feedback.

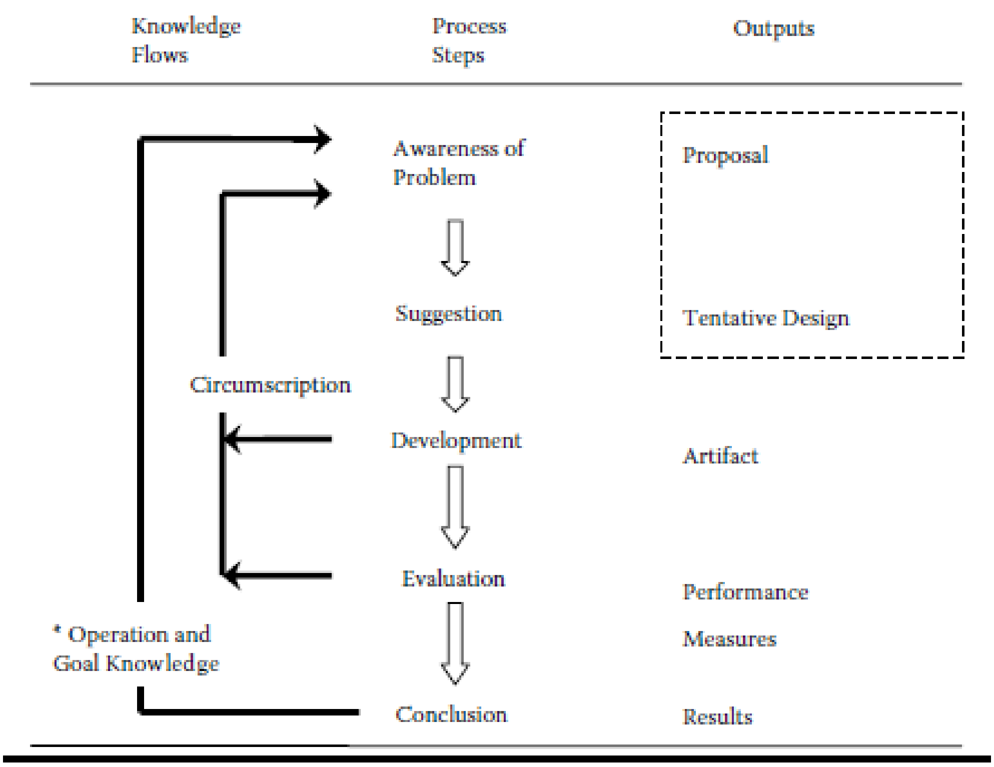



Figure 2: The general methodology of design science research (Vaishnavi and Kuechler Jr. 2007)

Figure 2 shows a phased approach for designing and evaluating the artifact. An important remark on this is that the approach itself is not sequential but rather iterative, which is also made clear by the knowledge flows. The methodology of this research depicted in the figure below is founded on the process steps described above.

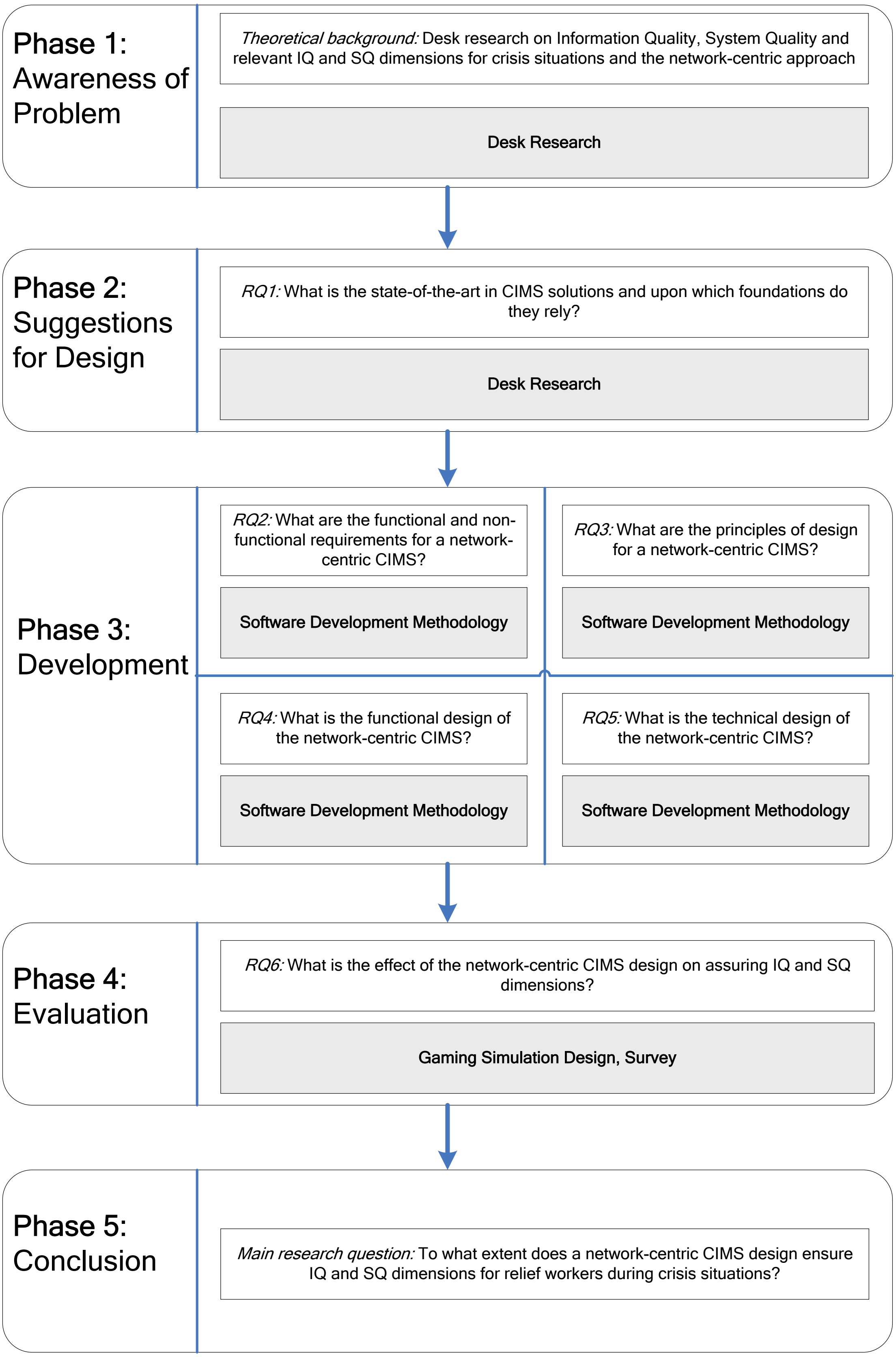



**Figure 3: Research Methodology**

For the sake of simplicity, Figure 3 suggests a sequential approach while in essence an iterative approach is carried out. Each research question is answered by following a specific research method (the grey box below each question). The phases of this methodology are discussed in more detail in the next paragraphs.

## 3.1 Phase 1: Awareness of Problem

To provide some theoretical background on the problem, desk research is carried out in phase 1. The first phase gives a more in-depth exploration on what crisis management stands for and which relief agencies are involved in managing a crisis. Also, we will discuss the IQ and SQ constructs and dimensions that can be used in the development of the software application. Desk research will also be carried out in researching which IQ and SQ dimensions were relevant in crisis situations. Furthermore, additional literature on a network-centric coordination approach will be studied. We will particularly research the application of a network-centric approach in military information systems. The expected outputs of this phase are:

1. An elaboration on crisis management and crisis response networks.
2. An explanation of the IQ and SQ constructs and dimensions.
3. A list of relevant IQ and SQ dimensions for crisis situations.
4. An explanation of what a network-centric approach stands for based on insights from the military paradigm.

## 3.2 Phase 2: Suggestions for Design

Vaishnavi and Kuechler propose a first tentative design in their methodology framework (Vaishnavi and Kuechler Jr. 2007). As our focus in this research is on designing a network-centric CIMS, we choose to build such a system based on insights from the military paradigm. Additionally, desk research is performed in which several state-of-the-art CIMS solutions are studied. The desk research will focus on CIMS solutions in a broad sense: from prototypes to fully operational systems. The desk research we perform in the first two phases has the advantage that it is efficient and effective to gain a lot of information. However, an important point of criticism towards desk research is that the results gathered could be outdated or flawed. Yet, we still choose to perform desk research because of the mentioned advantages.  The expected output of this phase is:

1. A list of network-centric design principles and/or characteristics.
2. A list of state-of-the-art CIMS solutions and their design principles and/or functionalities.

## 3.3 Phase 3: Development

The development phase will focus on the development of the network-centric CIMS where a software development methodology is pursued. There are several methodologies available for software development, of which the waterfall model (Royce 1970) is probably the best known. This methodology prescribes that software development processes are carried out sequentially. In this research, an extension of the waterfall model is utilized that goes by the name of 'Iterative and incremental development' (Larman and Basili 2003). In this methodology, the waterfall model processes are approached in an iterative way which will incrementally lead to a software product. The figure below shows a depiction of this iterative and incremental thought.

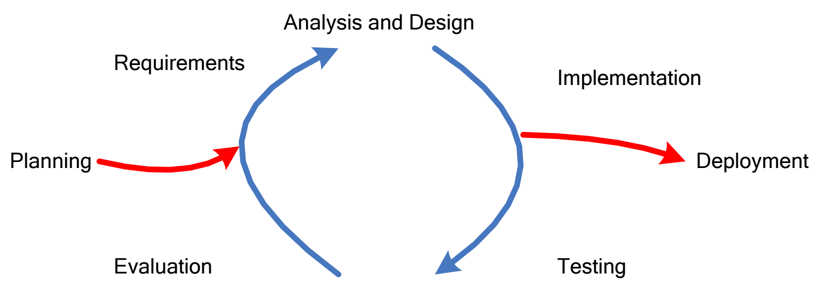



**Figure 4: Iterative and Incremental Development (Based on Larman and Basili 2003)**

The planning of this research will be leading for the development of the artifact. The first stage in developing the CIMS is formulating functional and non-functional requirements for the network-centric CIMS. Functional requirements are focused on the behavior of the system, whereas non-functional requirements focus on how a system is supposed to be. The requirements are for a large part derived from the insights on IQ and SQ dimensions. Functional requirements of the CIMS are based on the functionalities of state-of-the-art CIMS solutions. Furthermore, a set of network-centric principles will be defined that guides the conceptual and technical design of the CIMS. These principles are derived from the desk research on military network-centric systems of the previous phase. After defining the principles for design, several conceptual models are made as part of the functional design for the CIMS. These conceptual models will be formulated in UML (Unified Modeling Language) as this language is commonly seen as the standard for conceptual models in software engineering. These models will in their turn be the basis for the technical design of the CIMS. Several design choices and limitations need to be made in order to come up with a working CIMS given the timeframe for this master thesis. Implementing the technical design of this CIMS also requires error-handling and testing the product, which will also be done in this phase. The expected outputs of this phase are:

1. A list of functional and non-functional requirements for the CIMS.
2. A list of principles for the network-centric design of the CIMS.
3. Several conceptual UML models as part of the functional design.
4. Technical Design of the network-centric CIMS.

## 3.4 Phase 4: Evaluation

The design principles of the CIMS also need to be evaluated on whether relevant IQ and SQ dimensions are indeed ensured. This will be done by designing and hosting a gaming simulation in which a crisis situation is simulated. Afterwards, the design is evaluated on several information and system quality dimensions by sending out a questionnaire to the participants of the gaming simulation. For designing the gaming simulation, a framework developed by Meijer is utilized (Meijer 2009). This framework will be described in the game design section of this thesis report. Using a gaming simulation as an evaluation tool can have some drawbacks however: participants have to reserve a lot of time and they need to be willing to participate. Furthermore, a gaming simulation has a simulated context (Meijer 2009), which makes it hard to determine whether it reflects the reality enough for some of the participants. However, a gaming simulation can prove to be an interesting way to test the CIMS design principles, as a crisis situation can be simulated in a safe and controlled environment. On top of that, the survey can be used in evaluating the CIMS design principles adequately so that it is easy to distinguish which principles are having a positive or negative effect on effectively managing information in a crisis. The expected outputs of this phase are:

1. An experimental design of the session.
2. A game design for the gaming simulation.
3. A set of questionnaires for the gaming simulation.

## 3.5 Phase 5: Conclusion

In the final phase, the results of the gaming simulation, including the experiences of all participants, need to be analyzed. These results might show whether the network-centric CIMS we designed indeed ensures a number of IQ and SQ dimensions. The answers on all sub-questions will lead to a comprehensive answer on the main question given in this phase. Also, limitations of this study are discussed and possible leads for further research are proposed. Finally, we will pose several recommendations towards academics and practitioners based on the conclusions of this research.

# 4 Theoretical Background

This chapter will contain an elaboration on the theoretical foundations of this research. These foundations will serve as input of the CIMS design. We will first however elaborate on the definitions of crisis management and crisis response networks. The second section in this chapter will discuss the constructs Information Quality and System Quality. Afterwards, relevant IQ and SQ dimensions for crisis situations are identified. The third paragraph will discuss several coordination mechanisms for information management, namely the hierarchical and network-centric approach. Finally, the last section will cover the state-of-the-art in CIMS solutions in order to define the level-playing field of the CIMS we want to design. We finish this chapter with a concluding section. Consequently, the following research question is answered in this chapter:

*What is the state-of-the-art in CIMS solutions and upon which foundations do they rely?*

## 4.1 Crisis Management

Managing a crisis situation can prove to be a difficult task, as a crisis situation can be characterized as dynamic, unpredictable and error-sensitive (Bigley and Roberts 2001). As several agencies also have to work together in order to manage a crisis, it becomes even more complicated to adequately respond to a crisis. These characteristics show that crisis management is a complex concept, yet several scholars have tried to define crisis management adequately. For instance, Rosenthal and ‘t Hart state that: *‘crisis management involves making tough decisions in an environment of threat, urgency and uncertainty’* (Rosenthal and 't Hart 1991).

As this explanation of crisis management may be rather abstract, others describe crisis management as a set of 4 processes (Drabek and Hoetmer 1990; National Research Council 2007):

1. *Mitigation:* pro-actively minimizing the effects of a possible crisis on beforehand. Relief agencies can for instance take preventive healthcare measures and manage land zones near sea in order to minimize damage when a flooding occurs.
2. *Preparedness:* planning how to respond when a crisis occurs. Relief agencies often get prepared by performing realistic crisis exercises.
3. *Response:* in this phase, efforts are made to minimize the hazards created by a crisis. Relief agencies have to provide immediate assistance to save lives by providing emergency healthcare, shelter and transportation.
4. *Recovery:* recover the affected area. This can be done by reconstructing buildings and by providing medical aftercare to victims for instance.

In each of the four processes mentioned above, adequately working together is an important issue in order to guarantee effective crisis management. As various relief agencies have to collaborate in managing a crisis, it requires this complex network of actors to be well-aligned and efficient. It is therefore important to give some background information on the network of relief workers during a crisis situation. Consequently, the next section will discuss crisis response networks.

### 4.1.1 Crisis Response Networks

Characterizing a network of actors in a crisis situation is not unilateral since every crisis situation may require special expertise from different organizations. Yet, it is often seen as a task of the government, varying from local authorities to international departments, to manage a crisis. In most cases, a crisis also needs to be managed by a number of governmental authorities. One can think of the police department, the paramedics and the fire department. As these public agencies all have to work together to effectively repress the crisis, it is important to gain more insight in this network of actors. To this end, the figure below shows an example of an overview of information flows between relief agencies in a crisis situation. This overview is based on how information flows are managed during a crisis situation in the Netherlands.

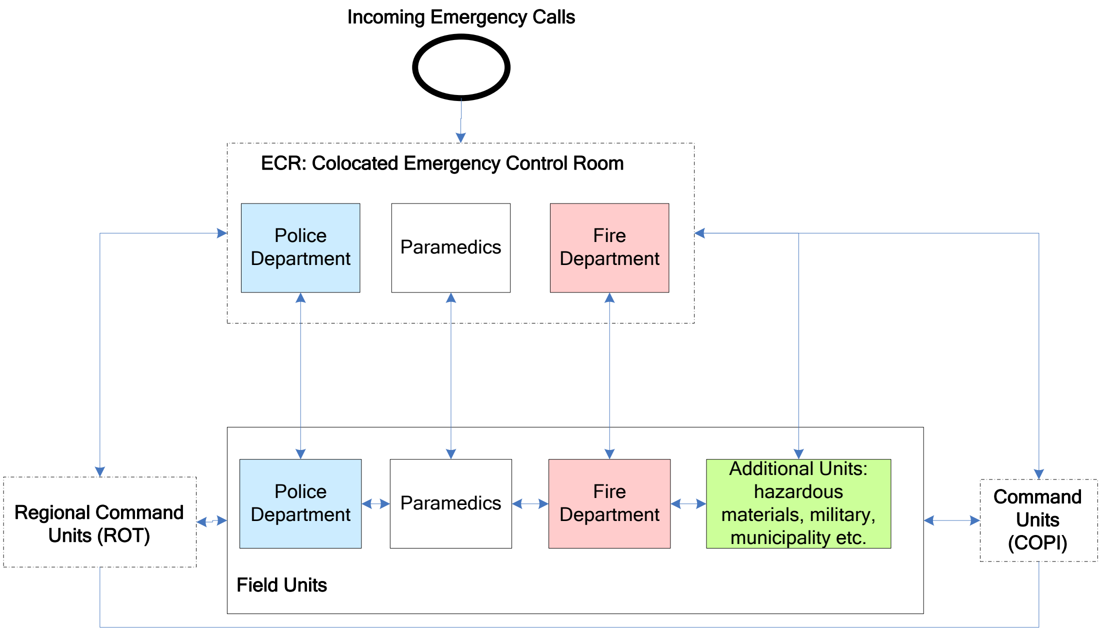



**Figure 5: An example of a crisis response network in the Netherlands (Based on Bharosa, Lee et al. 2010)**

Collaborating effectively during a crisis is a necessity, because mistaken agreements and a lack of coordination may have large consequences. Therefore, it is evident that this network of relief agencies needs to be robust and well-aligned. There are however several aspects that increase the complexity of resolving a crisis for this network:

1. *Heterogeneity between relief agencies:* several agencies are involved in managing a crisis and each agency differs on several aspects from the others. The heterogeneity between these agencies is an aspect that further complicates effective crisis management: because in multi-agency coordination of disasters, each agency has its own processes, information, applications and technology (Bharosa, Lee et al. 2010), the efficiency and effectiveness of disaster response may be hampered.
2. *Crisis situations are not routine tasks:* it is often difficult to predict when and where a crisis situation will occur. Also, each crisis can have the need for different expertise. The problem with these kinds of situations is that they need are not a routine task for relief agencies as they do not occur on a daily basis for each agency. As Quarantelli points out, channeling information through an organization becomes more complex as officials cannot assume non-routine tasks in crisis situations (Quarantelli 1988).
3. *Fragmentation in a crisis response network:* there is often much fragmentation in a crisis response network also with respect to information (De Bruijn 2006): not every agency possesses all relevant information for effectively repressing a crisis. Yet, an integrated overview of all relevant information is considered necessary for effective crisis management.
4. *Interdependencies between relief agencies:* during a crisis situation, relief agencies often have to rely on each other's work. For instance, firemen and paramedics depend on each other while repressing a fire with several casualties. Networks are often characterized by these interdependencies (Koppenjan and Klein 2004; De Bruijn 2006). As such, interdependencies in a crisis response network might even be more of a critical aspect as disastrous consequences may occur.

Despite these complicating aspects of a crisis response network, the public agencies still have the important task of repressing a crisis as effectively as possible. High-quality information and high-end information systems play a significant role in fulfilling this task (Ryoo and Choi 2006; Ianella, Robinson et al. 2007; Bharosa and

Janssen 2008). Therefore, we will go more into detail on the constructs information quality and system quality in the next section.

## 4.2 Relevant IQ and SQ Dimensions

As already mentioned in the problem statement of this thesis, little is known on whether a network-centric CIMS indeed ensures relevant IQ and SQ dimensions for crisis situations. To be able to design a CIMS for this purpose, several IQ and SQ dimensions have to be characterized first. Also, the relevancy of these dimensions for crisis situations should be examined. To this end, the constructs information quality (IQ) and system quality (SQ) are defined together with their dimensions. Finally, a set of relevant IQ and SQ dimensions for crisis situations is given.

### 4.2.1 Information Quality

The concept of information quality has been addressed as an important issue in managing information by many academic practitioners (Eppler 2001; Lee, Strong et al. 2002; DeLone and McLean 2003; Hu and Feng 2005; Nelson, Todd et al. 2005; Bharosa and Janssen 2008). High quality of information is often an important prerequisite for key decisions. This is why this concept is discussed by many scholars in several scientific publications. Nelson et al. have written an extensive overview article in which the concept of information quality is described  (Nelson, Todd et al. 2005). With respect to this article, Nelson et al. consider information quality as 'the quality of the output of an information system' (Nelson, Todd et al. 2005).

#### *4.2.1.1 Information Quality Dimensions*

IQ can be seen as quite an abstract and theoretical construct. Following the definition of Nelson et al, it is fairly difficult what quality actually stands for. For making this construct more understandable, several dimensions of IQ are defined that all represent a specific part of the 'quality construct'. Nelson provides us with a useful set of IQ dimensions given in the figure below:

Table 1. Information Quality Dimensions

| Dimension | Definition | Information quality category |
|---|---|---|
| Accuracy | The degree to which information is correct, unambiguous, meaningful, believable, and consistent. | Intrinsic |
| Completeness | The degree to which all possible states relevant to the user population are represented in the stored information. | Extrinsic; contextual |
| Currency | The degree to which information is up-to-date, or the degree to which the information precisely reflects the current state of the world that it represents. | |
| Format | The degree to which information is presented in a manner that is understandable and interpretable to the user and thus aids in the completion of a task. | Extrinsic; representational |

Figure 6: Information Quality Dimensions (Nelson, Todd et al. 2005)

The dimensions defined by Nelson et al. are also seen in a more comprehensive list Lee et al. have made, where 4 categories of IQ dimensions are also defined (Lee, Strong et al. 2002):

1. *Intrinsic IQ:* information has quality on its own right (the quality of an information object itself).
2. *Contextual IQ:* IQ needs to be considered within the context of the task at hand.
3. *Representational IQ:* quality dimensions of information concerned with representing it towards actors.
4. *Accessibility IQ:* quality dimensions of information concerned with providing access to actors.

| | Intrinsic IQ | Contextual IQ | Representational IQ | Accessibility IQ |
|---|---|---|---|---|
| Wang and Strong [39] | Accuracy, believability, reputation, objectivity | Value-added, relevance, completeness, timeliness, appropriate amount | Understandability, interpretability, concise representation, consistent representation | Accessibility, ease of operations, security |
| Zmud [41] | Accurate, factual | Quantity, reliable/timely | Arrangement, readable, reasonable | |
| Jarke and Vassiliou [16] | Believability, accuracy, credibility, consistency, completeness | Relevance, usage, timeliness, source currency, data warehouse currency, non-volatility | Interpretability, syntax, version control, semantics, aliases, origin | Accessibility, system availability, transaction availability, privileges |
| Delone and McLean [11] | Accuracy, precision, reliability, freedom from bias | Importance, relevance, usefulness, informativeness, content, sufficiency, completeness, currency, timeliness | Understandability, readability, clarity, format, appearance, conciseness, uniqueness, comparability | Usableness, quantitativeness, convenience of access[a] |
| Goodhue [14] | Accuracy, reliability | Currency, level of detail | Compatibility, meaning, presentation, lack of confusion | Accessibility, assistance, ease of use (of h/w, s/w), locatability |
| Ballou and Pazer [4] | Accuracy, consistency | Completeness, timeliness | | |
| Wand and Wang [37] | Correctness, unambiguous | Completeness | Meaningfulness | |

Figure 7: Information Quality dimensions (Lee, Strong et al. 2002)

The figures above show a wide range of information quality dimensions that can be used to assess IQ in several fields of practice. However, this also points out that that there should also be a selection of information quality dimensions for crisis situations specifically. It is of course not practical to satisfy all IQ dimensions when there is no need to.

### 4.2.2 System Quality

Another construct that plays an important role in the use of information systems is the construct of (information) system quality. This construct has also been widely discussed by several scholars, often in addition to the construct of information quality. There is a key difference between the construct of IQ and the construct of SQ: IQ looks at the quality of information whereas SQ looks at the quality of the information system. In this light, Nelson et al. consider the construct system quality as 'the quality of the information processing system required to produce the output' (Nelson, Todd et al. 2005).

#### *4.2.2.1 System Quality Dimensions*

As with information quality, several dimensions can be defined for this construct. In literature, there is less attention paid to this construct or sometimes the SQ dimensions are seen as IQ dimensions. Nelson et al. have however prepared a list of SQ dimensions usable also in this thesis.

Table 2. System Quality Dimensions

| Dimension | Definition | System quality category |
|---|---|---|
| Accessibility | The degree to which a system and the information it contains can be accessed with relatively low effort. | System-related |
| Reliability | The degree to which a system is dependable (e.g., technically available) over time. | |
| Response time | The degree to which a system offers quick (or timely) responses to requests for information or action. | Task-related |
| Flexibility | The degree to which a system can adapt to a variety of user needs and to changing conditions. | |
| Integration | The degree to which a system facilitates the combination of information from various sources to support business decisions. | |

Figure 8: System Quality Dimensions (Nelson, Todd et al. 2005)

Because SQ dimensions are often undervalued in quality issues related to information systems, it is for that reason important to evaluate SQ dimensions in this study and also to use these dimensions as performance criteria for the CIMS design. In the next paragraph, IQ and SQ dimensions relevant for crisis situations are derived from a study Bharosa et al. have performed on information and system quality requirements for multi-agency disaster management (Bharosa, van Zanten et al. 2009).

### 4.2.3 IQ and SQ Dimensions for Crisis Situations

As quite a number of IQ and SQ dimensions can be distinguished, it is rather difficult to say when a dimension is relevant in a crisis situation. Moreover, there is little research on crisis-specific IQ and SQ dimensions at this moment. It must however be stated that it is impossible to draw a list of IQ and SQ dimensions that is applicable in any crisis situation, as each crisis situation is a unique and complex circumstance. Still, we try to distinguish several dimensions for crisis situations as it can be useful for the further steps in this research. Bharosa et al. have studied which IQ and SQ dimensions are more relevant for crisis situations by performing case surveys: several crisis-related literature was examined on which IQ and SQ dimensions were (implicitly) mentioned as important for information management in that crisis situation. Eventually, they came up with two useful lists containing IQ and SQ dimensions relevant for crisis situations (Bharosa, van Zanten et al. 2009):

Table 1: Relevant IQ Dimensions (Based on (Bharosa, van Zanten et al. 2009) and (Nelson, Todd et al. 2005)

| Relevant IQ Dimensions | Explanation |
|---|---|
| **Relevancy** | The degree to which information is suited to its intended use (Dawes, Creswell et al. 2004). |
| **Quantity** | The amount of information. This dimension looks at the implications of possible information overload. |
| **Accuracy** | The degree to which information is correct, unambiguous, meaningful, believable and consistent. |
| **Timeliness** | The degree to which information is up to date. |
| **Completeness** | The degree to which all possible states relevant to the user population are represented in the stored information. |
| **Format** | The degree to which information is presented in a manner that is understandable and interpretable to the user and thus aids in the completion of a task. |
| **Consistency** | The degree to which information between several systems is consistent and in harmony. |
| **Availability** | The degree to which information is (made) available to those that need this information. |

Table 2: Relevant SQ Dimensions (Based on (Bharosa, van Zanten et al. 2009) and (Nelson, Todd et al. 2005))

| Relevant SQ Dimensions | Explanation |
|---|---|
| **Accessibility** | The degree to which a system and the information it contains can be accessed with relatively low effort. |
| **Response Time** | The degree to which a system offers quick (or timely) responses to requests for information/action. |
| **Reliability** | The degree to which a system is dependable (e.g. technically available) over time. |
| **Flexibility** | The degree to which a system can adapt to a variety of user needs and to changing conditions. |
| **Integration (Interoperability)** | The degree to which a system facilitates the combination of information from various sources to support (business) decisions. |

These two lists of IQ and SQ dimensions provide us an overview on which dimensions were of high importance in previous crisis situations. However, it cannot be said that these two lists are comprehensive; the lists can only give us *guidelines* for developing and evaluating a CIMS. Now that we know which IQ and SQ dimensions are generally relevant for a crisis situation, we will continue with our desk research on which approaches for information management are already discussed. As we plan to design a network-centric system, we first need to investigate what a hierarchical approach actually stands for.

## 4.3 Coordination Approaches for Information Management

In this section, we will describe several coordination approaches found in literature for information management. We decided to discuss two coordination approaches in particular as the question comes up which of these two approaches suits information management during crisis situations the most. The first approach we will discuss is the traditional, hierarchical approach. The second approach is now gaining more popularity in crisis response and is called the network-centric approach. The network-centric approach will be explained by using the example of Network-Centric Warfare as applied in the military for information management.

### 4.3.1 Hierarchical Approach

Traditionally, information management during crisis situations is done hierarchically (Bigley and Roberts 2001). A command and control structure is preserved between units of a public agency. Also, among all agencies, a strict command and control structure is preserved. For instance, in the Netherlands, the leader of the tactical command unit (COPI) is de facto the head of the firefighters (NIFV 2010). The authority structure in the hierarchical coordination approach is also very strict and precise. Field officers need to report the situation to their commanders who, in their turn, share information with other commanders. To illustrate information sharing in crisis situations, Schraagen et al. state that a crisis response team is characterized by the fact that members only pass information to their leader, but not to each other (Schraagen, Huis in 't Veld et al. 2010).

The hierarchical approach also maintains a strict centralized decision hierarchy in which only commanders are able to make the final decision (Schraagen, Huis in 't Veld et al. 2010) with respect to for instance a call for additional units. The process structure of hierarchical coordination is designed with authority as the main aspect: every relief worker is part of a specific authority structure in which the worker has its own tasks, responsibilities and rules. Bharosa states that this approach works appropriately in routine circumstances (Bharosa, Janssen et al. 2009).

Even though the hierarchical approach has been used extensively in information coordination during crisis management, the approach has been criticized for several reasons. The following reasons are found in literature for condemning hierarchical information sharing systems in crisis situations (Bharosa, Janssen et al. 2009):

1. A hierarchically coordinated information system is not considered flexible (Drabek and McEntire 2003): flexibility of information systems is an important issue in crisis situations as several agencies need to work with the same system.
2. A hierarchical information system does not support emergent events and processes (t' Hart 1993): because of the very nature of crisis situations, hierarchical systems almost always fail as they cannot effectively deal with unforeseen and uncertain events.

As crisis situations are characterized as complex and dynamic, hierarchical coordination approaches will almost always fail to a certain extent (Comfort and Kapucu 2006). As a result of this criticism, another approach for information management has gained more popularity in the field of crisis management: the network-centric approach. We will continue with explaining this approach in the next section by exploiting an example of the military paradigm, called Network-Centric Warfare.

### 4.3.2 Network-Centric Warfare Approach

To manage information more effectively during crises, several governments consider the aptitude of applying a network-centric approach in crisis situations, including the Ministry of the Interior of the Netherlands (Crisisplein.nl 2010). In the military domain, a network-centric approach has already gained some recognition, as we see that the concept of network-centric warfare (NCW) is being implemented increasingly (Cebrowski and Garstka 1998; Alberts, Garstka et al. 2002). Perry et al. consider NCW to be 'the linking of platforms into one shared-awareness network in order to obtain information superiority, get inside the opponent's decision cycle and end conflict quickly' (Perry, Button et al. 2002). Fewell and Hazen have reflected upon several definitions for network-centric warfare, including the definition of Perry, and they came with a more extensive description of the concept of NCW:

*'Network-centric warfare is the conduct of military operations using networked information systems to generate a flexible and agile military force that acts under a common commander's intent, independent of the geographic or organizational disposition of the individual elements, and in which the focus of the war fighter is broadened away from individual, unit or platform concerns to give primacy to the mission and responsibilities of the team, task group or coalition'* (Fewell and Hazen 2003).

By utilizing networked information systems and allowing full information sharing by each user of the network, more shared situational awareness can be realized across all combat units. Reflecting on these definitions for NCW and the objective of this approach in the military, several network-centric characteristics for an information system can be derived:

Table 3: Network-centric Characteristics (Based on Alberts, Garstka et al. 2002; Fewell and Hazen 2003; Stanovich 2006)

| Network-centric Characteristics | Explanation |
|---|---|
| **Flattened hierarchical organization structure** | The hierarchical command and control structure becomes flattened as information becomes available in the same format on every organizational level. |
| **Full information sharing** | Every node of the network (i.e. user) can share information with every other node (Fewell and Hazen 2003; Bharosa, Janssen et al. 2009). |
| **Decentralized decision-making** | Decision-making authority is distributed top-down to subordinate commanders. |
| **Self-synchronization** | Organizing and synchronizing activities from bottom-up (Hutchins, Kleinman et al. 2001). |
| **Shared situational awareness** | Every user of the network has a shared overview of the situation at hand. |
| **Interoperability** | Organizations and their information systems need to be interoperable (Stanovich 2006; Bharosa, Janssen et al. 2009). |

The table above gives a rough impression of what a network-centric approach stands for, based on insights from the military domain. As such, these characteristics are meant for military network-centric information systems. Yet, the characteristics might also serve as a solid basis for building a CIMS using a network-centric approach.

Even though there are several major differences between disaster response and military response, the characteristics above can still adopted in defining a network-centric approach in disaster response. A disaster response environment and a military environment both have the tasks of exerting command and control and building situational awareness (Stanovich 2006). Moreover, both environments can be typified by a complex and dynamic situation, with a lot of time pressure and possible threats for society (Bigley and Roberts 2001; Stanovich 2006). Therefore, we are able to use the insights derived in the field of NCW to design network-centric information systems suitable for disaster response.

With respect to military purposes, hierarchical information management systems are often criticized by the fact that they are inefficient and rigid, as mentioned in the section before (Bharosa, Janssen et al. 2009). A network-centric approach may have more potential because of its supposed benefits, such as greater efficiency, agility and adaptability in information management (Fewell and Hazen 2003; Wilson 2007). Several other advantages of employing a network-centric approach in the military are also mentioned, such as increased responsiveness of units, lower risks and costs and increase combat effectiveness (Alberts, Garstka et al. 2002). Yet, various hurdles in using a network-centric warfare approach are also seen in the military paradigm. It is important to know which hurdles are already mentioned in current literature to get a complete picture of the consequences of adopting a network-centric approach. Therefore, in the next section, these hurdles are discussed in more detail.

#### 4.3.2.1 Hurdles in following a network-centric approach

In this section, several hurdles in using a network-centric warfare approach are discussed. These hurdles contribute to a more critical view on network-centric approaches. As applying a network-centric approach is gaining popularity in crisis management, it is important to take note of possible drawbacks of using such an approach. Several scholars formulated a number of network-centric challenges in the military paradigm:

1. *Information Overload:* as more information becomes available for each user of a network-centric information system, the danger of information overload is apparent (Stanovich 2006; Wilson 2007).
2. *Unfiltered information:* as all information becomes available, it is difficult to distinguish processed intelligence from raw and unverifiable information (Stanovich 2006).
3. *A network-centric approach is at odds with effective command and control:* a network-centric approach 'flattens' a hierarchical process structure, which can lead to counterproductive situations (Stanovich 2006).
4. *Excessive control from superior commanders:* commanders receive much more information, in a timely fashion. As commanders might think to have a complete picture of the incident, they may control their subordinates too much in their tasks (Stanovich 2006).
5. *Ignoring control from above:* as subordinate commanders now also can see the information intended for superior commanders, they might draw their own conclusions and ignore commands from above (Stanovich 2006).
6. *Networking for Networking's sake:* the value of a networked information system for gathering real-time information is immense. Yet, there is a danger that this network will then be used as an information channel instead of for its intended purpose, namely command and control of response efforts (Barnett 1999). Utilizing the network might become an end, instead of a means for a more effective command and control (Stanovich 2006).

Despite the formulation of these network-centric hurdles, the potential of network-centric information systems for military purposes is still recognized in literature (Alberts, Garstka et al. 2002; Perry, Button et al. 2002). The question is however whether this success of network-centric information systems would also arise in crisis response situations. As Stanovich also points out, the hurdles mentioned above may be the starting point for exploring the impact of a network-centric approach towards command and control and information systems of emergency response (Stanovich 2006).

The figure below illustrates the difference in coordinating information management between a hierarchical approach and a network-centric approach in crisis situations. Several heterogeneous teams of relief workers are depicted with each having a position in the authority structure. For instance, FIELD workers have to share information with the ECR (Emergency Control Room) and the CoPI (Commando Place Incident), where the CoPI has more authority on making decisions. However, in a network-centric context, information management is coordinated by means of a system accessible to everyone. In this system, information is shared and managed amongst every relief worker and decisions can be made throughout each team of relief workers, regardless of their authority level.

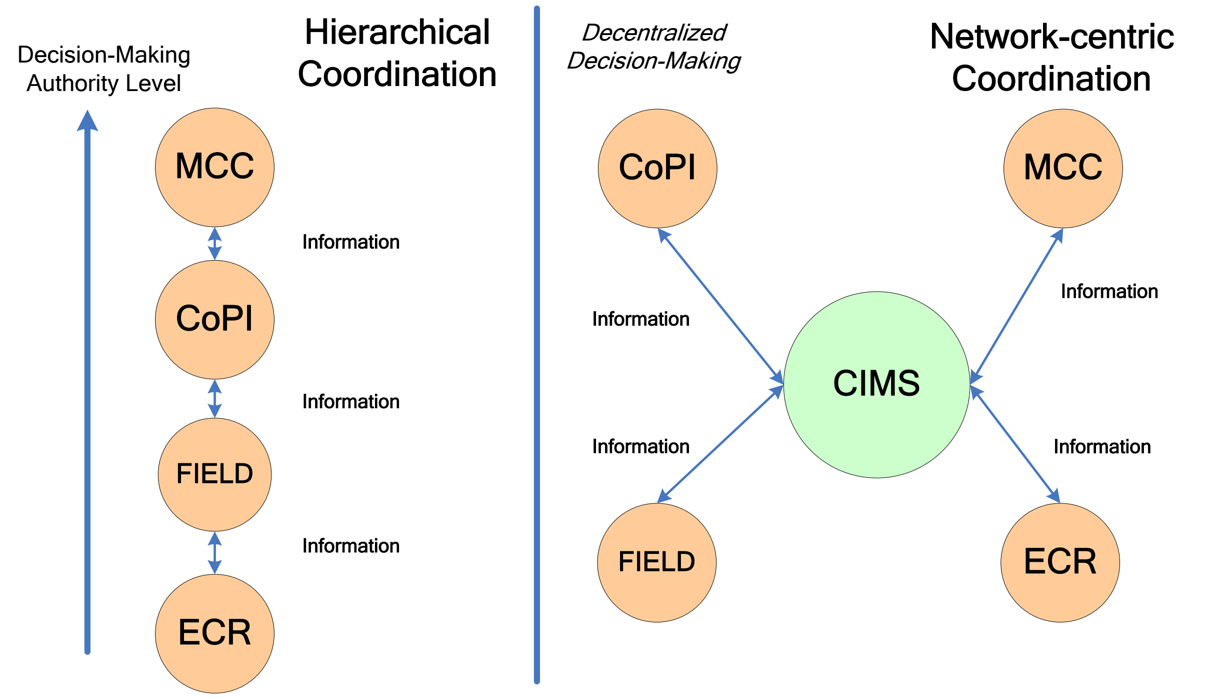



Figure 9: Information Management - Hierarchical vs. Network-centric Coordination (Based on Crisisplein.nl 2010)

Concluding this section, using network-centric systems might be valuable during crisis situations despite the hurdles mentioned above. These hurdles may be used to reflect on the use of network-centric CIMS by relief workers. These hurdles are also important to take into account while reviewing several state-of-the-art CIMS solutions as they might provide some insights in what kind of hurdles relief workers can come across. Therefore, we will continue with an overview of several state-of-the-art CIMS solutions so that we can get an overview of what type of systems are already available.

## 4.4 State-of-the-art CIMS solutions

In this paragraph, an outline is given of several state-of-the-art CIMS solutions. There are several research institutes and private parties engaged in developing state-of-the-art CIMS, each with a slightly different approach on how to design a suitable CIMS. The insights derived from this section are used to formulate useful requirements and principles for the network-centric CIMS we will develop.

### 4.4.1 EMISARI

EMISARI is a product developed at the New Jersey Institute of Technology and stands for 'Emergency Management Information System and Reference Index' (Turoff, Chumer et al. 2004). EMISARI is founded on a set of general and supporting design principles for a 'Dynamic Emergency Response Management Information System' (DERMIS). This set of principles is developed by (Turoff, Chumer et al. 2004) and tells designers which requirements the system needs to fulfill and which design principles are important to incorporate. The requirements for a DERMIS (or CIMS for this matter) are formulated as follows:

1. Extremely easy to learn via training or exercises.
2. Useable by people who understand their role and responsibilities in an emergency environment.
3. Focus on a concise and self-evident design.
4. Allow individual users a high degree of tailoring, filtering and focusing of the interface. In other words, the DERMIS should allow extensive personalization of the interface.
5. Serve to support planning, evaluation, training and exercises between crisis events.
6. Allow the operation of the response function with only a need for necessary hardware and software backups.
7. Designed as a structured communication process independent of the nature of the particular crisis.

The requirements for a DERMIS given by (Turoff, Chumer et al. 2004) are formulated on a high aggregation level and some are a bit unclear. The focus of these requirements lies however very much on the *user experience* of a DERMIS. Apart from these DERMIS requirements, (Turoff, Chumer et al. 2004) also came up with several generalized design principles that should be applied to any emergency response system:

1. *Use of a system directory:* the system directory should provide a hierarchical structure for all the data and information currently in the system and provide a complete text search to all or selected subsets of the material.
2. *Information Source and Timeliness:* every information object needs to be identified by its information source.
3. *Open Multi-directional Communication:* all those involved in a disaster need to react in the system.
4. *Content as Address:* the content of information is what determines the address (or the sender).
5. *Authority, Responsibility and Accountability:* a DERMIS should clarify which user is responsible for each specific piece of information.
6. *Psychological and sociological factors:* encourage and support the psychological and social needs of the crisis response team.

The principles above show important aspects of which a CIMS need to comply with. However, with respect to the IQ and SQ dimensions of the previous paragraph, this list of principles is far from complete for a CIMS design. Aspects like the format of information, the interoperability of systems and the validation of information are not seen back in DERMIS. Yet, the design principles above still have an important role in the design of the CIMS in this research.

### 4.4.2 HUODINI

HUODINI stands for **Hu**mb**o**ldt **Di**saster Ma**n**agement **I**nterface and can be used for the integration and visualization of heterogeneous information for disaster management (Fahland, Glässer et al. 2007). Information is aggregated from different public information sources on the web, such as seismographic information, personal blogs and photo's and news feeds (Fahland, Glässer et al. 2007).

Their main focus is on integrating user-created information in disaster management. In that sense, the authors claim to have developed a special type of CIMS, focusing on new types of information sources. Their design goals are formulated as follows (Fahland, Glässer et al. 2007):

1. *Delivery of timely information:* this reflects the IQ dimension 'timeliness'.
2. *Integration of textual and multimedia data:* this principle reflects the IQ dimensions 'format' and 'completeness'.
3. *Space and time context for all information:* the authors argue that each information object needs to have a space tag (e.g. an address) and a time tag.
4. *Best-effort, automatic information integration:* as the focus in this project lies on making information available as quickly as possible, automatic analysis and integration of information are applied. Users cannot alter this to their own personal wishes in this version of HUODINI.
5. *Maximum flexibility:* new web-based data sources should be easily integrated. To this end, the developers made use of specific wrappers to make the information easy to integrate in HUODINI.

Based on these design goals, the developers of HUODINI built a CIMS having the following technical architecture for the system:

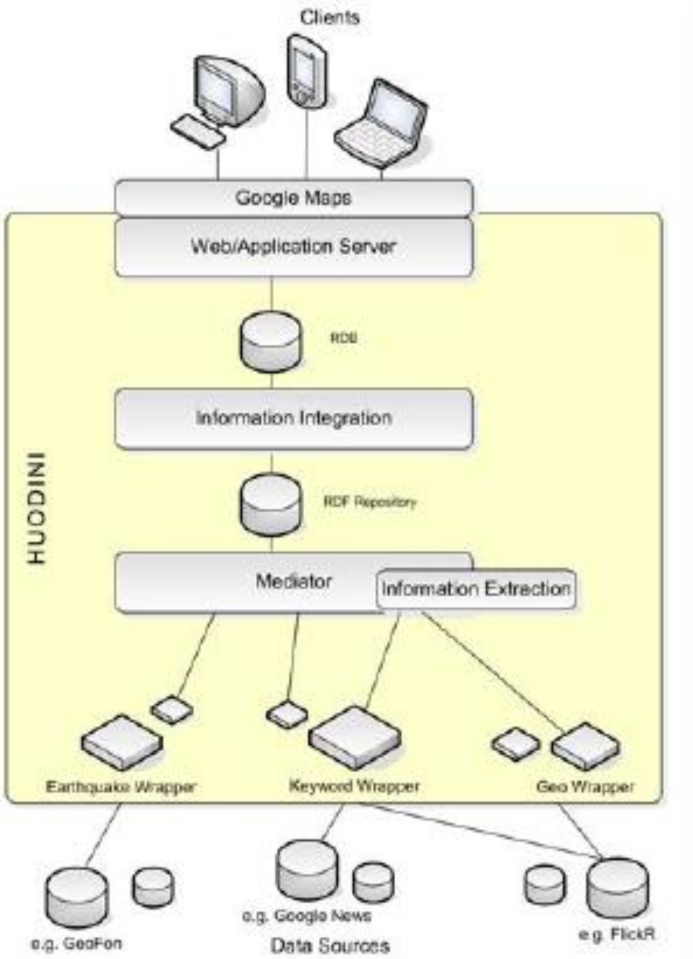



Figure 10: HUODINI - Technical Architecture (Fahland, Glässer et al. 2007)

An interesting feature of HUODINI is the mediator in this architecture: this mediator makes sure that all information given to the information integrator has the same format. This makes HUODINI easily extensible, as long as a wrapper for a new information source is developed. The result of developing HUODINI is seen in the screenshot below.


Figure 11: HUODINI – Screenshot (Fahland, Glässer et al. 2007)

### 4.4.3 DisasterLAN

DisasterLAN is a state-of-the-art web-based crisis information system designed for use in emergency operations centers (Buffalo Computer Graphics 2009). This software package has been developed by a commercial party, called Buffalo Computer Graphics (BCG). The system has already been incepted in the late nineties and, according to BCG, has gained wide acceptance in both public and private sector (Buffalo Computer Graphics 2009).

This commercial package has a lot of interesting features for effective crisis management, such as (Buffalo Computer Graphics 2009):

- *Contact Management:* for managing organizational and personnel contact information, photographs, phone numbers etc.
- *Weather:* for viewing geographically targeted weather alerts and forecasts
- *Situation Reports:* for developing, distributing and archiving incident-specific situation reports
- *Streaming video:* for monitoring video streams
- *Status Board:* for sharing textual and visual situational information
- *Message Broadcasting:* for instant distribution of urgent messages

DisasterLAN has numerous other features for assisting emergency managers during crisis situations, it however remains the question how BCG has developed this into an easy-to-use system. As DisasterLAN is a commercial package, a preview or screenshot was not made available, the features of this system are however promising.

### 4.4.4 CEDRIC

CEDRIC is the application environment for information management in crisis situations for the Dutch government. The main design principle of CEDRIC is 'net-centricity': sharing and receiving information by every relief worker during a disaster (Crisisplein.nl 2010). The following functionalities are supported by CEDRIC:

1. Up-to-date, multidisciplinary aggregation view of the disaster
2. Assigning and monitoring actions of relief workers
3. Message exchange between individuals and teams
4. Everyone has a synchronized time statement
5. Everyone sees who is online or offline
6. Search functionality
7. Database with useful information

The functionalities above have taken the multidisciplinary character of disasters into account. Because police, hospitals and fire departments need to work together, their information systems also need to comply with each other. The network-centric approach has already been discussed extensively in the previous section and the Ministry of Internal Affairs of the Netherlands types the difference between a hierarchical and network-centric approach with the figure below.

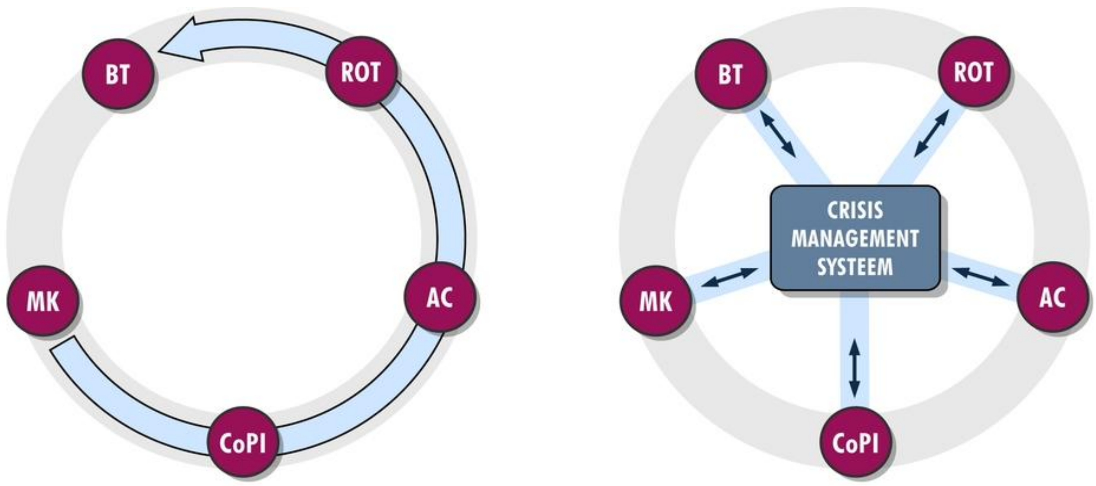



**Figure 12: Hierarchical information sharing vs. Net-centric information sharing (Crisisplein.nl 2010)**

Perhaps the most notable difference between hierarchical and net-centric information sharing is that all teams are able to share information with all other teams, regardless their authority level or decision-making power. The state-of-the-art CIMS solutions we discussed in this section will be used in the next chapter for formulating useful and sound requirements and design principles for our network-centric CIMS design.

## 4.5 Conclusions

This chapter was dedicated to providing a theoretical context in which this research would take place. To this end, we first engaged in defining crisis management and crisis response networks as part of framing the theoretical context. The main conclusion of this part was that in almost all cases, various heterogeneous relief agencies must work together for effectively managing a crisis. This collaboration however might generate several problems in terms of interoperability, different authority structures and differences in the way of working within each agency.

After we framed the context of crisis management, we then continued in defining IQ and SQ and all its dimensions. The quality of information and information systems plays a very important role in effectively resolving a crisis. In this sense, we needed to know which dimensions are of high relevance in crisis situations.

Based on a research performed by Bharosa et al., we could devise lists of relevant IQ and SQ dimensions for crisis situations.

As we were planning to develop a network-centric CIMS in this study, we also elaborated on two specific coordination mechanisms for information management: hierarchical coordination hierarchical and network-centric coordination. Based on the concept of network-centric warfare, we were able to see and to define the difference between the hierarchical approach and the network-centric approach. We also have drawn up a number of network-centric principles that can be used for adequately designing the CIMS in this study. In addition to these network-centric principles, we have derived a number of important principles by reviewing several state-of-the-art CIMS solutions. This CIMS solutions offered many insights on functional requirements and design principles. Even though we only looked at a limited number of CIMS solutions, we could still answer the first sub-question of this research.

In the next chapter, we will formulate several requirements and principles for the network-centric CIMS that we are going to build. These requirements and principles are largely based on the desk research performed in this chapter. For instance, the IQ and SQ dimensions form a solid basis for non-functional requirements for the CIMS. Also, the insights derived from the state-of-the-art CIMS solutions and the desk research on network-centric warfare can be used for defining functional requirements and design principles.

# 5 DIOS: Requirements and Principles

This chapter describes the requirements and principles for the CIMS we want to design. We decided to name the network-centric CIMS as follows: Disaster Interagency Orchestration System or DIOS. In this chapter, we first discuss the functional requirements of DIOS. In the second section, the non-functional requirements will be defined in which both IQ and SQ requirements are addressed. Attention is also paid to the requirements for the software itself. Subsequently, a number of design principles are formulated, partly based on the state-of-the-art CIMS solutions of the previous paragraph and partly based on network-centric characteristics derived in the previous chapter. As the title of this chapter already indicates, we have chosen to give the following name to our network-centric CIMS design: Disaster Interagency Orchestration System, or DIOS. The goal of this chapter is to answer the next sub-questions of this research:

*What are the functional and non-functional requirements for a network-centric CIMS?*
*What are the principles of design for a network-centric CIMS?*

## 5.1 Functional Requirements

Functional requirements are requirements that are dealing with what the system should do, but not how the system should do it (Bahill and Dean 1999). In other words, which functionalities should this information system have? In the table below, the functional requirements of the system are displayed. These functional requirements are largely based on the functionalities provided by the state-of-the-art CIMS discussed in the previous chapter.

Table 4: Functional Requirements of DIOS

| Functionality | Functional Requirement | Derived from state-of-the-art CIMS |
|---|---|---|
| **Logging in and out** | The system should allow a secure login with username and password. | CEDRIC |
| **Profile selection** | The system should allow selection of a role based on username and password. | EMISARI, CEDRIC |
| **Messaging** | The system should incorporate a messaging system so that each user can send and receive messages. | DisasterLAN, CEDRIC |
| **Information Requests** | The system should present a list of information requests of users so that others can fulfill these requests. | - |
| **Map** | The system should provide digital maps to clarify the crisis situation. | HUODINI, DisasterLAN |
| **Reliability Rating** | The system should allow users to rate the reliability of information. | - |
| **Real-time update** | The system should update all information real-time. | EMISARI, CEDRIC |
| **Standardized Input** | The system should have standardized input forms for each information type. | HUODINI |
| **Standardized Output** | The system should have standardized output tables for each information type. | HUODINI |
| **Accountability** | The system should show who posted which information. | EMISARI |
| **Date and Time** | The system should generate and show an automatic date and timestamp of each information entry. | DisasterLAN |
| **External Information** | The system should incorporate the use of relevant external information (e.g. of companies related to a disaster). | - |

Apart from the requirements based on the characteristics of other CIMS solutions, we also brainstormed on fulfilling several other requirements that could be useful to implement. The most notable functionalities we added by ourselves are: Information Requests, Reliability Rating and External Information. These functionalities can be of added value as they might improve the information management processes. One can think of acquiring information more effectively by incorporating the access to several external information sources. Another example is the importance of validating information, which can partly be done by a shared rating mechanism. Finally, the information demand is made easier by implementing specific information requests. In the next section, we will continue with defining several non-functional requirements for DIOS, based on relevant IQ and SQ dimensions.

## 5.2 Non-functional Requirements

Next to functional requirements, the use of non-functional requirements is also an important step in developing a software application. Non-functional requirements are used to judge the operation of an information system (Bahill and Dean 1999). Therefore, several IQ and SQ requirements are formulated to which the information system should comply. Apart from IQ and SQ requirements, several software requirements are also formulated in this section.

### 5.2.1 Information Quality Requirements

As already said before, the role of IQ requirements can be of great importance in crisis situations. Ensuring a high IQ on relevant dimensions can indeed contribute to a more effective crisis management. In the previous chapter, the relevant IQ dimensions of a crisis situation were already addressed by (Bharosa, van Zanten et al. 2009). There, the following IQ dimensions were described as relevant for a crisis situation:

Table 5: IQ requirements for DIOS

| IQ dimension | Requirement |
|---|---|
| **Relevancy** | The system should output information which is suited to its intended use in crisis management. |
| **Quantity** | The system should prevent information overload. |
| **Accuracy** | The system should cope with inaccurate information. |
| **Timeliness** | The system should output information that is up-to-date. |
| **Completeness** | The system should output information that is complete, within relevant boundaries. |
| **Format** | The system should output information that has the same consistent format for presentation. |
| **Consistency** | The system should cope with inconsistent information. |
| **Availability** | The system should make information available to every information requestor. |

Apart from the IQ requirements mentioned above, it is also important to define several SQ requirements for DIOS as the quality of the information system itself is also a significant aspect of a good design.

### 5.2.2 System Quality Requirements

SQ requirements focus primarily on the information system itself, whereas IQ requirements focus more on the output of the system (the information). (Bharosa, van Zanten et al. 2009) have also investigated a number of relevant dimensions SQ, these are listed below:

Table 6: SQ requirements for DIOS

| SQ dimension | Requirement |
|---|---|
| **Accessibility** | The system should be accessible the same way to every relief worker. This requirement is based on the net-centric way of sharing information, explained in the previous chapter. |
| **Response time** | The system should minimize the response time of processing information sharing. |
| **Reliability** | The system should have an uptime of 99.9%. |
| **Flexibility** | The system should adapt to changing disaster situations. |
| **Interoperability** | The system should support integration of different types of information systems. This |

requirement is further discussed in the next paragraph, where a software solution is formulated to satisfy this requirement.

These requirements are guiding for the design of DIOS. We will however also use the IQ and SQ dimensions/requirements for assessing DIOS itself. These requirements are therefore a very important part of this thesis as we try to design such a system in which these requirements are fulfilled to a satisfying extent.

Next, we will discuss several software requirements as part of the non-functional requirements for DIOS. These software requirements prescribe which choices are made on software level and why these choices are made.

### 5.2.3 Software Requirements

In a disaster situation, many parties are involved who in their daily operations are relatively autonomous. This also means that their information systems may not have the same standards and applications, while these agencies still have to work together in order to prevent or repress a crisis. This indicates a need for standardized interfaces that are accessible for each relief agency. Yet, these interfaces still need to be capable of working with the autonomous information systems at each separate relief agency.

A Service Oriented Architecture (SOA) can be an outcome for this interoperability problem. Within a SOA, each involved actor can publish a service on the network and other actors can use these services. Services can even be combined to create new services. In the figure below, a conceptual scheme of a SOA is depicted.

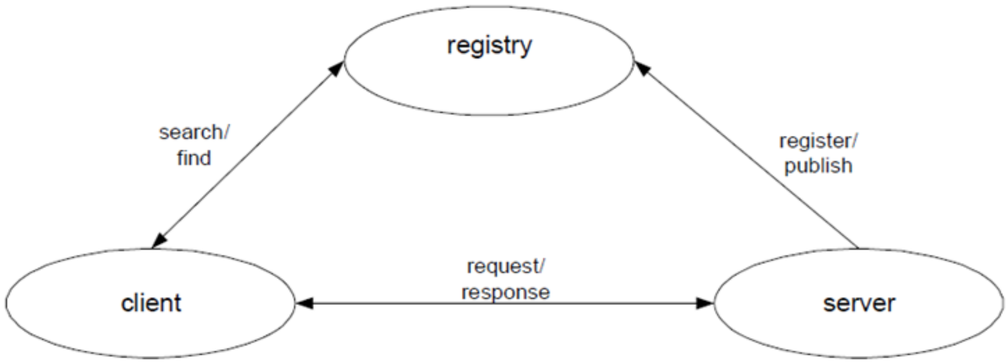



**Figure 13: Service Oriented Architecture (Erl 2007)**

This approach addresses two of the most important design goals set forth by (Pilemalm and Hallberg 2008), namely to (1) make it possible for crisis management teams to keep working the same way as to what they are used to and (2) allow the use of existing resources from several agencies in a crisis situation. Therefore, an important requirement for the CIMS is to make use of *web services* to cope with the interoperability problem. The communication between web services uses Extensible Markup Language (XML), which is a commonly used standard for encoding web applications (W3C 2010). The services itself are described by Web Services Description Language (WSDL). WSDL is an XML format for describing network services as a set of endpoints operating on messages containing either document-oriented or procedure-oriented information (W3C 2010). The information that is sent between services is encapsulated in envelopes with the use of the Simple Object Access Protocol (SOAP). SOAP is a lightweight protocol for exchange of information in a decentralized, distributed environment (W3C 2010). Finally, a Universal Description Discovery and Integration (UDDI) repository is used for registering all available services. UDDI is a platform-independent, XML-based registry for businesses worldwide to list themselves on the Internet (OASIS 2010). By using XML, WSDL, SOAP and UDDI, relief agencies are able to operate autonomously while still using and integrating each other's services.

Apart from choosing interface and communication protocols for the CIMS, it is also necessary to know which programming language will be chosen for this information system. The advantages of the SOA approach and Web services is that the Web services can be written in any suitable language, like C#, Java, C, C++ or COBOL. In this research, the choice was made to program in C# as it is a modular language to program web services in.

Next to the programming language for programming the web services, the website itself should also be scripted. As the choice was made for C#, a logical alternative for the scripting language is ASP.NET as both C# and ASP.NET are running on the same .NET framework of Microsoft. The drawback of this choice is a vendor lock-in effect, yet for this proof of principle it was suitable enough. All software requirements are listed below to give a comprehensive overview.

Table 7: Software requirements for DIOS

| Software choice | Requirement | Why? |
|---|---|---|
| **Communication Protocols** | XML, WDSL, SOAP and UDDI | As DIOS needs to be interoperable, web service protocols are used. |
| **Programming Language** | C# | Modular language to program web services. |
| **Scripting Language** | ASP.NET | Runs on the same framework as C# and has built-in features for developing web services. |
| **Application Framework** | Microsoft .NET Framework 3.5 SP1 | Provides a well-designed framework for easily implementing web services and web applications. |

One can see that the choice for software requirements is largely based on the SQ requirement of interoperability: the requirement of interoperability is in this sense translated to the use of web services as it is made possible to let heterogeneous systems work with the same web services. Eventually, we opted for a complete Microsoft-based application because the application framework gave us the opportunity to program relatively fast within our skill level. In the next section, we will elaborate on the design principles for DIOS. These principles are prescriptive statements that tell what the CIMS should do on a high aggregation level.

## 5.3 Design Principles

In this section, the design principles of CIMS are discussed. In this thesis, we look at design principles as prescriptive statements for an information system. Design principles are formulated on a higher aggregation level than functional requirements, as these principles are not only applicable on this specific instance of a CIMS. Furthermore, the principles give the designer the choice on how to translate them to the information system. The principles are unrelated to specific technology or persons (Perks and Beveridge 2002); they give the designer more freedom in design choices.

Table 8: Design Principles of DIOS

| Design Principle | Explanation | Derived from: |
|---|---|---|
| **Categorization** | Categorize information systematically in the CIMS. | HUODINI |
| **External Information** | Allow access to external information sources in the CIMS. | - |
| **Real-time Updates** | Depict the latest information available for each information type in the CIMS. | HUODINI, CEDRIC |
| **Aggregation** | Aggregate information in the CIMS in a situational overview. | CEDRIC |
| **Reliability** | Show and allow rating of information for depicting reliability of information. | - |
| **Memory** | Save all information entries in the CIMS. | HUODINI |

| | | |
|---|---|---|
| **Information Sharing** | Allow full information sharing between all users of the system. | NETWORK-CENTRIC WARFARE |
| **Self-synchronization** | Synchronize automatically all screens of all users to enable shared situational awareness. | NETWORK-CENTRIC WARFARE |
| **Interoperability** | Make the CIMS interoperable among all heterogeneous systems: this principle has already been taken care of by the SQ requirement of interoperability. | NETWORK-CENTRIC WARFARE |

We have incorporated three network-centric warfare design principles in the table above. We defined 6 network-centric characteristics however, based on insights from the military in the previous chapter. The other characteristics (flattened organization structure, decentralized decision-making and shared situational awareness) are more concerned with the *process* of managing information during a crisis. Therefore, these characteristics will be seen back in the gaming simulation design, where we partly pre-define the processes participants need to abide to.

## 5.4 Conclusion

Chapter 5 focused on defining the requirements and principles for a network-centric CIMS. The chapter began by defining the functional requirements and these were mainly based on features of the state-of-the-art CIMS solutions, discussed in chapter 4. Additionally, we formulated several other functional requirements, namely Information Requests, Reliability Rating and External Information. For more details on these requirements, we refer to section 5.1.

The next step was to establish a number of non-functional requirements, consisting of IQ requirements, SQ requirements and software requirements. IQ and SQ requirements were based entirely on the set of relevant IQ and SQ dimensions that emerged in section 4.2. By defining the functional and non-functional requirements for a network-centric CIMS, we have answered the second sub-question of this research.

To answer the third sub-question, a number of design principles were formulated that prescribe what a network-centric CIMS should accommodate. These design principles were based on both the state-of-the-art CIMS solutions as several network-centric warfare principles derived in the previous chapter. It was important to define these network-centric warfare principles in order to ensure that the design in the subsequent chapters was indeed a network-centric design.

Now that the requirements and design principles for the system are known, we continue with the functional design in chapter 6. This functional design will consist of a number of conceptual models that fit the requirements and design principles of this chapter, thereby also complying with the network-centric principles mentioned in this chapter.

# 6 DIOS: Functional Design

Based on the requirements of the previous paragraph, a functional design is made in order to model the structure of the software application. This functional design will be used as input for the technical design, in which the database and web-applications of the CIMS are programmed. There are several models available that can be used for designing conceptual models. In this research, the choice was made to focus on designing use cases (section 6.1), scenarios (section 6.2) and class diagrams (section 6.3). As the interaction between user and information system is rather limited (only information input and information output), interaction diagrams and activity diagrams were not taken into account. We consider this functional design useable for a network-centric CIMS as we now design a system that is also based on several network-centric principles, such as full information sharing and interoperability. As a result, this chapter is concluded in section 6.4 and provides the answer to the following question of this thesis:

*What is the functional design of a network-centric CIMS?*

## 6.1 Use Cases

In this section, we first start with conceptualizing the use cases for a network-centric CIMS in this research. We have chosen to develop a use case diagram, which is part of the Unified Modeling Language (UML) framework. The main reasons for choosing UML are that UML is easily extensible and very much understandable for other software developers in case this system will be updated.

As already mentioned a use case diagram is part of the UML framework and consists of several use cases. A use case is the description of a system's behavior on the users input (Alexander and Maiden 2004). In other words, what does the system do when the user interacts with the system? We have defined a total of 18 use cases, sorted in three particular groups, namely (1) system access (in orange), (2) information input (in green) and (3) information output (in yellow). The primary user in this system is the *relief agent*. As we are designing a network-centric CIMS, no distinction is made between commanders and subordinates; every relief agent can do the same with the system. Therefore, only one user is defined in this functional design. Below, the use case diagram for the network-centric CIMS is shown.

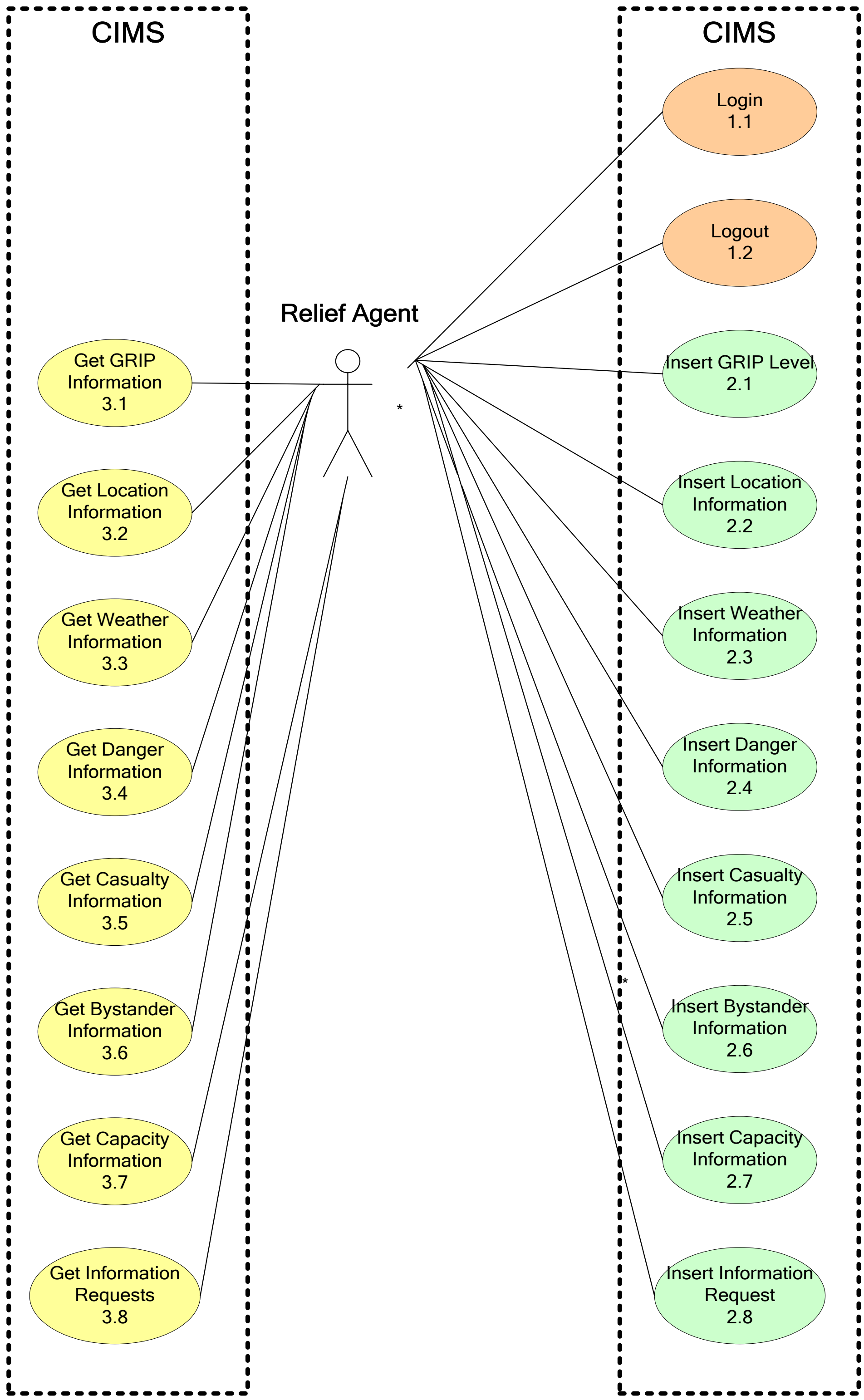



Figure 14: Functional Design - Use Case Diagram

In the next section, the use cases of this part are utilized for drawing up several realistic user-centric scenarios. These scenarios are also part of the functional design and tell the designer which steps a user may take in using the system.

## 6.2 Scenarios

The use cases of the previous paragraph serve as input for constructing realistic scenarios an end-user, in this case a relief agent, can encounter. As part of this functional design, scenarios are described by structurally describing the flow of events a user goes through. The following scenarios are considered realistic scenarios and are based on the given use cases of the previous section.

---

**Scenario 1**

Name: Login and Logout
Actor: Relief Agent (Alice)

*Flow of events:*

1. Alice just got her login credentials in her email for the new CIMS that is going to be used in the police department.
2. Alice goes to the website of the CIMS and fills in her credentials. Alice then presses the login button.
3. The system grants Alice access and Alice sees dashboard screen of the application.
4. Alice then decides to logout because she just wanted to test his credentials.
5. Alice presses on the logout button and she is logged out of the system.

Use cases: 1.1 and 1.2

---

**Scenario 2**

Name: Insert GRIP and Location Information
Actor: Relief Agent (Bob)

*Flow of events:*

1. Bob just received a message from his commander that the GRIP level has been increased to 2 because of a big fire. Also, the location is now changed to the address Jaffalaan 5, Delft.
2. Bob immediately logs in with his credentials for the CIMS.
3. Bob sees the dashboard screen for this disaster and goes to 'Enter Information'.
4. Bob then has to fill in the following data: GRIP Level, Location Information.
5. Bob fills in everything and presses the 'OK'-button.
6. Bob has successfully entered the information into the system.

Use cases: 2.1 and 2.2

---

**Scenario 3**

Name: Insert Weather and Danger Information
Actor: Relief Agent (Charles)

*Flow of events:*

1. Charles just received a message from his commander that the wind speed has changed to 5 Bft. From another source, Charles heard that there was a collapsing danger because of an explosion in Delft.
2. Charles immediately logs in with his credentials for the CIMS.
3. Charles sees the dashboard screen for this disaster and goes to 'Enter Information'.
4. Charles then has to fill in the following data: Weather information, Danger information.
5. Charles fills in everything and presses the 'OK'-button.

6. Charles has successfully entered the information into the system.

Use cases: 2.3 and 2.4

---

**Scenario 4**

Name: Insert Casualty and Bystander Information
Actor: Relief Agent (John)

*Flow of events:*

1. John, a paramedic, just rescued 5 severely wounded people from a collapsed building. He however also sees that there are 10 journalists at the disaster scene who really are in danger.
2. John immediately logs in with his credentials for the CIMS.
3. John sees the dashboard screen for this disaster and goes to 'Enter Information'.
4. John then has to fill in the following data: Casualty information, Bystander Information.
5. John fills in everything and presses the 'OK'-button.
6. John has successfully entered the information into the system.

Use cases: 2.5 and 2.6

---

**Scenario 5**

Name: Insert Capacity information and post an Information request
Actor: Relief Agent (George)

*Flow of events:*

1. Police officer George wants to know how many bystanders are situated in the source area around the disaster. Also, George knows there are 10 police cars standby for assistance. This information may help other relief workers.
2. George immediately logs in with his credentials for the CIMS.
3. George sees the dashboard screen for this disaster and goes to 'Enter Information'.
4. George then has to fill in the following data: Capacity information.
5. George fills in everything and presses the 'OK'-button.
6. George also fills in an information request for the number of bystanders in the disaster area.
7. George again presses the 'OK'-button.
8. George has successfully entered the information into the system.

Use cases: 2.7 and 2.8

---

**Scenario 6**

Name: Get complete situational overview of the disaster
Actor: Relief Agent (Amy)

*Flow of events:*

1. Police officer Amy needs to have a situational report (SITRAP) immediately of the disaster, because decisions on capacity and evacuation are made.
2. Amy immediately logs in with her credentials for the CIMS.
3. Amy sees the dashboard screen for this disaster and goes to the Dashboard of information.

4. An immediate overview is given of the latest information for each information type (location, GRIP, weather, dangers, casualties, bystanders, capacity and information requests).

Use cases: 3.1 till 3.8

---

In the next section, a class diagram is made that can be used for defining the database diagram, application code and the website in the technical design. Also, this class diagram can serve as a reference model for documentation of crisis specific information objects.

## 6.3 Class Diagram

Class diagrams are static models which are modeled using UML. In software engineering, class diagrams can be used for defining the structure of classes, in case an object-oriented programming paradigm is followed (Ambler 2009). This is because class diagrams depict the classes, of which an object can be an instance. Within this class, attributes and methods can be formulated. Given the fairly straightforward use case functionalities (inserting information and selecting information), the methods and attributes of each class are roughly the same. The figure below depicts the class diagram.

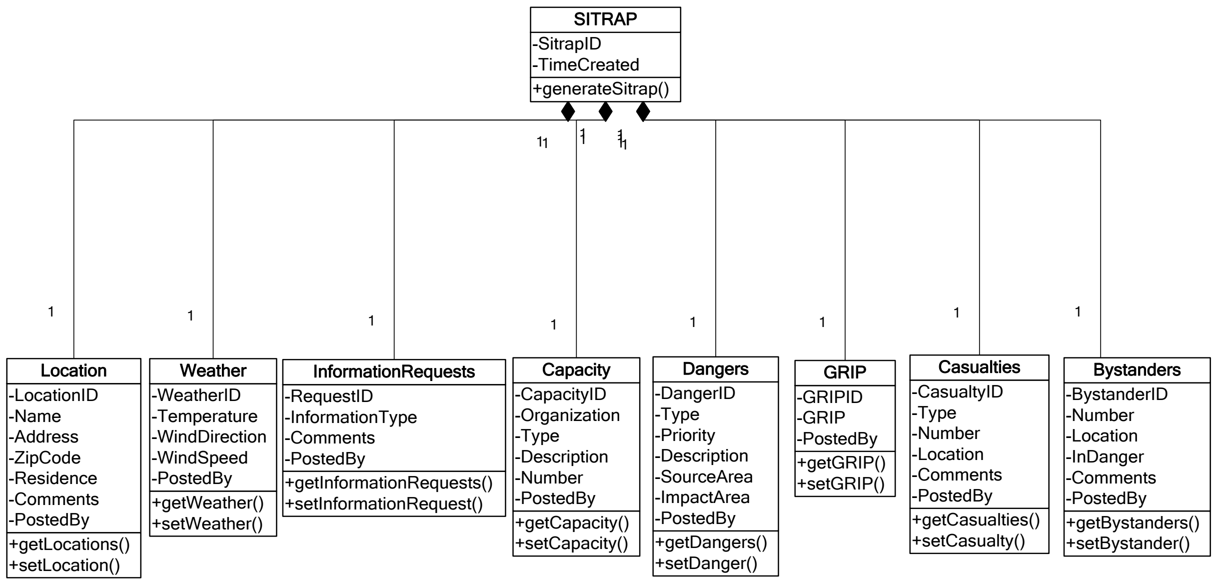



Figure 15: Functional Design - Class Diagram

One can see that the main class in this functional design is the SITRAP (i.e. situational report). This report consists of several, predefined information objects, such as ‘Dangers’, ‘Location’ and ‘Casualties’. This is in line with the functional requirements of ‘Standardized Input’ and ‘Standardized Output’ as mentioned in section 5.1. Furthermore, the methods in each class are only ‘get and set’-methods. This is because the main functionalities of this system are information input and output. One important notice is that the use cases Login and Logout are not linked to this class diagram as several packages offer a standardized way to implement this functionality.

## 6.4 Conclusion

In this chapter, the functional design of DIOS was discussed. Based on the requirements and network-centric principles of the previous chapter, we first started to define a number of use cases. These use cases are primarily focused on system access, information input and information output. Furthermore, we only distinguished one type of user in this system: the relief agent. As we are designing a network-centric CIMS, no distinction is made between commanders and subordinates; every relief agent can do the same in this system. The next step was to translate the use cases to realistic user scenarios in order to model the process of using the system. Finally, we created a class diagram with repeated claim that it consisted mainly of information input and output classes. The main class in this diagram, the class 'SITRAP' (i.e. situational report), is an aggregation of all other classes. Users can use the SITRAP class to have a functional overview of all information supplied to the system.

In the next chapter, the models of this chapter will be translated into a technical design of DIOS. To this end, a three-layered approach for modeling the technical design is used, consisting of a presentation layer, an application layer and a data layer.

# 7 DIOS: Technical Design

Developing the technical design of DIOS is done in phases. Currently, there are 2 operational versions available of DIOS: DIOS 1.0 and DIOS 2.0. In this chapter, both technical designs are discussed and compared. The first section will address DIOS 1.0, followed by a section on DIOS 2.0. Eventually, a comparison between DIOS 1.0 and DIOS 2.0 will be made. Afterwards, the testing procedures of DIOS are mentioned and several conclusions are drawn with respect to this technical design. At the end of this chapter, an answer is found on the following research question:

*What is the technical design of a network-centric CIMS?*

## 7.1 DIOS 1.0

DIOS 1.0 was initially developed by a team formed at the Information and Communication Technology department at Delft University of Technology. After a pre-test of DIOS 1.0, we decided to extend and adjust DIOS 1.0, which resulted in DIOS 2.0. DIOS 2.0 will be discussed in the next paragraph. First, an overview is given of the technical design of DIOS 1.0.

### 7.1.1 Technical Architecture

Based on the requirements and the conceptual design of the previous chapters, a technical architecture was developed to give an overview on how DIOS 1.0 can be developed. An important notion is that not all requirements are satisfied as there were strict time constraints in place. The figure below shows the technical architecture used in DIOS 1.0. The layers in the architecture are separately discussed in the following paragraphs.

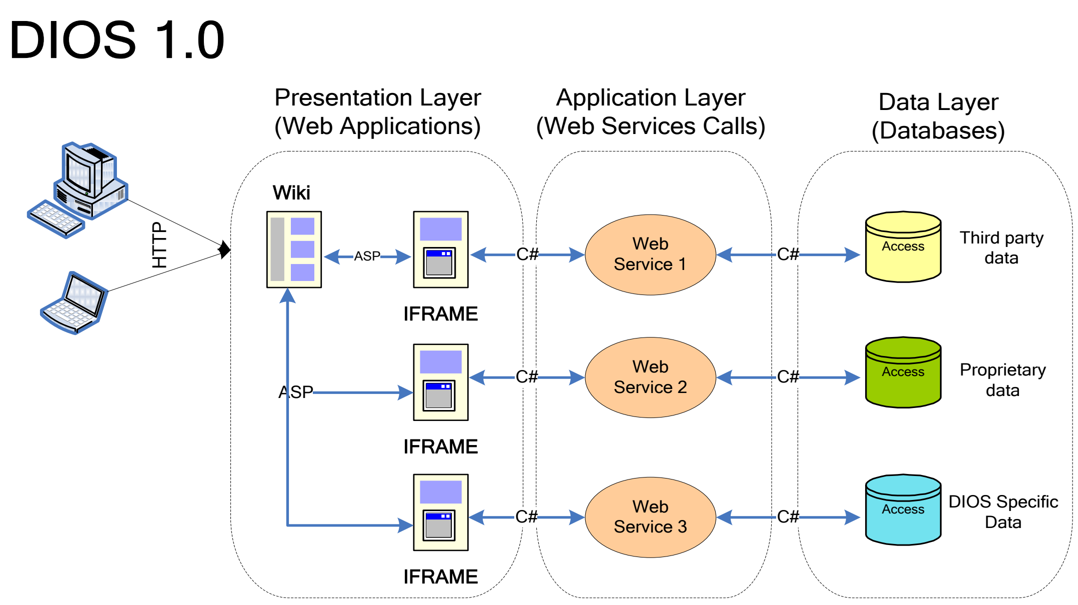



Figure 16: DIOS 1.0 - Technical Architecture

### 7.1.2 Presentation Layer

Initially, DIOS 1.0 used a wiki page to present the information to the users. This was done by utilizing the open-source package *'ScrewTurnWiki 2.0.37'*. By utilizing this wiki, users could log in and select their own dashboard in which information was presented. I-Frames were used in the presentation layer to present the information in structured tables. All I-Frames were refreshed every 10 seconds by enabling a post back to the server on which the website was hosted. The I-Frames were coded using ASP.NET. ASP.NET is a server-side language that can be used for developing web sites and web applications. Several screenshots are depicted below of the website to visualize the presentation layer of DIOS 1.0.

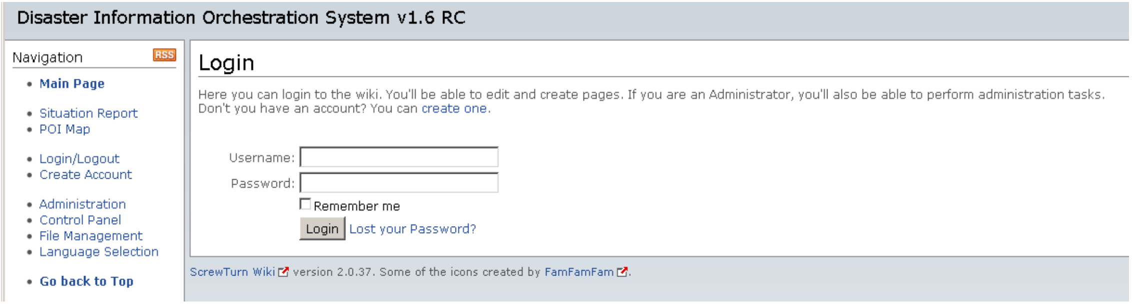



Figure 17: DIOS 1.0 - Login Screen

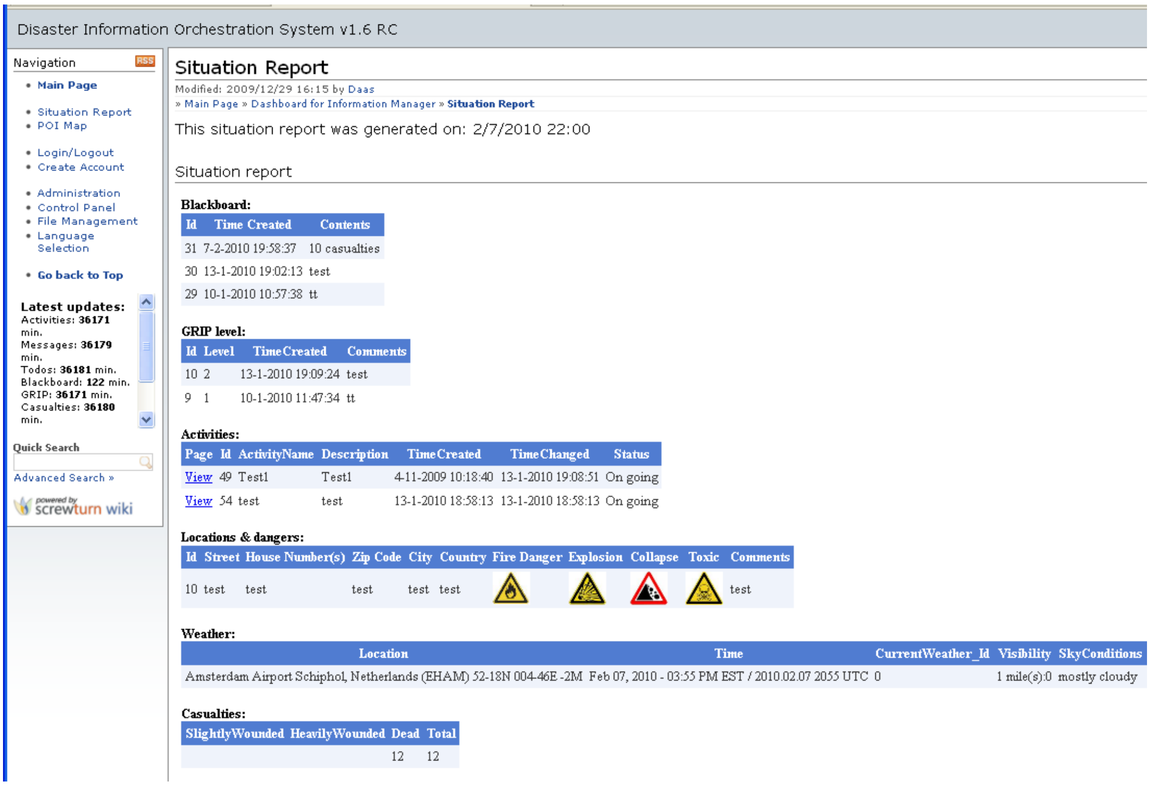



Figure 18: DIOS 1.0 - Situation Report

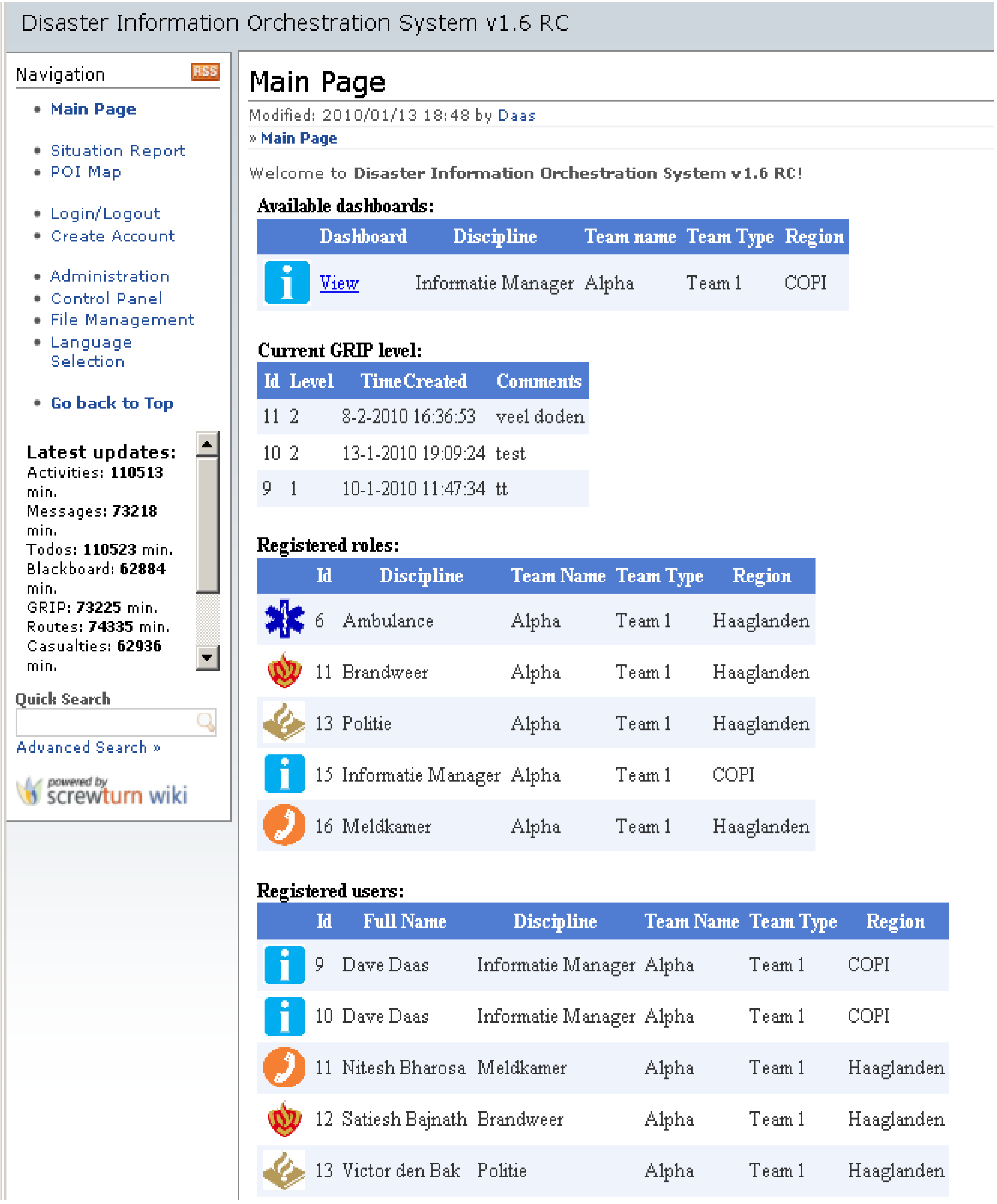



Figure 19: DIOS 1.0 - Main Page

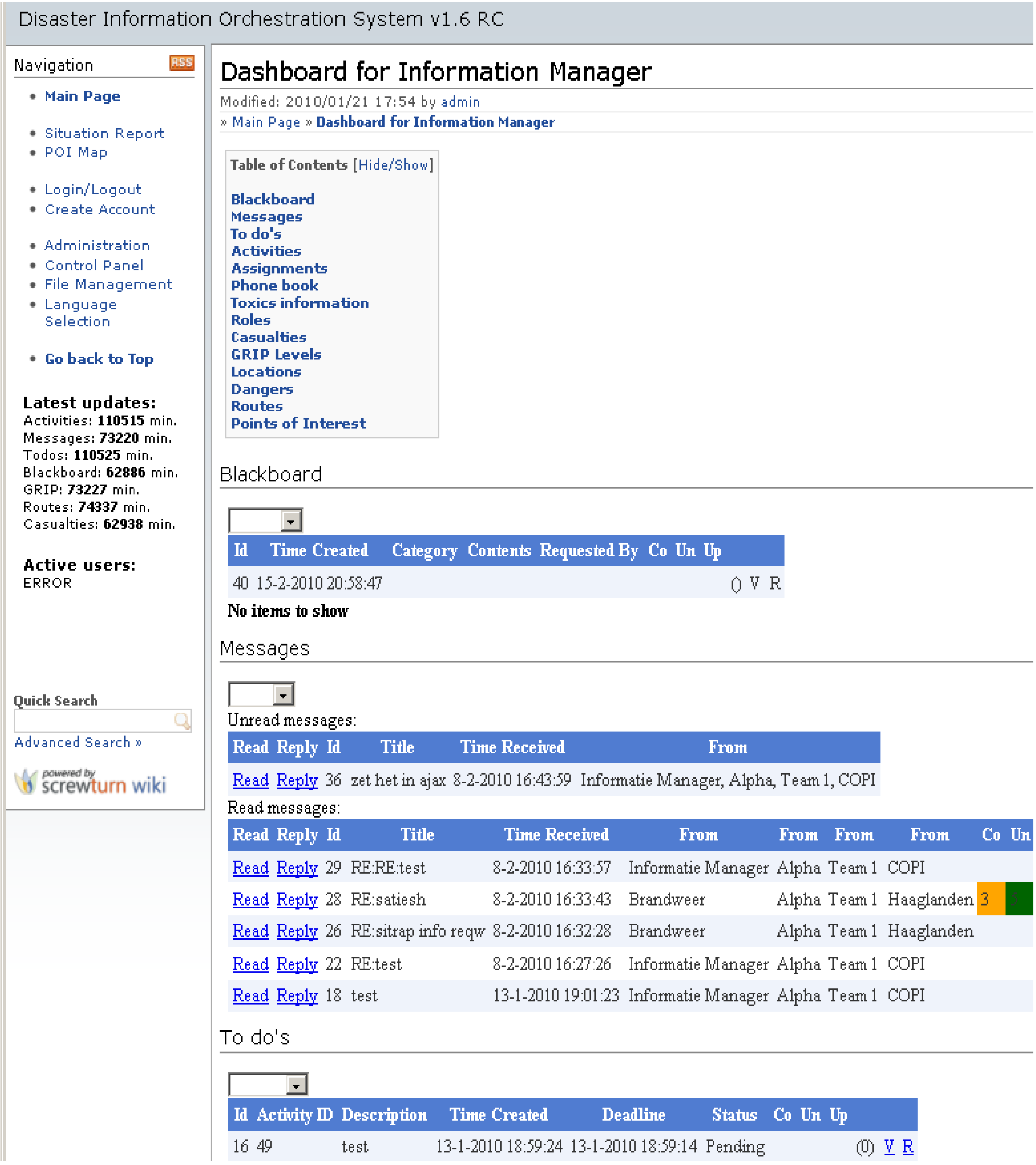



Figure 20: DIOS 1.0 - Dashboard for Information Manager

### 7.1.3 Application Layer

Apart from developing the presentation layer, it was necessary to let the web applications communicate with information sources. For this purpose, the web applications made use of web services. Fixed web service links were used and were coded in the C# programming language. Each web service can have several web service methods for inserting, deleting, updating or selecting data from a specific data source. An overview of all web services used in DIOS 1.0 is given in the table below. The table below is neither a complete nor a perfect set of web services for use in crisis situations. Yet, since DIOS is designed as a proof of principle, the designers were still satisfied with this list.

Table 9: DIOS 1.0 - Web Service Definitions

| Web Service | Explanation | Web Service Methods |
|---|---|---|
| **Activity** | The activity web service allows creating a specific environment in which the other web services are used. This web service gives a situational overview of all activities. | CreateActivity()<br>DeleteActivity()<br>UpdateStatus()<br>ListActivities()<br>GetStatus() |
| **To Do** | The To Do web service shows a list of all tasks that need to be handled. Everyone can see this list and update it when a task is completed. | CreateToDo()<br>DeleteToDo()<br>UpdateStatus()<br>ListToDoItems()<br>ListToDoItemsOfActivity()<br>GetStatus() |
| **Phonebook** | The phonebook allows the information manager to look up phone numbers and contact information. | FindNumber() |
| **Toxics** | This web service allows emergency services to look up toxics. It has the same information as the thick toxic manuals in paper currently in use. | FindToxic() |
| **Weather** | The weather web service has been created by a third party and is freely available on the internet. It shows that web services can be accessed from around the world. | GetWeather() |
| **Messages** | This is a simple text based message service. Everyone can send messages to each other. | CreateMessage()<br>ReadMessage()<br>ListUnreadMessages()<br>ListReadMessages() |
| **Roles** | This is strictly an administrative web service. It allows the information manager to create roles and to channel only the relevant information to them. | CreateRole()<br>DeleteRole()<br>UpdateRole()<br>ListRoles()<br>ListMyRoleInformation() |
| **Casualties** | This web service shows a table with all the casualties in the area. | CreateCasualty()<br>DeleteCasualty()<br>DeleteAllCasualties()<br>CountCasualties()<br>ListAllCasualties() |
| **Flight Information** | This web service allows searching a database with flight and passenger information in case this is necessary. | PassengerList()<br>Flights() |
| **Container List** | The contents of containers can be retrieved using this web service. | ShowContainerList()<br>SearchContainerContent() |
| **Point of Interest** | This web service shows a Google Map with all kinds of points of interest. This could for instance be locations that can be used to shelter those who are evacuated. | FindPOI()<br>CreatePOI() |

### 7.1.4 Data Layer

Since web services were used in the application layer, the data sources in the data layer could be heterogeneous. Several data sources were used, including third party data (for retrieving weather reports), proprietary data (e.g. internal data of relief agencies, this was however simulated) and DIOS Specific Data (data used for that is disaster-specific).

The main data source used in this project was a Microsoft Office Access Database (version 2003). This relational database management system comes with an easy-to-use graphical user interface, which allows the modeler to easily adjust, select and insert data. MS Office Access is often used for small-scale projects in which the use of data is not intensive. The major drawbacks of using MS Office Access as your relational database management system are however:

1. *Scalability:* Access limits the size of the database to approximately 1 GB without having serious read or write issues.
2. *Weak Security:* Access provides no database security on its own, apart from authentication. The database can easily be copied on a USB stick and encrypting the database involves several complicated steps.

Since DIOS 1.0 was developed as a proof of principle, MS Office Access was chosen as the database management system despite these drawbacks. Furthermore, Access is easy in use and has smooth integration with the web services coded in the application layer. The figure below shows a database diagram with several table definitions for visualizing and specifying the database tables of the MS Office Access database.

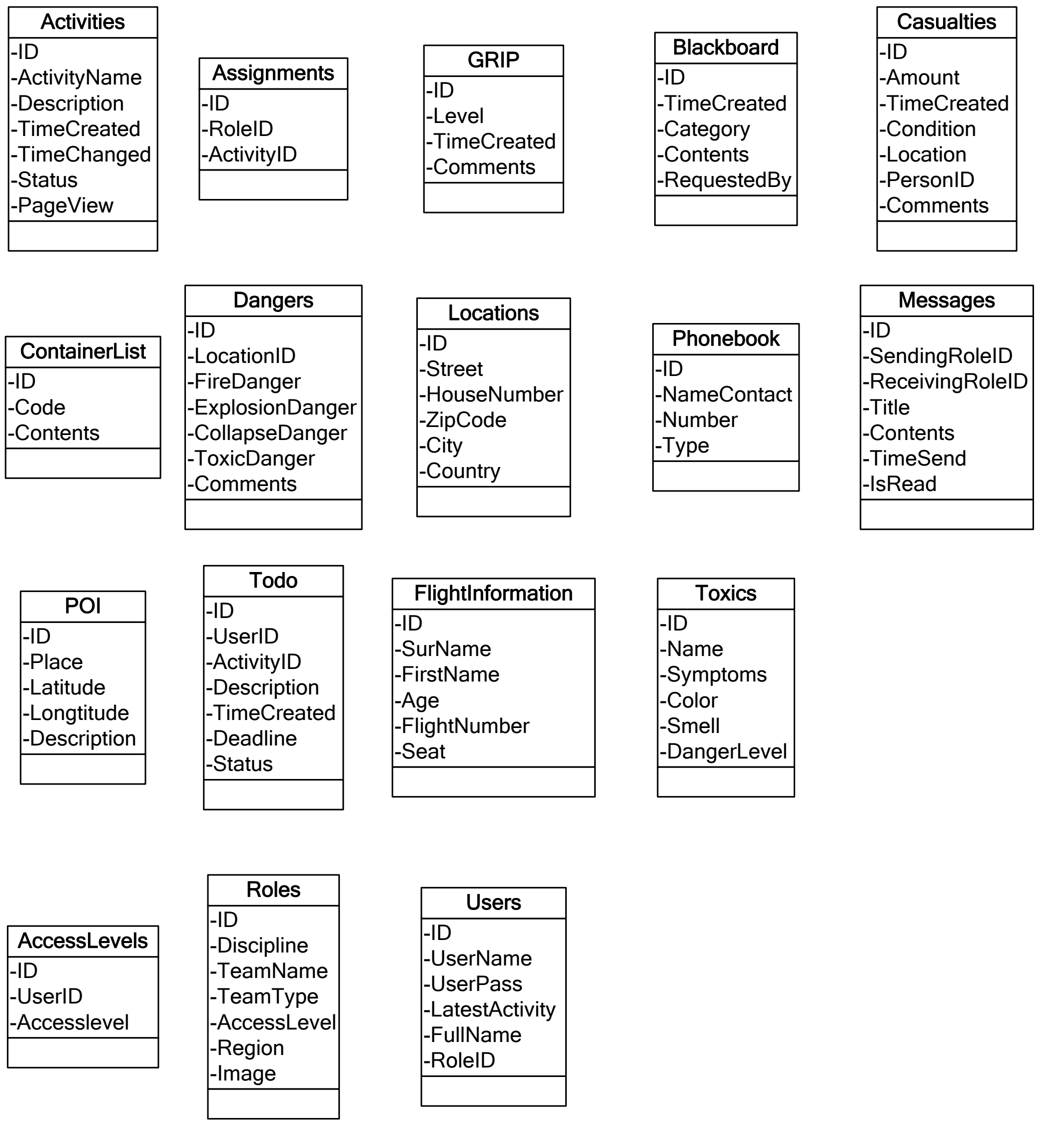



**Figure 21: DIOS 1.0 - Database Diagram**

## 7.2 DIOS 2.0

The development of DIOS 2.0 was started after a pre-test of the gaming simulation (Master of Disaster Game) for this master thesis. To this end, DIOS 1.0 was revised and several important functionalities were removed and added. In paragraph 1.3, the differences between DIOS 1.0 and DIOS 2.0 are discussed alongside the reasons for changing the system itself. First, an impression is given of DIOS 2.0 in the following subsections.

### 7.2.1 Technical Architecture

The requirements and functional design of the previous chapter were the basis of the technical architecture of DIOS 2.0. The technical architecture of DIOS 1.0 also played an important role in drawing up the architecture of DIOS 2.0. The picture below shows the technical architecture used in DIOS 2.0. The layers in the architecture are separately discussed in the next subsections.

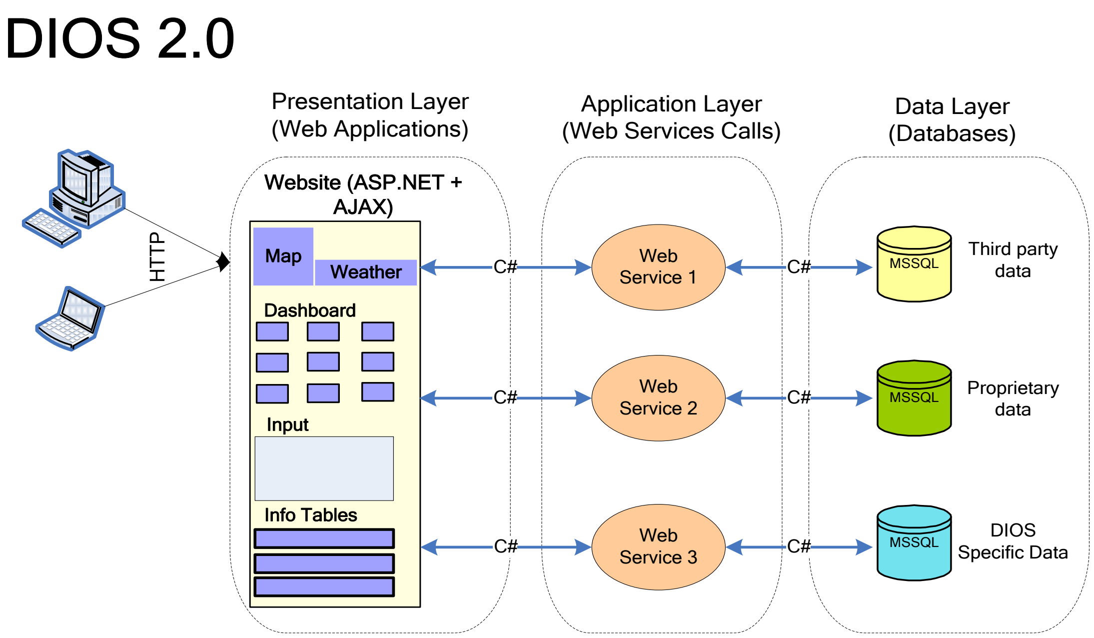



Figure 22: DIOS 2.0 - Technical Architecture

### 7.2.2 Presentation Layer

Several important changes were made in the presentation layer compared to the design choices made in DIOS 1.0. The most notable changes are the removal of the wiki and the introduction of a dashboard in DIOS 2.0. More differences between DIOS 1.0 and 2.0 are discussed in paragraph 7.3. DIOS 2.0 now has one main website (DIOS.aspx) which consists of 4 distinct parts:

1. *Map and Weather information:* in the first part, the map of the disaster scene can be loaded together with the current time and weather information
2. *Dashboard:* the dashboard shows the latest information concerning relevant information for disasters (e.g. casualties, bystanders, dangers, information requests etc.)
3. *Input:* this part of the website gives the user the possibility to input data into the system. This is done in a structured manner where several tabs are used for several different information objects
4. *Information Tables:* whereas the dashboard only shows the latest information available for each type of information, the information tables keep track of all information entries into the system, providing a full ‘information system memory’ for each crisis.

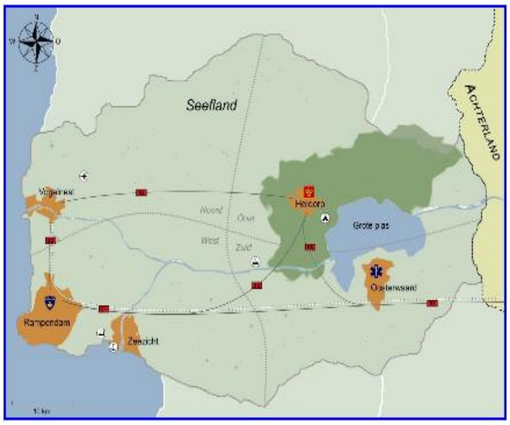
The screenshots below represent each part of the presentation layer in DIOS 2.0. As the gaming simulation took place at the Police Academy of the Netherlands, it was decided that DIOS 2.0 would be coded in Dutch. Therefore, the screenshots below show the use of Dutch instead of English.

DIOS 2.0 – Delft University of Technology

Datum: 08-04-2010 Tijd: 11:47:00

Einde: 17:00:00

Map




Weer

Rampendam

5 °C

| | |
|---|---|
| Windrichting | 200 |
| Windkracht | 4 |
| Geplaatst Door: | IM-GMK |
| Namens: | Brandweer |
| Tijd van plaatsing: | 12-3-2010 15:56:40 |

Figure 23: DIOS 2.0 - Map and Weather Information

**GRIP**

| | |
|---|---|
| Creatie | 12-3-2010 16:07:18 |
| GRIP | 0 |
| GeplaatstDoor | IM-CoPI |

**Slachtoffers - Lichtgewond**

| | |
|---|---|
| Creatie | 12-3-2010 16:00:42 |
| Aantal | 85 |
| Locatie | Faculteit scheikunde |
| GeplaatstDoor | IM-Veld |

**Informatie Verzoeken**

| | |
|---|---|
| Creatie | 12-3-2010 16:03:57 |
| InformatieType | Gevaren |
| Beschrijving | Maskers in veld verplicht. Methanol leidt tot irritatie van huid en slijmklieren |
| GeplaatstDoor | IM-GMK |

**Locatie**

| | |
|---|---|
| Creatie | 12-3-2010 15:33:21 |
| Naam | faculteit bouwkunde |
| Adres | newtonweg 5 |
| Woonplaats | Rampendam |
| GeplaatstDoor | IM-CoPI |

**Slachtoffers - Zwaargewond**

| | |
|---|---|
| Creatie | 12-3-2010 16:00:59 |
| Aantal | 20 |
| Locatie | Faculteit scheikunde |
| GeplaatstDoor | IM-Veld |

**Capaciteit**

| | |
|---|---|
| Creatie | 12-3-2010 16:05:37 |
| Organisatie | Politie |
| Type | Personeel |
| Beschrijving | agenten |
| Aantal | 35 |
| GeplaatstDoor | IM-GMK |

**Omstanders**

| | |
|---|---|
| Creatie | 12-3-2010 15:58:01 |
| Aantal | 3 |
| Locatie | prins v oranjestraat |
| InGevaar | Ja |

**Slachtoffers - Omgekomen**

| | |
|---|---|
| Creatie | 12-3-2010 16:04:44 |
| Aantal | 7 |
| Locatie | Faculteit scheikunde |
| GeplaatstDoor | IM-Veld |

**Gevaren**

| | |
|---|---|
| Creatie | 12-3-2010 16:03:13 |
| Type | Explosie |
| Prioriteit | Hoog |
| Brongebied | fac Bouwkunde |
| Effectgebied | |

Figure 24: DIOS 2.0 – Dashboard


Figure 25: DIOS 2.0 - Information Input


Figure 26: DIOS 2.0 - Information Tables Collapsed

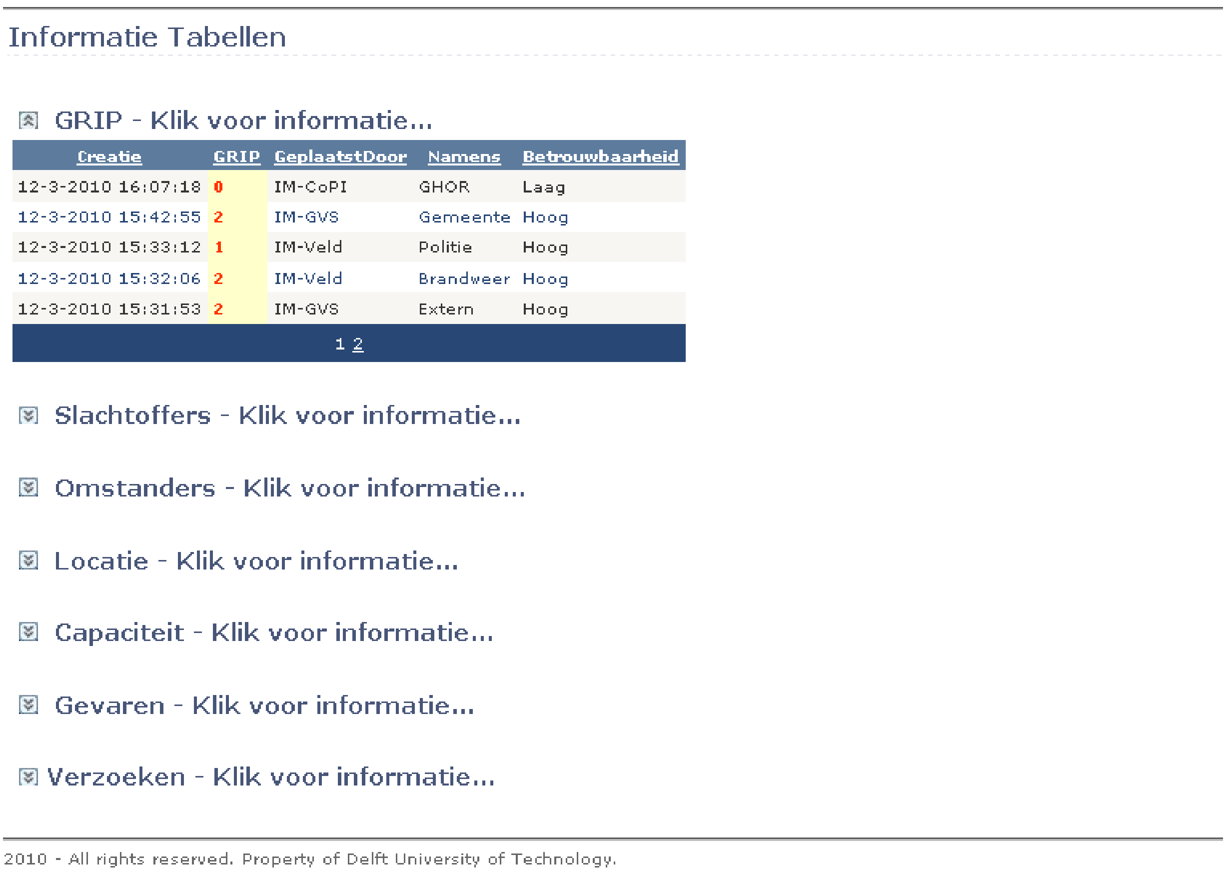



Figure 27: DIOS 2.0 - Information Tables - GRIP Collapsed

#### 7.2.2.1 Using AJAX Technology in DIOS 2.0

In addition to changes in the structure of the website, extra technology was used to automatically refresh the information tables and the dashboard. This technology is called AJAX and stands for *Asynchronous JavaScript and XML*. AJAX is actually a set of several technologies that can be used in enriching web applications (Garrett 2005).

AJAX technology allows a web application to be more interactive by enabling *partial-page updates*, which means that parts of a webpage can be updated without having to refresh the whole page, which is usually done by pressing the F5 button. This enhancement gives the user a much richer experience with web applications (Garrett 2005). Well-known examples of web pages that use AJAX are:

1. *Google.com:* Google now provides Google Suggest: each time you type in a search question, Google comes up with suggestions of what the search question might be.
2. *Google Maps:* When you zoom in or out using Google Maps, the map is immediately loaded, without having to refresh the whole page.
3. *Youtube.com:* In case someone wants to rate a video, the user can just select the number of stars and the rating for the video is updated without a full page refresh.

In DIOS 2.0, AJAX technology was specifically used to enable real-time updates for the Dashboard and Information Tables of the web site. Furthermore, AJAX was also implemented in hiding and showing the information tables for preventing information overload of the user. In addition, AJAX was used for calling web services real-time by using direct JavaScript calls instead of using the SOAP protocol. The next section will discuss the use of web services more in-depth.

### 7.2.3 Application Layer

The application layer of DIOS 2.0 also consists of several web services that can be used for modifying, inserting or selecting data. An overview of all web services used in DIOS 2.0 is given in the table below. These web services are largely based on the set of web services employed in DIOS 1.0. Also, the web services in DIOS 2.0 are also adjusted on the scenario played in the gaming simulation. For more details on the code of the application, we refer to Appendix B: Application Code.

Table 10: DIOS 2.0 - Web Service Definitions

| Web Service | Explanation | Web Service Methods |
|---|---|---|
| **GRIP** | Inserting and Showing GRIP values (GRIP is an indication used in the Netherlands that tells how severe a disaster is). | InsertGRIP()<br>ShowGRIP() |
| **Casualties** | Information provision and entry concerning casualties (Deceased, Heavily Wounded, Lightly Wounded). | InsertCasualty()<br>ShowDeceased()<br>ShowHeavilyWounded()<br>ShowLightlyWounded() |
| **Information Requests** | Users can post an information request when they need information on something. | InsertInfoRequest()<br>ShowInfoRequests() |
| **Location** | Insert and Show updates of a Location (usually the disaster scene). | InsertLocation()<br>ShowLocations() |
| **Capacity** | This web service is used for inserting and showing the capacity, expressed in vehicles or officers, of each relief agency. | InsertCapacity()<br>ShowCapacity() |
| **Bystanders** | Information concerning bystanders who are at the disaster scene. | InsertBystanders()<br>ShowBystanders() |
| **Dangers** | Users can post and see information concerning several dangers on the disaster scene, such as a collapsing danger, a toxic danger or an explosion danger. | InsertDanger()<br>ShowDangers() |
| **Weather** | Weather information can be assessed and modified using this web service. | InsertWeather()<br>ShowWeather() |

### 7.2.4 Data Layer

In DIOS 2.0, the data layer consisted of a Microsoft SQL Server, which operated separately next to the web server. The SQL Server contained 1 database with all specific data of DIOS. There was no use of third-party data during the 'Master of Disaster' gaming simulation, as it was too risky to depend on relatively unknown service providers during the simulation. Yet, the use of third-party data in DIOS 2.0 was also easily possible due to the use of web services in the application layer. However, in the gaming simulation, we simulated third-party data by saving this data locally in the MS SQL Server Database (the tables are: HazardousMaterials and ShelterLocations).

MS SQL Server 2008 Express Edition was chosen as the database management system for DIOS 2.0 because it is free to use, easy to install and extremely easy to integrate with web services written in C#. The Integrated Development Environment (IDE) used in DIOS 2.0 was Microsoft Visual Web Developer 2008, which ships with a free edition of MS SQL Server 2008. In this IDE, it was made easier for the developer to use a MS SQL database in combination with web services because of the pre-defined classes for retrieving and inserting data. The database diagram below shows which database tables were drafted and which elements make up each table.

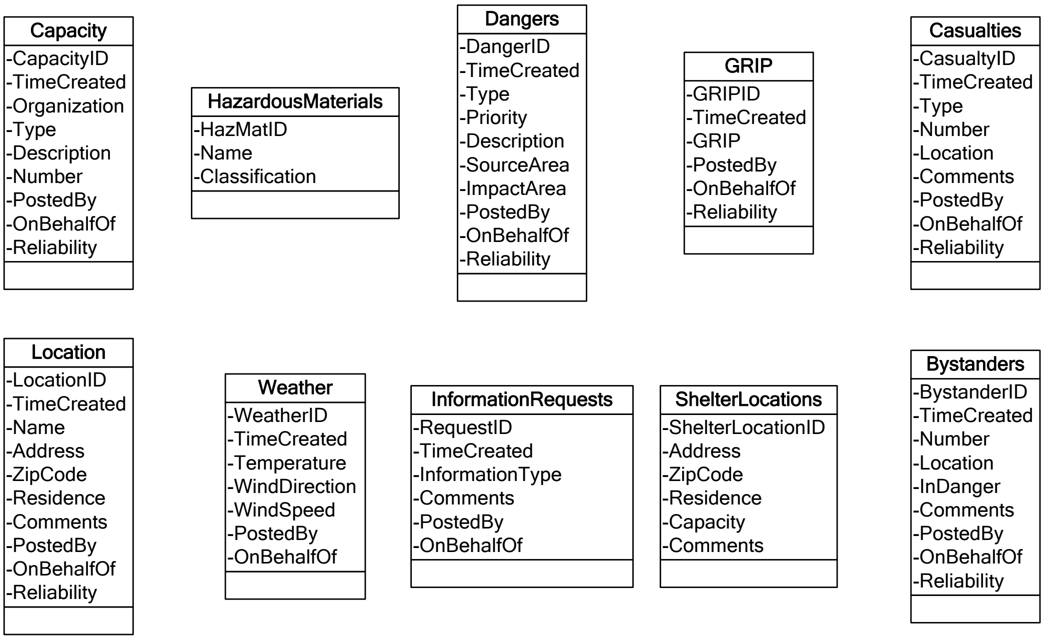



Figure 28: DIOS 2.0 - Database Diagram

This three-tier architecture was a steady basis for incrementally developing the application. Also, after each part of the presentation layer was added, testing and debugging iterations were made in which all layers were tested on consistency and error handling.

## 7.3 DIOS 1.0 vs. DIOS 2.0

In the next section, a comparison between DIOS 1.0 and DIOS 2.0 is made. The functionalities between the two versions differ significantly in all layers of the application. The section below will put out the differences occurred in each layer and why other design choices are made in the development of DIOS 2.0.

### 7.3.1 Comparing both Presentation Layers

The biggest differences are probably seen in the presentation layer of the application. Besides removing the wiki and inserting a dashboard, DIOS 2.0 consists of complete other technologies, such as AJAX. The table below shows the key differences, including why we chose to update DIOS 2.0 in such a way.

Table 11: Comparing DIOS 1.0 and DIOS 2.0 - Presentation Layer

| Feature | DIOS 1.0 | DIOS 2.0 | Reason |
|---|---|---|---|
| **Wiki** | Available | Not available | Using the wiki would take too much time to familiarize the players of the gaming simulation. |
| **Logging in/out** | Available | Not available | Given the strict timeframe of redesigning DIOS, the Login feature could not be implemented. |
| **Roles** | Explicitly Specified | Implicitly Specified (users can indicate who they are when posting information) | There was too little time to implement roles for each player. |
| **Refresh Rate** | Full Page Refresh each 10 seconds | Partial Page Refresh using AJAX | AJAX makes the user experience better and more intuitive. |
| **Wiki Search Function** | Included | Excluded | No wiki was installed, therefore no search function was made. |
| **Use of Google Maps** | Yes, in POI Web | No, made use of a | For the purpose of a gaming |

| | | | |
|---|---|---|---|
| | Service, but not fully operational | static map | simulation, a static map was sufficient. |
| **Dashboard** | Yes, but not generic | Yes, generic and for every user accessible | A dashboard can give users the latest update of the situation in one eye catch. |
| **Collapsible Panels** | No | Yes, for information tables | Collapsible Panels can prevent information overload by not showing all available information. |
| **Rating Information** | Done with a scale (1-5) and colors (green-orange-red) | Done with 1 reliability indicator with a scale (Low-Medium-High) | Easy to implement and easy to understand for users. However, the colors and 1-5 scale could be recommended for further development. |
| **External Information** | Implicitly Mentioned | Explicitly Mentioned as a Tab in the Input | The role of external information can be of significance in disasters, so an explicit notion seems important. |

### 7.3.2 Comparing both Application Layers

There are no real changes made in the application layer, except for calling the web services. In DIOS 1.0, a web service was called by using a 'fixed link web service': a static URL that points to the web service. In DIOS 2.0, calling web services is implemented differently: by using JavaScript, a copy of the web service is created on the web server and that copy is called first. Only when that copy becomes corrupted, the real web service (the 'Fixed Link Web Service') is called. It makes a difference in efficiency to call web services using JavaScript because operations (like inserting and selecting data) can be implemented more quickly.

### 7.3.3 Comparing both Data Layers

The main change in the data layer is the use of a different database. The migration from MS Office Access to MS SQL Server was a pretty easy process. Since both database management systems use the same query language (SQL - Structured Query Language), only changing the engine (JET DB to ADO DB) could be called difficult. Yet, an easy transition took place where no genuine problems were countered. The table below shows the changes made in DIOS 2.0 compared to 1.0 on the data layer level.

**Table 12: Comparing DIOS 1.0 and 2.0 - Data Layer**

| Feature | DIOS 1.0 (MS Access) | DIOS 2.0 (MS SQL Server) | Reason |
|---|---|---|---|
| **Size** | Maximum of 1 GB without real read/write problems. | Maximum of 8 GB without real read/write problems. | With respect to possible real implementation, an SQL database more sufficient. |
| **Security** | Can be put on USB/CD<br>No authentication measures. | 2 Authentication measures (on the server and through the web services)<br>Automatic encryption of the database<br>Can only be used by the designated MS SQL Server. | As relief workers can have sensitive information, also during disasters, security of data is a must. |
| **Implementation** | Using JET DB and SQL queries. | Using ADO DB and SQL queries. | ADO DB provides for a more easy implementation when it comes to linking web services to a database. |

Although certain aspects of DIOS 2.0 are more advanced than those of DIOS 1.0, the insights and some features of DIOS 1.0 remain important in the further development of this system. Perhaps features from DIOS 1.0 can come back, should this system be further developed.

## 7.4 Testing Procedures of DIOS

An important phase in developing an information system is the testing phase as this phase often points out several overlooked errors. These errors can then be solved on time in order to have a stable system at the end. We also held a testing phase for examining all functionalities of DIOS 2.0. To this end, we evaluated DIOS with a number of master students from Delft University of Technology on February 16$^{th}$. During this test, it appeared that DIOS had crashed on the web server. This was unfortunate; however, some important lessons were learned from this pre-test:

1. After this crash, DIOS was thoroughly checked for programming errors. An incremental and iterative way of working was pursued in order to minimize the risk of another crash.
2. Precautions were taken in case DIOS would not work at the Police Academy: a backup plan was conceived and DIOS was made independent of the web server, in case the web server did not function.
3. DIOS has been tested by a large test team of PhD students and master students. In the section below, the testing procedures are briefly discussed.

Following the crash of DIOS at the pre-test, a big test session was held 10 days before the session at the Police Academy. 12 testers were asked to simultaneously use the DIOS system as intensively as possible, so a thorough error handling could be done subsequently. The result of the test was positive; DIOS did not crash and was still functioning afterwards. Still, there were some improvements made to DIOS:

1. *Error handling for special characters:* characters like question marks, brackets and exclamation marks were entered during the test session and this resulted in errors. After the test, a small character handler was built so that no errors were generated.
2. *Error handling for script attacks:* during the test, a small html script was also entered in DIOS, resulting in several errors. The information fields were reprogrammed afterwards, so that html and JavaScript scripts could not generate errors in DIOS.

The pre-test shows that testing an information system is an extremely important step in the development process. Error handling and user friendliness of a system contribute greatly to the usefulness of a CIMS. This means that a CIMS should always be tested thoroughly, even though this CIMS was a proof of principle. Eventually, during the session at the Police Academy, the updated version of DIOS was utilized. Consequently, the system did not crash during the session at the Police Academy.

## 7.5 Conclusion

In this chapter, we have discussed the technical design of DIOS. First, we presented the DIOS 1.0 system, a version under development at Delft University of Technology. Based on the defined requirements, principles and functional design, the development of DIOS 1.0 was started. This system had a number of interesting features, such as logging in and out, a personalization of the system and partial implementation of Google Maps. However, a major disadvantage of DIOS 1.0 was that this system used full-page refreshing: every 10 seconds, the web application refreshed completely. The user-experience was therefore significantly hampered. Furthermore, because of the full-page refreshing feature of DIOS 1.0, we could not say that DIOS 1.0 was a full network-centric system, because users had to wait every 10 seconds until information was released. In a time-critical situation such as a crisis, every second counts, so because of the full-page refreshing trait, we decided to further develop DIOS and make version 2.0.

Consequently, the main difference between DIOS 1.0 and 2.0 is that refreshing now takes place partially by using AJAX technology. The user does not see a whole page refresh, only parts of the page (e.g. one table) are refreshed immediately when an update is posted. In addition, we decided that every user sees the same screen as everyone else, thereby removing the personalization feature of DIOS 1.0. This choice was made to implement the network-centric principle of *shared* situational awareness, where everyone has immediate access to the *same* information.

Eventually it became clear that several trade-offs had to be made between a number of requirements (e.g. personalization vs. shared situational awareness) in order to have a functioning network-centric CIMS given the time that we had. However, the result was an operating system that could be evaluated at the Police Academy. But before this could be done, several test sessions were held to make DIOS 2.0 even more robust and error-prone.

In the next chapter, the gaming simulation design (our means of evaluating DIOS 2.0) will be discussed. This gaming simulation, called 'Master of Disaster' was played at the Police Academy of the Netherlands. In this session, professionals could get acquainted with a network-centric CIMS and they could give their own opinion on the use of this system during the simulation of a crisis.

# 8 Evaluation of DIOS: 'Master of Disaster' Gaming Simulation

This chapter elaborates on the design of the evaluation session for evaluating DIOS on IQ and SQ dimensions. For this purpose, an experimental design, a gaming simulation design and a survey design are discussed in the subsequent paragraphs. The outcome of the evaluation session tells us what the effect is of the DIOS design principles on ensuring IQ and SQ dimensions in crisis situations. Two gaming simulations were organized: (1) a game with Master-students of Delft University of Technology and (2) a game with professional relief workers. Consequently, the first gaming simulation will function as a pre-test for the second gaming simulation. Each game is designed as a quasi-experiment with two consecutive rounds and two evaluation surveys. Finally, we end this chapter with some concluding remarks. This chapter contributes to answering the final sub-question by providing a means to assess the effect of a network-centric CIMS on IQ and SQ dimensions.

## 8.1 Experimental Design

There are many possibilities for conducting an experiment in which propositions can be evaluated. Campbell and Stanley consider an experiment as *'that portion in research in which variables are manipulated and their effects upon other variables are observed'* (Campbell and Stanley 1969). In other words, an experiment can be used to determine cause-and-effect relationships between variables. There are many different types of experimental designs, of which a true experiment is seen as the most valid one. There are two types of experiments a researcher can choose to test his cause and effect relationships: (1) True Experiments and (2) Quasi-Experiments.

A true experiment is characterized by the following aspects: more than one purposively created group, common measured outcome(s), and random assignment (Gribbons and Herman 1997). Because of the random assignment of participants of the experiment, the groups can be compared well and the change in the observed variable cannot easily be predicated to differences of the participants themselves. This makes the internal validity of a randomized experiment quite strong: the observed change can be predicated to the change made in the control variable.

True experiments have several drawbacks however: they are often expensive, time-consuming and in several cases not doable because it is nearly impossible to control all important variables that could influence the experiment (Gribbons and Herman 1997). The figure below shows two examples of a true experiment: a posttest-only randomized experiment and a pretest-posttest randomized experiment. An important notion is that that are always two groups in each experiment: a treatment group ($R_1$) and a control group ($R_2$).

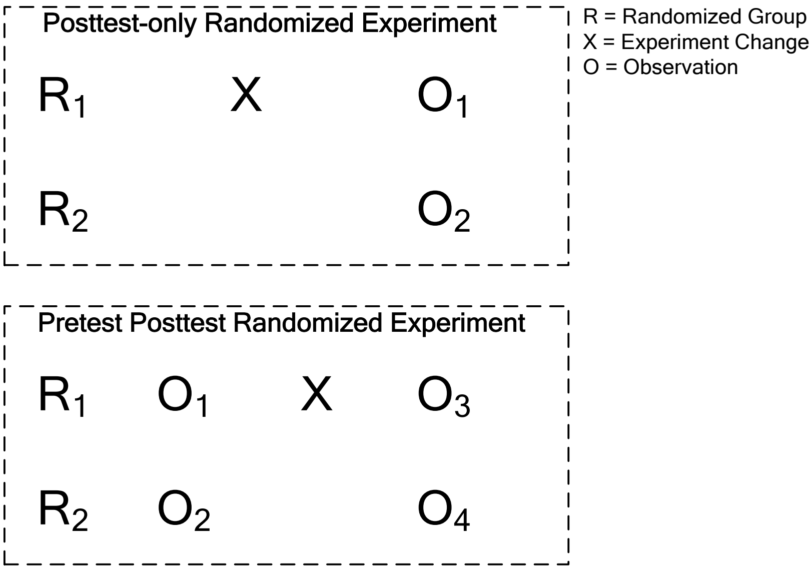



Figure 29: True Experimental Designs (Trochim 2006)

However, because true experiments are often difficult to perform, quasi-experiments can also be used to a certain extent. Quasi-experiments differ from true experiments in the aspect that no random assignment has taken place. In addition, it may also occur that no control group exists in a quasi-experiment (Gribbons and Herman 1997; Shadish, Cook et al. 2002). Several quasi-experiments are available for testing cause and effect relationships; in the figures below, the design of a number of quasi-experiments is shown, including the one that was chosen for this research, which is filled in green.

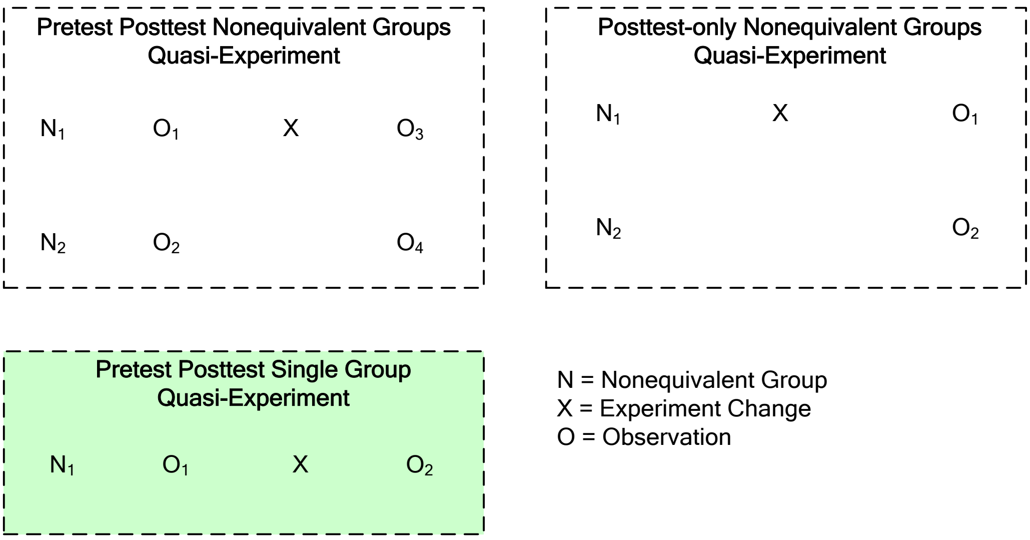



Figure 30: Quasi-Experimental Designs (Trochim 2006)

As depicted above, there are no randomized groups in a quasi-experiment, the groups are non-equivalent. Because the groups in a quasi-experiment are non-equivalent, the internal validity of the experiment drops, as the causal relationship between control variable and observed variable can now also partly be predicated to the learning effect or to the similarity of the participants in the treatment group. In this research, a pretest posttest single group quasi experiment was performed. This means that there is only 1 group of participants, which is non-equivalent. There are however two observation moments (pre and post). Yet, this quasi-experiment has a number of disadvantages:

1. *Limited internal validity:* because the group is not randomized, the cause-effect relationship can never be fully contributed to the dependency between the control variable and the observed variable.
2. *No control group:* as there is no control group to control the measurements of the treatment group, this quasi-experiment loses in validity strength.

Ultimately, the choice was still made to perform a quasi-experiment because of a trade-off between validity of the experiment and the feasibility of the research given the time and budget constraints. In this quasi-experiment, the focus will lie on measuring the scores on IQ dimensions, SQ dimensions and the experiences of the relief workers during the session. The main goal of the experiment is to see a discrepancy between round 1 and 2 on IQ and SQ dimension scores. Additionally, the experiences and attitudes of all relief workers may provide extra insights on the use of a network-centric CIMS.

## 8.2 Gaming Simulation Design

In literature there is much debate about the use of different definitions for a gaming simulation. Some authors call it a game (Duke 1980), others a serious game (Michael and Chen 2005) and others want to define it as a simulation game (Pierfy 1977; Faria and Nulson 1996). The term 'gaming simulation' was however already utilized by Duke and Greenblatt in 1981 (Greenblatt and Duke 1981).

Duke and Geurts defined a gaming simulation as follows: *'a special type of model that uses gaming techniques to model and simulate a system. A gaming simulation is an operating model of a real-life system in which actors in roles partially recreate the behavior of the system'* (Duke and Geurts 2004)

As definitions for a simulation game or gaming simulation are often used as synonyms used in literature, it is difficult to choose which definition for a game or gaming simulation is the most appropriate in this thesis. Meijer argues that the term gaming simulation can be used when the aim is to study the behavior of participants (Meijer 2009). As the interaction of the participants with DIOS and their judgment of the DIOS propositions are the most important in this research, the term *gaming simulation* is used in this research project. We called the gaming simulation the 'Master of Disaster Game'. In his PhD thesis, Meijer devised a framework for designing a gaming simulation session. This framework gives designers the opportunity to systematically design a gaming simulation.

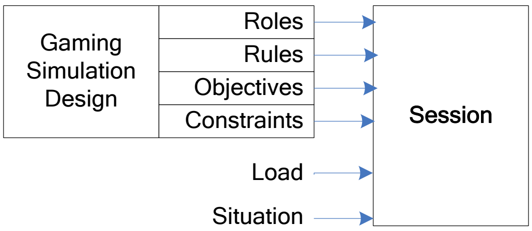



**Figure 31: Gaming Simulation Design Framework (Meijer 2009)**

The elements of a gaming simulation (Roles, Rules, Objectives and Constraints) are used to define the structure of the gaming simulation itself. Apart from these elements, there are also specific session elements, i.e. Load and Situation. The next paragraphs will discuss each gaming simulation element for the Master of Disaster Game in more detail.

### 8.2.1 Gaming Simulation – Roles

The Master of Disaster Game is a gaming simulation that simulates the processes of information management in a disaster situation. The roles in a gaming simulation can be divided into roles for participants and roles for game facilitators (Meijer 2009). The roles for participants are divided into 4 groups with each group having a specific task in this gaming simulation.

Table 13: Master of Disaster Game – Roles

| Group | Roles | Explanation |
|---|---|---|
| **Emergency Control Room (ECR)** | 1. ECR – Police<br>2. ECR – Paramedics<br>3. ECR – Fire Department | The ECR is the first point of contact for reporting a disaster. They need to coordinate 911-calls and other information requests from relief agencies. |
| **Commando Place Incident (CoPI)** | 1. CoPI – Chairman<br>2. CoPI – Information Manager<br>3. CoPI – Police Commander<br>4. CoPI – Paramedics Commander<br>5. CoPI – Fire Department Commander<br>6. CoPI – Local Representative | The CoPI is responsible for the efficient coordination of the field workers on a tactical level so that the disaster can be repressed accordingly. |
| **Municipal Crisis Center (MCC)** | 1. MCC – Mayor<br>2. MCC – Information Manager<br>3. MCC – Police Commander<br>4. MCC – Paramedics Commander<br>5. MCC – Fire Department Commander<br>6. MCC – Municipal Crisis Manager | The MCC is responsible for efficient coordination of relief workers on a strategic and responsible for informing the press. |
| **Field Workers (Field)** | 1. Field – Police Officers<br>2. Field – Paramedics<br>3. Field – Fire Fighters | The relief workers in the field need to gather information for their commanders so that the disaster can be repressed as much as possible. |

Apart from the roles participants have to fulfill, several roles for facilitators can also be defined for a sound gaming simulation.

Table 14: Roles for Facilitators

| Roles for Facilitators | |
|---|---|
| **Mailman** | The mailman will deliver messages between several roles in round 1. This is part of the representation of an information management system where communication is going by mail. |
| **DIOS Assistant** | The DIOS operator will assist the participants who have to work with DIOS in the second round of the gaming simulation. |
| **Journalist** | The journalist wants to bring the news for their corporation as quickly as possible. For this purpose, he/she wants to gain as much relevant information on the disaster as possible. |
| **Observers** | The goal of the observers is to observe the participants as good as possible with help of an observation protocol. |

Each role in this gaming simulation has a role description that the participant can read on beforehand. An example of a role description can be found in Appendix A: Gaming Simulation Materials. The figures below show a map of the gaming simulation setting. In other words, the pictures below show which role should take place at which table in round 1 and in round 2.

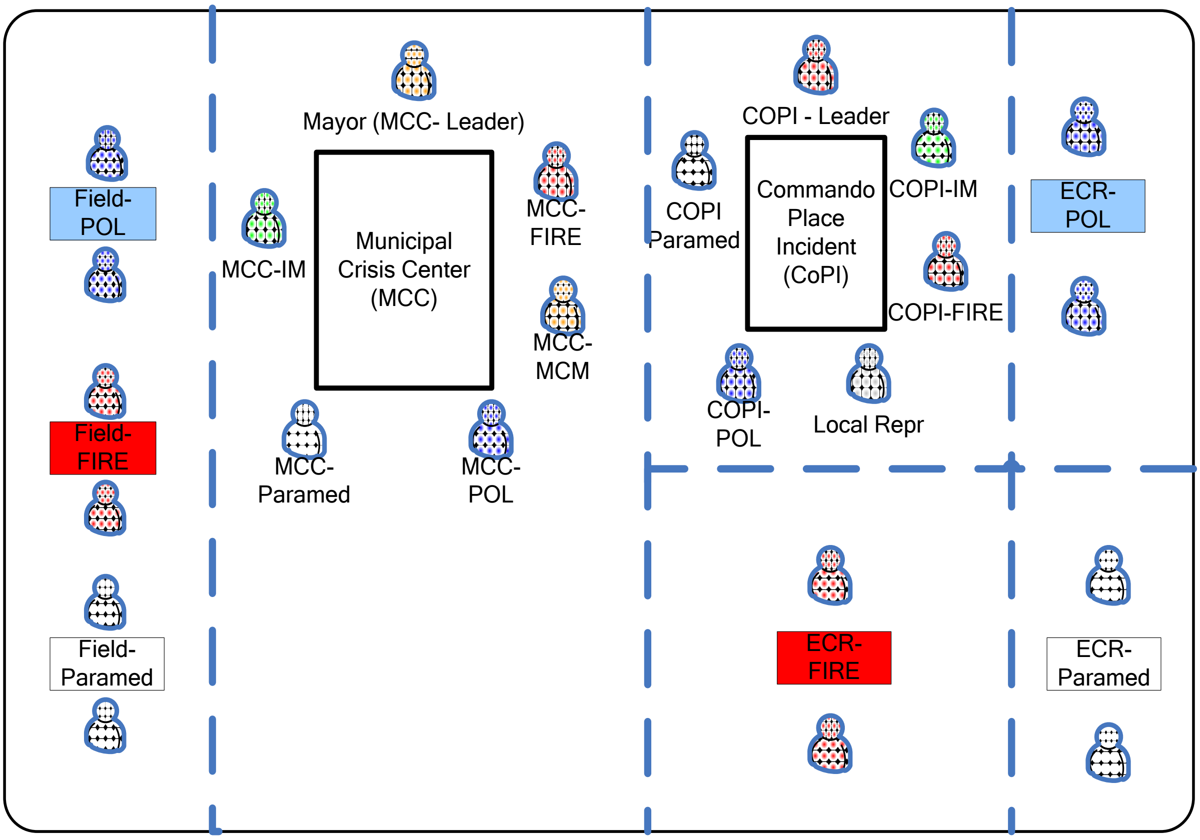



Figure 32: Gaming Simulation Setting Map - Round 1

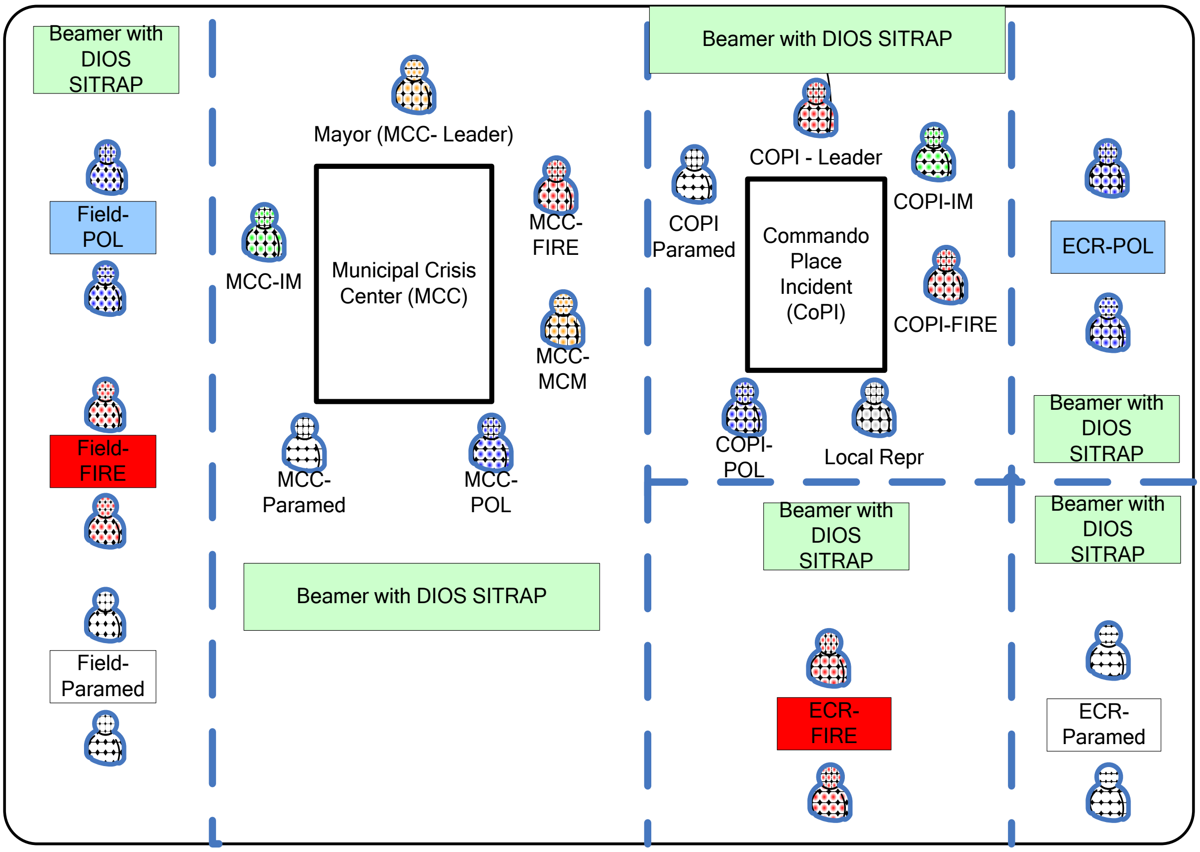



Figure 33: Gaming Simulation Setting Map - Round 1

### 8.2.2 Gaming Simulation – Rules

Rules in a gaming simulation can limit the behavior of participants in order to control the environment (Meijer 2009). There will be some rules that will be explained during the session. These rules are necessary in order to replicate the condition of a real disaster as much as possible. The rules for the Master of Disaster Game include:

- All communication between teams should be done using SITRAP forms, Information Request forms and/or the DIOS system.
- Forms should be put in mailboxes (outbox). The outgoing forms will be delivered by the mailman, only in round 1.
- Everyone is expected to play the same role in the second round. This can of course lead to a learning effect amongst the participants. However, due to time constraints and a slightly different scenario it is more efficient for the participants to play the same role in both rounds.
- Role-specific rules are indicated in the role descriptions (see Appendix X: Gaming Simulation Material).
- Participants have to write only in capital letters on each form.
- Participants are not allowed to walk to other teams and communicate with them.
- Participants need to turn off their mobile phones.

### 8.2.3 Gaming Simulation – Objectives

In contrast with common gaming simulations, the participants are initially not motivated to ‘win’ or to finish first place as this gaming simulation is not intended for that purpose. ‘Master of Disaster’ wants to mimic the information management processes in a disaster setting and wants to experiment with a new type of information management system.  Yet, a price is still given to the best player of each team, based on the judgment of the observers. Therefore, participants still have an incentive to do their best in order to mirror real-life motivations for resolving a crisis. The objective of each participant is framed as: *'complete a situational report (SITRAP) with the highest information quality possible'.*

In order to achieve this objective, participants need to engage in the processes of information management (see also chapter 2 for more details on these processes, (Choo 1995)), including the following activities:

- Information Collection (within your team and between teams)
- Information validation and enrichment
- Information Sharing (when requested by others)

### 8.2.4 Gaming Simulation – Constraints

Constraints are those design elements that limit the range of actions possible in a gaming simulation. In contrast to rules, which define what is allowed or forbidden; constraints shape the minimum/maximum value of time, punishments, points and other variables (Meijer 2009). The constraints of the Master of Disaster Game sessions are:

- A meeting in the CoPI and MCC can have a maximal duration of 15 minutes
- The number of participants is limited to 25
- The time of the gaming simulation in total cannot exceed 3 hours

### 8.2.5 Gaming Simulation – Loads

Loads can be defined as the values of all variables in the design of the gaming simulation (Meijer 2009). A load can also be described as a scenario. In the paragraphs below, two loads are discussed: Load A (for round 1) and Load B (for round 2). For both loads, a fictional setting is designed set in the safety region Seefland. In this safety region, the city of Rampendam is chosen as the location where the disasters will take place. First, some background information on Seefland and Rampendam is given in the paragraph below.

#### *8.2.5.1 Seefland and Rampendam*

The simulated disasters will occur in the fictional safety region called 'Seefland'. Officially, the Netherlands is divided in 25 safety regions. Safety regions are governmental organizations, responsible for disaster preparation and response. In such organizations, the regional police, fire department and ambulance services work together to effectively prevent and repress a disaster. Safety regions usually consist of 3 to 8 municipalities in a region. We chose to develop our own fictitious safety region, instead of an existing safety region, for the following reasons:

1. The participants of the gaming simulation are professionals working in different safety regions in the Netherlands. Hence, using an existing safety region might benefit some of the participants familiar with that safety region. As such, using a fictitious safety region unknown to all guarantees the same level of context or load information throughout all the participants.
2. When using an existing safety region, some participants that work in this existing safety region might feel represented and others working in a different safety region may not feel represented.
3. A fictitious safety region allows the designers of the gaming simulation to control load conditions for experimental purposes. For instance, we can simulate a hospital and a university in the same safety region without any discussion on whether this is realistic or not.

Within the safety region of Seefland, there are several municipalities, including the city of Rampendam. The maps below show an overview of the fictitious safety region and of the city of Rampendam. All maps are made by Victor den Bak.

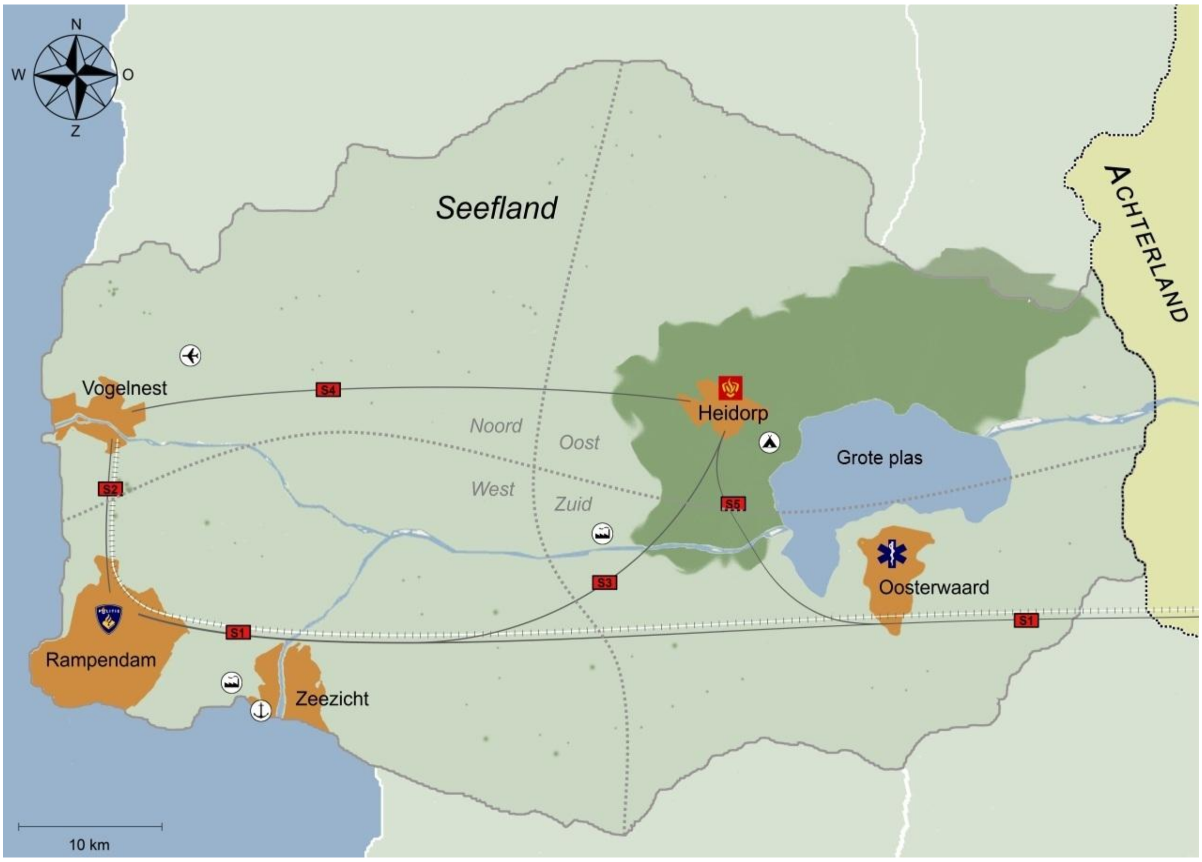



Figure 34: Master of Disaster Game - Map of Seefland

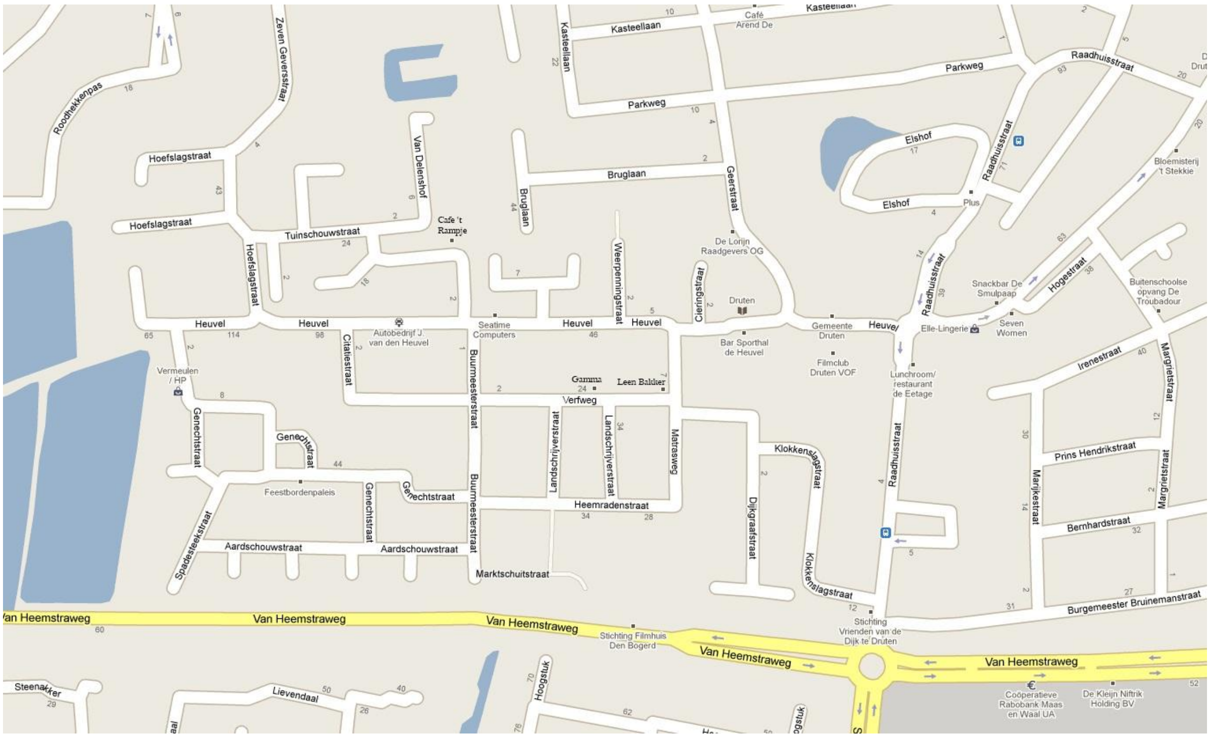



Figure 35: Master of Disaster Game - Map of Rampendam (Load A)

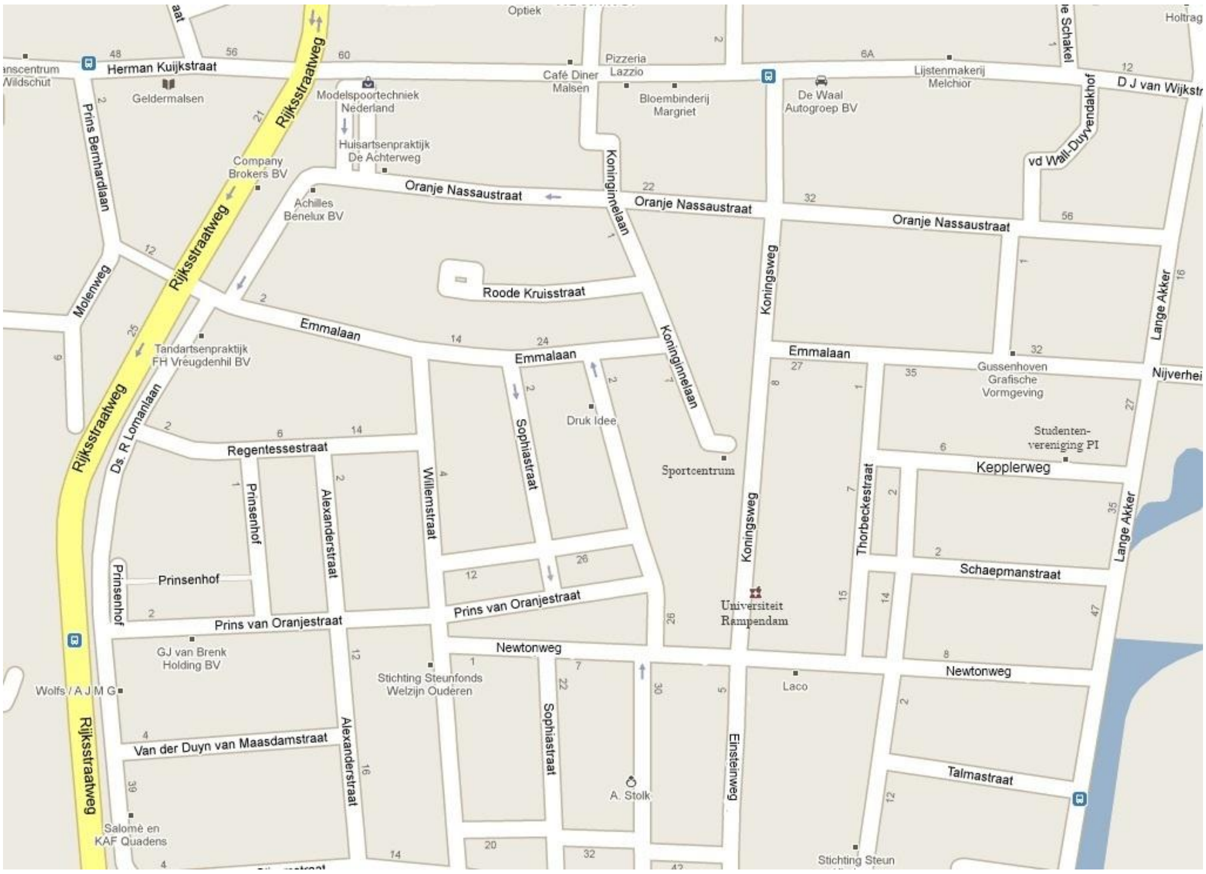



Figure 36: Master of Disaster Game - Map of Rampendam (Load B)

Both loads are held in the city of Rampendam. However, there is a big difference between the two loads regarding the contents of each disaster. In the following paragraphs, both loads and their contents are discussed in more detail.

### 8.2.5.2 Load A: Fire on a Business Complex

Load A is about a fire at a business complex in Rampendam. At this business complex, there are two do-it-yourself stores situated: Gamma and LeenBakker. These shops have explosive and toxic material in their warehouses, which can lead to disastrous consequences for the environment surrounding Rampendam. In this load, participants have to work without DIOS as an information management system. Communication between teams is done with the use of forms and a mailman.

All participants already received their start information and the ECR employees receive the following message:

- 13:41:22 – 12-03-2010 – 87 FIRE - **PRIORITY 1** – 3122 – FIRE BUSINESS COMPLEX
- 13:41:29 – 12-03-2010 – 87 AMBU - **PRIORITY 1** – 3122 - FIRE BUSINESS COMPLEX
- 13:41:45 – 12-03-2010 – 87 **POLI** - **PRIORITY 1** – 3122 - FIRE BUSINESS COMPLEX

### 8.2.5.3 Load B: Fire on a University Complex

Load B has a scenario in which the architecture faculty of the University of Rampendam is on fire. The great danger of this fire is that it borders on the chemistry lab of the Faculty of Chemistry. In this lab, there are many poisonous and explosive materials stored. There is also a collapsing danger of the Faculty of Architecture.

In this load, participants have to work with DIOS as an information management system. All participants already received their start information and the ECR employees receive the following message:

- 15:41:22 – 12-03-2010 – 87 FIRE - **PRIORITY 1** – 3122 – FIRE FACULTY OF ARCHITECTURE

- 15:41:29 – 12-03-2010 – 87 AMBU - **PRIORITY 1** – 3122 - FIRE FACULTY OF ARCHITECTURE
- 15:41:45 – 12-03-2010 – 87 **POLI** - **PRIORITY 1** – 3122 - FIRE FACULTY OF ARCHITECTURE

#### *8.2.5.4 Differences between Load A and Load B*

Even though the events in the loads are roughly the same, there are some differences between the loads, mainly due to the use of DIOS as the new information management system in Load B. The main difference is the way of coordinating information management processes in crisis situations. The figure below shows the difference between Load A and Load B and is based on the difference in the hierarchical and network-centric approach.

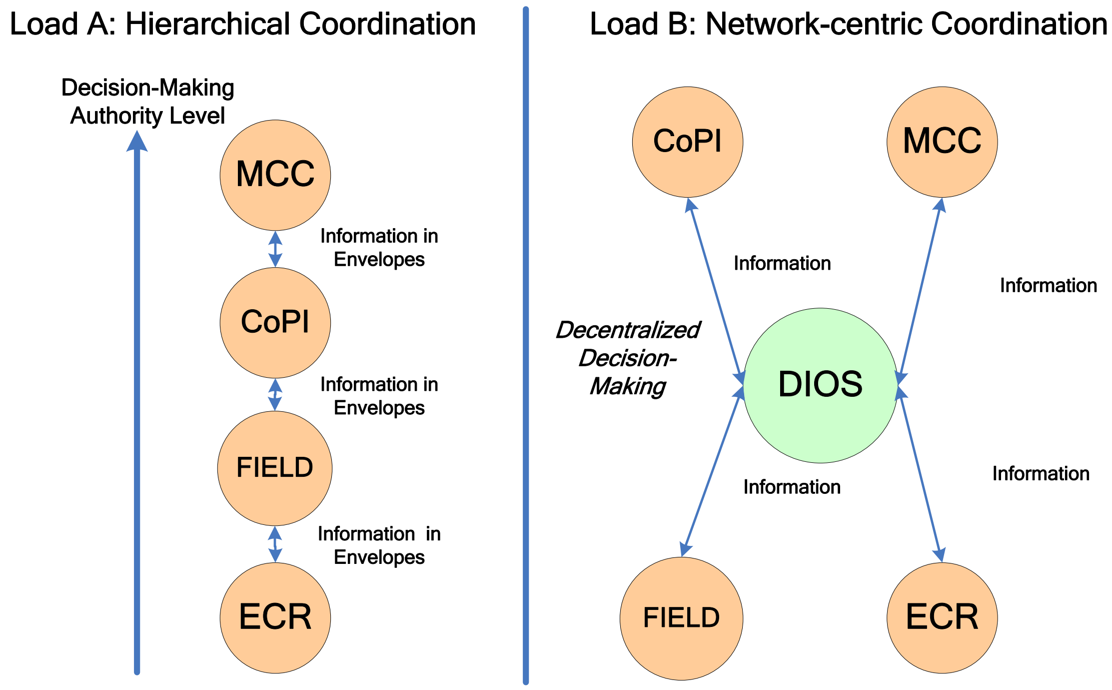



**Figure 37: Difference between Load A and B - Information Management Coordination**

The table below gives an overview of differences between load A and B. A major difference between load A and B is that in load B several network-centric principles are implemented in the process structure. The following principles are put into practice in load B:

1. *Decentralized decision-making:* all players are allowed to make decisions; a formal authority structure is not fully pertained.
2. *Flattened hierarchy structure:* in this situation, there is no process in which subordinates have to specifically inform their higher commanders. This is now done automatically as everyone is updated with the same information.
3. *Shared situational awareness:* this is actually more a result of the rule that everyone needs to post all information they receive so that everyone is updated with this information.

It is important that these network-centric principles are implemented in load B so that an honest comparison can be made between the results of load A and load B with respect to the insurance of IQ and SQ dimensions. Thus, the effect of a network-centric CIMS on IQ and SQ dimensions can only be measured if the processes are also structured in a network-centric fashion. The table below shows several differences between Load A and B.

Table 15: Master of Disaster Game - Differences between Load A and B

| Variable | Load A | Load B |
|---|---|---|
| **Type of SITRAPS** | Team SITRAP<br>Column SITRAP | Network SITRAP: everyone can contribute to the same SITRAP |
| **SITRAP-form** | Team SITRAP in MS WORD<br>Column SITRAP on paper forms | Network SITRAP in DIOS |
| **Information Synchronization** | Asynchronous information sharing thru paper SITRAPS | Synchronous information sharing using DIOS: everyone can see the same information immediately |
| **Facilitator Roles** | Mailman<br>Journalist | DIOS Assistants (4x)<br>Journalist |
| **Rating of Information** | None | Available in DIOS |
| **Memory of Information** | Fragmented in paper SITRAPS | Aggregated in DIOS |
| **Location maps** | On paper (large map on table) | Projection in DIOS |
| **Information supply** | Through the Mailbox, on paper | Real Time supply in DIOS |
| **Location of disaster** | Business Complex | University |
| **Information Manager tasks** | Generate paper SITRAP and send to other teams via MS WORD and Gmail | Generate SITRAP in DIOS<br>Prioritize and handle info request directly using DIOS<br>Communicate and rate the reliability of the information in DIOS |

### 8.2.6 Gaming Simulation – Situation

The situation stands for all variables that surround the gaming simulation session, but are not part of the design (Meijer, 2009). One can think of the venue, the participants and the space in which the gaming simulation is hosted. There are two situations defined for this gaming simulation: Situation 1 (Pre-test) and Situation 2 (real gaming simulation session).

Table 16: Master of Disaster Game - Situational Variables

| Situational variable | Pretest | Situation 2 |
|---|---|---|
| **Date** | Tuesday 16 February 2010 | Friday 12 March 2010 |
| **Duration** | 13:30-16:00 | 13:30 – 16:30 |
| **Location** | TBM Room I and J, Faculty TPM, Delft University of Technology | Gaming Suite, Police Academy, Ossendrecht |
| **Participants** | spm4341 Master Students | Policy Academy Students |
| **Implications for participants** | Exclusion of examination | Acquaintance with DIOS |
| **Game facilitators** | - Marijn Janssen<br>- Nitesh Bharosa<br>- Satiesh Bajnath<br>- Jalal Bani Hashemi<br>- Andreas Boon<br>- Soebhaash Dihal<br>- Victor den Bak | - Satiesh Bajnath<br>- Nitesh Bharosa<br>- Marijn Janssen<br>- Sebastiaan Meijer<br>- Anne Fleur van Veenstra<br>- Victor den Bak<br>- Navin Mangre<br>- Ryan Mangre |

The flow diagram below indicates how a Master of Disaster Game looks like. Each specific part of the flow diagram is discussed in the next sections.

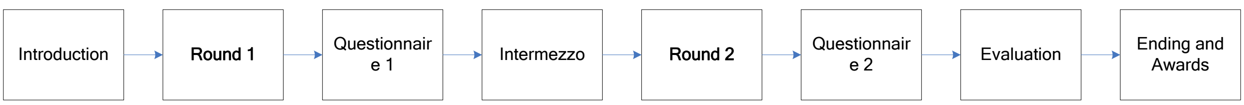



Figure 38: Master of Disaster Game - Flow Diagram of Situation

**Program**

The agenda of the gaming simulation consist of the following items:

13:30-13:45 Introduction by dr.ir. Marijn Janssen and ir. N. Bharosa
13:45-14:30 Round 1
14:30-14:45 Evaluation of round 1
14:45-15:00 Intermezzo
15:00-15:45 Round 2
15:45-16:00 Evaluation of round 2
16:00-16:30 Ending and awards

**Introduction**

In the introduction the facilitators will inform the participants how the game simulation will take place. All role descriptions will be given and participants have time to read through it (approximately 15 minutes). After the introduction the participants are requested to take their seat in the team they are assigned to.

**Round 1: Disaster information management in the current situation**

The game simulation starts with simulating a disaster situation in Rampendam and it is up to the participants to manage this disaster effectively and efficiently. The goal of the participants is to minimize the number of casualties and physical damage. In order to do so, participants need to collect and share information for instance about the situation on the field, the hazards and resources they have available. The participants will use Microsoft Word to generate situational reports of the scene. Also, some participants have a Gmail account that can be used for communication purposes.

**Questionnaire 1**

After round 1, the participants are asked to fill in a short questionnaire on the experience they had with resolving the disaster. Questions are asked with respect to Information Quality, System Quality, decision-making and perception of information exchange. After filling out this questionnaire, the participants have a short break of 15 minutes.

**Intermezzo**

In this intermezzo, the facilitators will reflect on the process of round 1 and what the participants achieved. The facilitators will also introduce DIOS shortly and they will tell the participants what will happen in round 2.

**Round 2: Disaster with DIOS**

In round 2, a slightly different game scenario is played by the participants when it comes to different events and the use of a different information system for generating situational reports. DIOS attempts to aid the participants in resolving the disaster more effectively and efficiently than in round 1 by assisting in a better information management during crisis situations.

**Questionnaire 2**

Subsequent to round 2, the participants have to fill in another short questionnaire on their experience in resolving the disaster. Again, the same questions are asked to the participants plus some extra questions on the information they received from the DIOS system.

**Evaluation**

The session will be concluded with an evaluation of the results of round 2. The facilitators will briefly discuss the process of round 2 and afterwards the facilitators will thank the players for their time and cooperation.

**Ending and Awards**

At the end of the session, all facilitators will thank the participants for their cooperation and a small award ceremony is held for the best participant of each team. The next section will move on with the design of the surveys used in the sessions. As written above, there are two questionnaires used in each session: one after each round.

## 8.3 Survey Design

In the previous section, the complete gaming simulation design is addressed. As part of the gaming simulation sessions, two questionnaires are needed for each session to assess and measure the opinion of all participants on the propositions of DIOS. The first questionnaire will be distributed after playing the first round (Load A). The second questionnaire is logically distributed after playing the second round (Load B). The questionnaires are identical, except for a few extra questions in the second questionnaire.

Conducting a survey has some important advantages over other data gathering techniques (Walonick 2004):

1. Questionnaires are very cost effective compared to face-to-face interviews.
2. Questionnaires are easy to analyze. It is easy to add data and perform data analysis using well-known software packages (e.g. SPSS, Excel).
3. Questionnaires are often familiar to the audience.

However, there are also some drawbacks to conducting a survey for gathering data (Walonick 2004):

1. Questionnaires are structured so they can be suggestive. Thus, there is little flexibility for the respondent to reply to his own way of structuring.
2. Physical expressions cannot be captured in a questionnaire, while 90% of all communication in this manner.

Since questionnaires are cost-effective and easy to analyze, the choice was made for conducting a survey instead of personal interviews during the gaming simulation session. On top of that, it is simply too time-consuming and intensive to conduct a personal interview with each participant. As previously mentioned, the two questionnaires in research are identical, with a few additional parts for questionnaire 2. The table below shows the components of both questionnaire 1 and 2.

Table 17: Parts of the Survey

| Part | Description | Q1 | Q2 |
|---|---|---|---|
| **A. General Questions** | Demographics of the respondents | X | |
| **B. Evaluation of the Game Round** | 8-10 questions concerning the gaming simulation itself | X | X |
| **C. Evaluation of Information Quality** | 20 questions on the assessment of information quality | X | X |
| **D. Evaluation of System Quality** | 19 questions on the assessment of system quality | X | X |
| **E. Evaluation of system functionalities** | 12 questions on the assessment of the propositions of DIOS | | X |
| **F. Suggestions and Comments** | Open fields for comments | X | X |

While designing the survey, an important trade-off between the length of the survey and the number of dimensions that we want to test was made. To give the participants not a lengthy survey, it was decided not to take every relevant IQ and SQ dimension into account. This is obviously a disadvantage for the research, the trade-off was however important enough because the session would then end up to be less fun for the participants. Furthermore, several system functionalities are evaluated in part E of the survey. We however did not elaborate on the results of part E as it goes beyond the demarcations for this research.

In part B, C, D and E, a 7-point Likert scale was used to measure the opinion of the participants with respect to the formulated statements. A 7-point scale was chosen for this study because this type of scale makes sure that the data can be considered of interval measurement level, despite the sometimes difficult interpretation of the scale itself. The scale looks as follows:

1. Strongly Disagree
2. Disagree
3. Slightly Disagree
4. Neutral
5. Slightly Agree
6. Agree
7. Strongly Agree

In this survey, several statements are formulated for reflecting the use of multiple indicators for 1 dimension. For instance, the dimension IQ Timeliness is measured three times using 3 different statements. In addition, a series of statements are reverse coded in this survey. This means that the statement has an inverse load compared with positively worded statements. An example of a positive statement and a reverse coded statement are given below:

1. The information I received was up-to-date (positive statement).
2. The information I received was outdated (reverse coded statement).

Some authors argue that reverse coding may have a negative impact on the reliability of scales (Weems and Onwuegbuzie 2001). However, this impact is offset by performing reliability analysis. Moreover, with reverse coding the attitude of a respondent is measured more adequately because only positive statements may constitute a bias (De Vaus 2002). Both questionnaires can be found back in Appendix E: SPSS Codebook.

## 8.4 Conclusion

This chapter discussed how DIOS 2.0 could be evaluated on relevant IQ and SQ dimensions. To this end, we first started to develop an experimental design. After considering the options and limitations we had for this research, we eventually opted for a particular type of quasi-experiment, namely a single group pretest posttest quasi experiment. In this type of quasi-experiment, 1 group of participants had to fill in two questionnaires: 1 questionnaire after they used a hierarchical approach for information management and 1 questionnaire after they used a network-centric approach, including DIOS, for information management.

This experimental design was reflected in a gaming simulation design where we simulated a crisis situation in two rounds. As part of this gaming simulation, several elements had to be designed: roles, rules, loads and procedures. In the first round, participants needed to manage information using a hierarchical approach for information management. Then they had to complete a questionnaire in which they assessed several IQ and SQ dimensions. Subsequently, the participants had to utilize a network-centric approach in managing information in round 2. For a large part, they evaluated DIOS 2.0 in this round. After round 2, a questionnaire was given again where participants had to assess several IQ and SQ dimensions.

The results of both surveys (round 1: hierarchical approach, and round 2: network-centric approach) will be discussed in the next chapter. There, we will also address the session experiences of all participants, because these experiences might explain the results for a substantial part.

# 9 Results

In this chapter, the results of the quasi-experiment held at the Police Academy of the Netherlands are discussed. We will look at the results derived from the questionnaires we distributed after playing round 1 and 2 of the gaming simulation. As part of this chapter, the data preparation of the survey results will be addressed first. Second, the results on IQ and SQ dimensions for round 1 and 2 are discussed and statistically compared. In the final section, we will discuss the results, including the experiences of all participants during the gaming simulation session. In this chapter, we finally are able to answer the last sub-question of this research:

*What is the effect of the network-centric CIMS design in ensuring IQ and SQ dimensions?*

## 9.1 Data Preparation

Before all the results of the gaming simulation session at the Police Academy can be analyzed, the data must first be prepared. The next subsection will elaborate on the data preparation. Afterwards, the results of the gaming simulation session are addressed. The data presented in this chapter is retrieved from the two surveys that were distributed during the gaming simulation session. The first step of the preparing the data is to create a codebook. The codebook shows how questions from the surveys are translated into variables, what values these variables can have, which value labels are assigned and what measurement level each variable has. The complete codebook can be found in Appendix E: SPSS Codebook. For analyzing the data derived from the experiment, two software packages were used:

1. *SPSS Statistics 17.0:* this data-analysis tool can be used for performing several statistical analyses. In this research, the reliability analysis and the Wilcoxon Signed Rank Test were performed with this software tool.
2. *MS Office Excel 2007:* this application ships as part of the MS Office 2007 suite. Excel 2007 is used for generating descriptive tables, histograms and pie-charts.

Since 3 different statements were given per IQ and SQ dimension, these statements needed to be translated back to dimensions. This is done by performing a reliability analysis, which checks whether statements that initially belong together still measure the same. The tables below show the results of reliability analysis for dimensions of both round 1 and 2.

**Table 18: Results Reliability Analysis - Round 1**

| IQ/SQ Dimension | IQ/SQ Statements | Cronbach's Alpha |
|---|---|---|
| **IQ_TIMELINESS** | R1_IQ_TIMELINESS_1<br>R1_IQ_TIMELINESS_3_REC | .804 |
| **IQ_CORRECTNESS** | R1_IQ_CORRECTNESS_2_REC<br>R1_IQ_CORRECTNESS_3_REC | .534 |
| **IQ_COMPLETENESS** | R1_IQ_COMPLETENESS_1<br>R1_IQ_COMPLETENESS_2_REC | .682 |
| **IQ_OVERLOAD** | Scale could not be constructed | Negative alpha |
| **IQ_RELEVANCY** | R1_IQ_RELEVANCY_1<br>R1_IQ_RELEVANCY_2_REC<br>R1_IQ_RELEVANCY_3_REC | .766 |
| **IQ_CONSISTENCY** | R1_IQ_CONSISTENCY_2_REC<br>R1_IQ_CONSISTENCY_3_REC | .506 |
| **SQ_RESPONSETIME** | Scale could not be constructed | .222 |
| **SQ_ACCESSIBILITY** | R1_SQ_ACCESSIBILITY_1<br>R1_SQ_ACCESSIBILITY_3 | .613 |
| **SQ_SATISFACTION** | R1_SQ_SATISFACTION_1<br>R1_SQ_SATISFACTION_2 | .859 |

Table 19: Results Reliability Analysis - Round 2

| IQ/SQ Dimension | IQ/SQ Statements | Cronbach's Alpha |
|---|---|---|
| IQ_TIMELINESS | R2_IQ_TIMELINESS_2_REC<br>R2_IQ_TIMELINESS_3_REC | .713 |
| IQ_CORRECTNESS | R2_IQ_CORRECTNESS_2_REC<br>R2_IQ_CORRECTNESS_3_REC | .637 |
| IQ_COMPLETENESS | R2_IQ_COMPLETENESS_2_REC<br>R2_IQ_COMPLETENESS_3_REC | .657 |
| IQ_OVERLOAD | Scale could not be constructed | .208 |
| IQ_RELEVANCY | R2_IQ_RELEVANCY_2_REC<br>R2_IQ_RELEVANCY_3_REC | .726 |
| IQ_CONSISTENCY | R2_IQ_CONSISTENCY_1<br>R2_IQ_CONSISTENCY_2_REC<br>R2_IQ_CONSISTENCY_3_REC | .514 |
| SQ_RESPONSETIME | R2_SQ_RESPONSETIME_1<br>R2_SQ_RESPONSETIME_2_REC | .730 |
| SQ_ACCESSIBILITY | R2_SQ_ACCESSIBILITY_2<br>R2_SQ_ACCESSIBILITY_3 | .815 |
| SQ_SATISFACTION | R2_SQ_SATISFACTION_1<br>R2_SQ_SATISFACTION_2 | .599 |

As can be seen above in the tables, a value for Cronbach's Alpha is given for each scale. Cronbach's Alpha is a measure for the internal reliability of a scale. There are several rules of thumb available for the Cronbach's Alpha coefficient, > 0.9 is considered: Excellent; > 0.8: Good; > 0.7: Acceptable; > 0.6: Questionable; > 0.5: Meager, and < 0.5: Unacceptable (George and Mallery 2003). These rules will be used to interpret the reliability scores above. The scores marked red above are definitely unacceptable. The other scales are in the range of .506 - .859. This range of values is not unacceptable and therefore, these scales are used for showing the results in the next paragraph. We can however *not* use the following scales for the results:

1. Round 1: IQ_OVERLOAD.
2. Round 1: SQ_RESPONSETIME.
3. Round 2: IQ_OVERLOAD.

## 9.2 Gaming Simulation Results

The subsections below will discuss the results of the gaming simulation session at the Police Academy. These results are based on scales that were defined in the previous section. Besides the scales for IQ and SQ dimensions, the propositions are also addressed. However, first some demographic results of the respondents are shown.

### 9.2.1 Results – Demographics

In Part A of questionnaire 1, some questions were asked on background information of respondents. Participants were asked which organization they worked for, how long they worked there and how often they have encountered a serious crisis situation (GRIP 1 or higher). In this quasi-experiment, we had a sample size of 22 respondents. The graphs below show some figures on demographic data of the respondents.

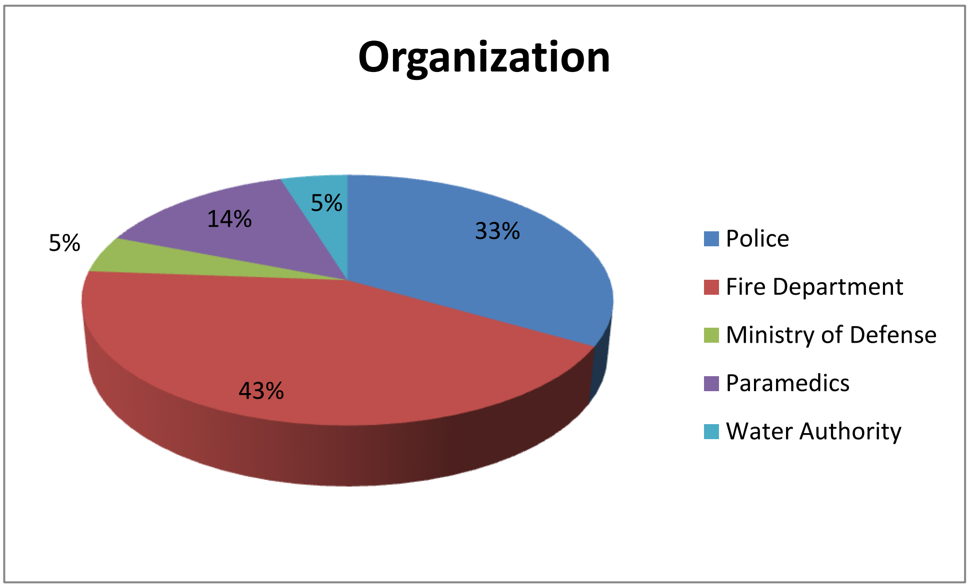



Figure 39: Demographics – Organization (N=22)

What we can conclude with respect to the sample size is that we had a heterogeneous group of relief workers that participated in this quasi-experiment. An interesting notion is that 43% of all relief workers, worked at the fire department, while the session was held at the Police Academy. The heterogeneity in relief workers makes the results regarding the IQ and SQ dimensions even more interesting as this group of relief workers is a fair representation of relief workers that are present at a crisis.

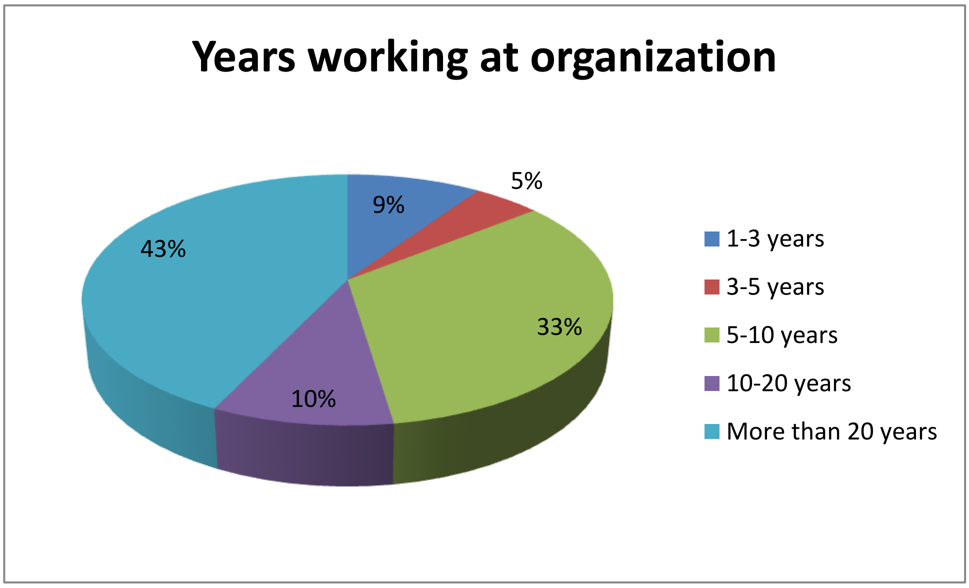



Figure 40: Demographics - Years working at Organization (N=22)

The figure above shows that our sample of relief workers has a lot of experience in working at their organization. We cannot immediately state that they also have a lot of experience with crisis situations, we can however say that this sample consists more of relatively experienced relief workers, who are probably already much familiarized with the way of working in their own organization. This may hamper collaboration between organizations during crisis response.

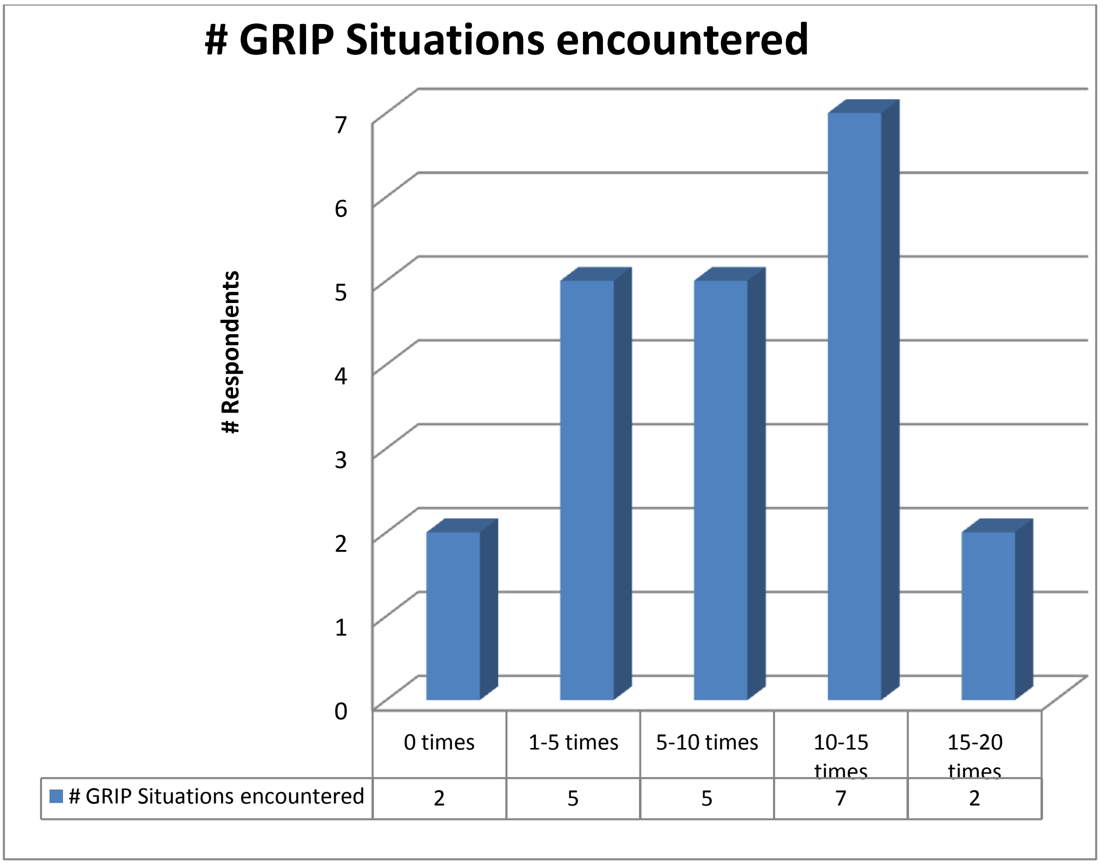



Figure 41: Demographics - # GRIP Situations encountered (N=22)

Figure 41 above shows that most participants already encountered a GRIP situation of GRIP 1 or higher. This means that most relief workers already experienced a multi-disciplinary crisis situation. Consequently, they can reflect on the usefulness of this gaming simulation for a wide range of scenarios. In the next sections, we will elaborate on the results with respect to ensuring IQ and SQ dimensions in round 1 and 2.

### 9.2.2 Results – IQ Dimensions

In section 9.1, data preparation was discussed so that the results of the IQ dimensions could be displayed. In this section, the results of IQ dimensions of both round 1 and 2 are portrayed. Afterwards, it is determined if there is actually a significant difference between the Round 1 and Round 2 for each IQ dimension. This is done by performing the non-parametric Wilcoxon-test in section 9.2.4. As there were only 22 respondents in total in this experiment, a parametric test (like the paired samples t-test) had to be rejected as the normality requirement was not met. The tables and graphs below show the scores on the IQ dimensions for round 1 and 2.

Table 20: Results - IQ Dimensions - Round 1 (N=22)

| Round 1 | Timeliness | Correctness | Completeness | Relevancy | Consistency |
|---|---|---|---|---|---|
| Mean | 3.80 | 4.33 | 3.46 | 3.71 | 4.63 |
| Standard Deviation | 1.53 | 0.94 | 1.23 | 1.44 | 1.31 |

Table 21: Results - IQ Dimensions - Round 2 (N=22)

| Round 2 | Timeliness | Correctness | Completeness | Relevancy | Consistency |
|---|---|---|---|---|---|
| Mean | 4.29 | 5.00 | 3.71 | 3.78 | 4.00 |
| Standard Deviation | 1.44 | 1.19 | 1.20 | 1.35 | 0.89 |

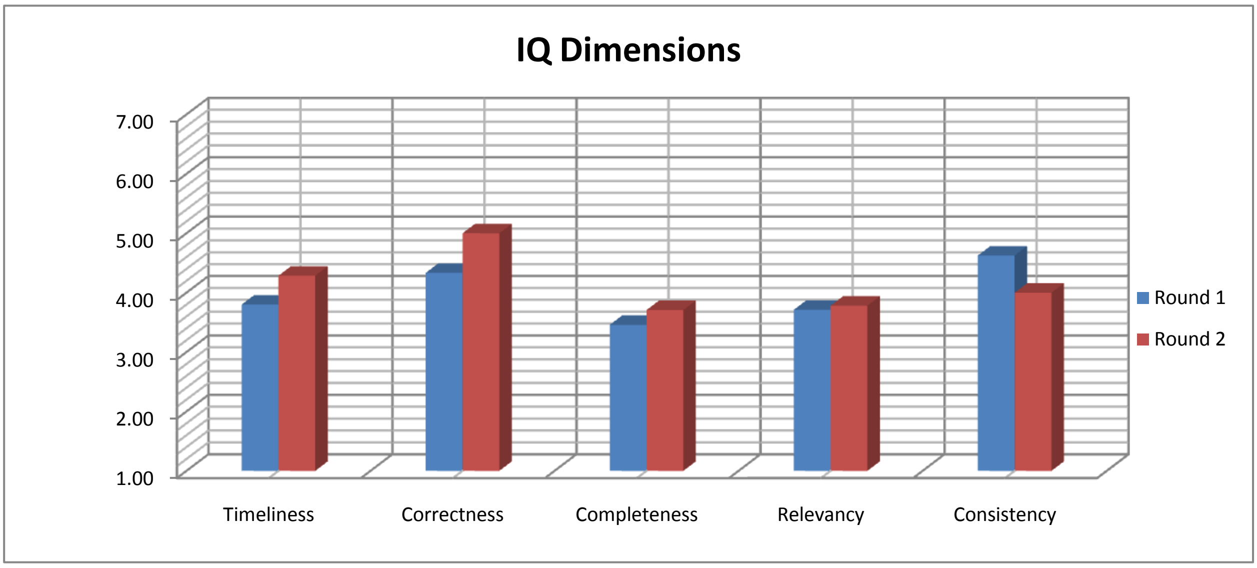



Figure 42: Results – IQ Dimensions (N=22)

As we look at the figure above, we can see that in round 2 higher scores are found for each IQ dimension, except for IQ-Consistency. Furthermore, we do not see high scores in general. Now, an important step in answering the last sub-question is to see whether the differences between round 1 and 2 on each IQ dimension are statistically significant. This is done in paragraph 9.2.4. First, we will go more into detail on the results with respect to the SQ dimensions.

### 9.2.3 Results – SQ Dimensions

Besides several IQ dimensions, SQ dimensions were also measured in this study. However, since only two SQ scales were valid in both round 1 and 2 (Accessibility and Satisfaction), the results are rather limited in this section. Again, tables and a graph are displayed to visualize the gap between round 1 and 2.

Table 22: Results - SQ Dimensions - Round 1 (N=22)

| Round 1 | Accessibility | Satisfaction | Response Time |
|---|---|---|---|
| Mean | 2.47 | 2.53 | - |
| Standard Deviation | 1.03 | 1.40 | - |

Table 23: Results - SQ Dimensions - Round 2 (N=22)

| Round 2 | Accessibility | Satisfaction | Response Time |
|---|---|---|---|
| Mean | 4.53 | 3.40 | 3.75 |
| Standard Deviation | 1.33 | 1.35 | 1.61 |


Figure 43: Results – SQ Dimensions (N=22)

In the next section the discrepancy between round 1 and 2 on both IQ and SQ dimensions is significantly tested using the Wilcoxon Signed Rank Test. This test can tell us whether the effect DIOS has generated really is a significant effect with respect to each dimension.

### 9.2.4 Results – Wilcoxon Signed Rank Test

The Wilcoxon Signed Rank Test is a non-parametric statistical test in which the median difference of a pair of variables is tested (Crichton 2000). As Wilcoxon states in his article, we can use ranking methods to 'obtain a rapid approximate idea of the significance of the differences in experiments of this kind' (Wilcoxon 1945).

The Wilcoxon-test has a parametric alternative, namely the Student-t paired samples test. However, this parametric student-t test requires that the data follows a normal distribution (Hair, Anderson et al. 1995). This is not the case in this dataset, and because of the low sample size (N=22) we cannot approximate a normal distribution by using the Central Limit Theorem (to do so, a minimum of N = 30 is necessary). Therefore, a non-parametric alternative had to be chosen for this experiment.

In the table below, the results of the Wilcoxon-test are shown: for each pair of dimensions (round 1 and round 2), a significance level is given, telling us whether the mean in round 1 significantly differs from the mean in round 2. A listwise deletion procedure was pertained to cope with missing values in the dataset. In case the significance level is <=0.05, the difference between round 1 and 2 is significant. This is the case for four dimensions:

1. IQ – Timeliness.
2. IQ – Correctness.
3. IQ – Consistency.
4. SQ – Accessibility.

Table 24: Results - Wilcoxon Signed Rank Test

| Pairs | IQ - Timeliness | IQ - Correctness | IQ - Completeness | IQ - Relevancy | IQ - Consistency | SQ - Accessibility | SQ - Satisfaction |
|---|---|---|---|---|---|---|---|
| Z | -1.017[a] | -1.805[a] | -.966[a] | -.543[b] | -1.962[b] | -3.268[a] | -1.716[a] |
| P-value | **.009** | **.041** | .334 | .587 | **.050** | **.001** | .086 |

The other pairs do not have a significant difference; this tells us that the difference might be based on coincidence. This however does not mean that there is no observable difference for these dimensions. The discussion of results in the next chapter will elaborate on these findings.
Concluding this section, we can now state that there is a positive significant difference between round 1 (hierarchical approach) and round 2 (network-centric approach) on the dimensions: IQ-Timeliness, IQ-Correctness and SQ-Accessibility. We can also conclude that there is a negative significant difference on the IQ-Consistency dimension.

In other words, to answer the last sub-question of this research, the network-centric CIMS utilized in round 2 has a positive effect on the dimensions IQ-Timeliness (3.80 → 4.29), IQ-Correctness (4.33 → 5.00) and SQ-Accessibility (2.47 → 4.52) compared to using a hierarchical approach. The network-centric CIMS has however a significant negative effect on the dimension IQ-Consistency (4.63 → 4.00).

## 9.3 Discussion of Results

The results derived from both questionnaires will be discussed in this section. The most important results for this thesis are that we have seen a positive significant improvement on the scores of IQ-Timeliness, IQ-Correctness and SQ-Accessibility when DIOS was used. Interestingly, the data also reveals that the dimensions IQ-Overload (this dimension had however no statistically constructed scale; we observed the values of the statements separately) and IQ-Consistency deteriorated in particular. With respect to information overload, it was already predicted in literature that this would be a major issue in using a network-centric CIMS (e.g. Fewell and Hazen 2003; Stanovich 2006). One possible explanation for the deterioration of IQ-Consistency is that in a network-centric CIMS, relatively more information becomes available for everyone, which may lead to the discovery of more inconsistent information on the average.

### 9.3.1 Session Experiences

Apart from the results on IQ and SQ dimensions derived from the questionnaires, we also discovered some interesting aspects with respect to the attitude and experiences of the relief workers during the session. The course of the gaming simulation was as follows. When the relief workers played the first round, we could notice that some players already had a negative stance towards the gaming simulation session as their expectations were not fully met. After the first round, several players demanded that the scenario in the second round had to change as they would then feel more identified in the scenario. We then hosted the second round in which we played the slightly adjusted scenario. In the evaluation session afterwards, the discussion with the participants was of high importance as it revealed several insights with respect to what players think of using a network-centric CIMS.

We observed that several relief workers had a somewhat negative stance towards *using a network-centric CIMS*, even before the gaming simulation session. This may be the result of the active imposition and promotion of network-centric systems by the Ministry of Internal Affairs of the Netherlands. A relief worker clarified this problem as follows: *'This is an attempt to incorporate a network-centric information system in a hierarchical process structure. This leads to a mismatch.'* A firefighter also stated: *'We know what a network-centric approach stands for. But it is not a complete solution for information problems !'*

Maybe because of this disinclined look towards network-centric systems, a few relief workers were initially of the opinion that we were promoting our network-centric CIMS as well. As such, this also means that there is a danger that relief workers are not fully willing to accept a network-centric system because it requires major changes in their way of working.

Furthermore, as we conducted the gaming simulation with a heterogeneous group of relief workers (see section 9.2.1), a lot of relief workers also were of opinion that they experienced difficulties in collaborating effectively. Heterogeneity of relief agencies was already pointed out as a potential problem for effective crisis management. The use of a network-centric CIMS caused some confusion and misalignment on which tasks are the most important and who needs to take responsibility for which action. If we relate this problem to organizational structures as defined by Mintzberg, we see that hierarchical organizations are efficient when they have to perform routine tasks. A hierarchical organization is then typed as a 'machine bureaucracy' in which every subordinate has to follow up orders from his/her supervisor and they have to work according to standard operating procedures (Mintzberg 1980). As each relief agency has its own authority structure and procedures which they follow during a disaster, information sharing is made more difficult. There are certainly several procedures drawn up for all relief agencies on what to do during a disaster, yet because disasters are to a large extent unpredictable, it becomes more difficult to share information in a structured fashion when even these procedures are not applicable.

Another point in this matter was that we were not able to completely satisfy the expectations of all participants. Some relief workers expected a learning workshop on network-centric information systems instead of only a gaming-simulation after which they could tell their experiences. We also found that relief workers experienced a mismatch between the network-centric CIMS and the hierarchical process structure they are acquainted with. Based on these results, we can conclude that the emergency response community in the Netherlands is not fully prepared to work with a network-centric CIMS as of yet.

The experiences the participants had during the gaming simulation session are of great importance for the results from the surveys. The fact that relief workers were not very enthusiastic during the session can also have influenced the scores of the questionnaires. The most important aspect in this sense was that among a number of relief workers, a negative stance was evident against network-centric systems. Until this attitude towards network-centric CIMS changes, the acceptance of such a system might be impaired. This negative stance was partly caused by a mismatch in expectations, a mismatch in their normal way of working and the processes simulated in the game and finally the difficult collaboration between different heterogeneous relief workers. Consequently, if a relief agency were to implement a network-centric CIMS, acceptance would be an important factor in the implementation.

Of course, the session experiences of participants had their impact on the results. This was perhaps seen in the relatively moderate scores on the IQ and SQ dimensions. However, the fact remains that this study can also use the session experiences as an important result, alongside the results gotten from the surveys. It is very important to know how users stand towards accepting a network-centric CIMS, apart from the fact whether a network-centric CIMS itself contributes to a high IQ and SQ. Consequently, the results regarding the session experiences are also taken into account in answering the main question of this thesis.

In the final chapter, the conclusions of this study formulated based on the results of this study. Thus seeks an appropriate answer to the research question of this thesis. In addition, it examines the limitations of this study and will be a number of recommendations towards practitioners and academics.

# 10 Conclusions and Recommendations

In this final chapter, we join the answers of all sub-questions to find an answer to the main research question of this thesis. The main research question was formulated as follows:

*To what extent does a network-centric CIMS design ensure IQ and SQ dimensions for relief workers during crisis situations?*

We will start with formulating the conclusions of this research in the first section. After drawing the conclusions in the first section, we then elaborate on the limitations of this research. Finally, we will pose several recommendations towards practitioners and academics with respect to further research in this field.

## 10.1 Conclusions

To answer the main question of this research, we first began to explore the concepts of IQ and SQ. We did research on what dimensions are used to define IQ and SQ dimensions and which dimensions are in fact relevant in crisis situations. Immediately, a remark was made as a generic set of IQ and SQ dimensions is difficult to formulate.

Subsequently, the research focused more on what a ‘network-centric 'system stands for. The literature review showed us a number of findings from the military paradigm with respect to a network-centric system. Finally, we were able to derive a number of important network-centric design principles that would be leading for the CIMS design.

After including some desk research on state-of-the-art CIMS solutions, we started the actual design of the network-centric CIMS. At the beginning, we decided to call the system DIOS. It was an iterative process in which requirements and principles have been continuously redefined. Ultimately, the process resulted in a network-centric CIMS design consisting of a functional and technical design.

However, to answer the main question of this research, it was necessary to evaluate the network-centric system in a way having IQ and SQ dimensions as performance criteria. Eventually, the choice was made to design a gaming simulation session in which a crisis situation was simulated. A gaming simulation was deliberately chosen as method as it can be used to study the behavior of participants. A sample of 22 relief workers joined as participants and they had to play two rounds: round 1 used a conventional (hierarchical) approach for information management, and round 2 used a network-centric approach for information management. This network-centric approach consisted of using a network-centric CIMS design and adjustments to the process structure of the second round of the game. After each round, relief workers had to indicate to which extent the CIMS actually ensured IQ and SQ dimensions.

The results of this session were statistically analyzed and the following can be concluded: using a 7-point scale, the data analysis on the collected questionnaire data (N=22) revealed that DIOS, as a network-centric CIMS design, can ensure the following IQ and SQ dimensions for a crisis situation (the scores for round 1 and round 2 are given in brackets): the data indicates significant improvements on the *correctness of information* (R1: 4.33; R2: 5.00), the *timeliness of information* (R1: 3.80; R2: 4.29) and the *accessibility of the information* system (R1: 2.57; R2: 4.53) during a crisis situation.

Yet, our dataset did not show statistically significant improvements on other IQ or SQ dimensions when DIOS was used. Interestingly, the data reveals that the dimensions *IQ-Overload* and *IQ-Consistency* deteriorated in particular. With respect to information overload, it was already predicted in literature that this would be a major issue in using a network-centric CIMS (e.g. Fewell and Hazen 2003; Stanovich 2006). One explanation for the low score on IQ-Consistency is that in a network-centric CIMS, relatively more information becomes available for everyone, which may lead to the discovery of more inconsistent information on the average.

Apart from the results on IQ and SQ dimensions, the research revealed some interesting findings with respect to the attitude and experiences of the relief workers during the session. We observed that several relief workers had a somewhat negative stance towards using a network-centric CIMS, even before the gaming simulation session. This may be the result of the active imposition and promotion of network-centric systems by the Ministry of Internal Affairs of the Netherlands. This also means that there is a danger that relief workers are not fully willing to accept a network-centric system because it requires major changes in their way of working. Furthermore, as we conducted the gaming simulation with a heterogeneous group of relief workers, a lot of relief workers also were of opinion that they experienced difficulties in collaborating effectively. The use of a network-centric CIMS caused some confusion and misalignment on which tasks are the most important and who needs to take responsibility for which action. Another point in this matter was that we were not able to completely satisfy the expectations of all participants. Some relief workers expected a learning workshop instead of only a gaming-simulation after which they could tell their experiences.

We also found that relief workers experienced a mismatch between the network-centric CIMS and the hierarchical process structure they are acquainted with. Based on these results, we can conclude that the crisis response community in the Netherlands is not fully prepared to work with a network-centric CIMS as of yet.

If we consider the results of this research, we can conclude the following with respect to the main question: a network-centric CIMS has the advantages of more timely information, more correct information and a more accessible information system than utilizing a hierarchical CIMS. Yet, a network-centric CIMS is not likely to solve all IQ and SQ problems in a crisis situation; information overload and inconsistency are for instance worsened. Moreover, in the Netherlands we have seen that several relief workers already have a negative stance towards using a network-centric CIMS as this requires major changes in their current way of working. We also see that a hierarchical approach also has its disadvantages (e.g. inefficient information sharing and inflexible systems). We can therefore conclude that the solution for ensuring IQ and SQ dimensions in crisis situations may lie in combining a hierarchical and network-centric approach for designing a CIMS. Further research needs to investigate CIMS designs that leverage both the advantages of a network-centric approach (e.g. timely and correct information) and of a hierarchical approach (e.g. alignment with the process structure and prevalence of the authority structure).

This study contributes to previous research in the field of crisis management because this research provides more clarity on the use of network-centric information systems in crisis situations to ensure IQ and SQ dimensions. Based on this research, we may conclude that the solution may lie in combining both a hierarchical and a network-centric approach for designing a CIMS. A full network-centric CIMS is not likely to be completely successful in crisis response, at least in the Netherlands. Because little research was done on using network-centric CIMS, the conclusions of this study are important for the further development of CIMS for crisis situations. In addition, this research contributes to the critical evaluation of network-centric CIMS in the Netherlands by giving users (i.e. relief workers) the opportunity to state their own opinion on possible future usage of a network-centric CIMS.

## 10.2 Limitations of this research

Apart from the conclusions drawn in the previous section, we will try to reflect on the limitations of this research in this section:

- An important limitation of this research is that the gaming simulation in this research was only tested once. Several authors recommend testing a gaming simulation around 10 times to ensure more robustness and to test the structural validity (Duke and Geurts 2004). Also, this gives facilitators more experience in hosting a session, which reduces the risk of this element being a limitation in the simulation.

- With respect to the chosen experimental design (pre-test post-test quasi-experiment), the research was limited to only one group of participants, having no control group and no random assignment of participants. This leads to a less powerful experiment in terms of internal validity and reliability as a quasi-experiment is more difficult to use for developing theory because of its non-random character.
- Furthermore, we only analyzed the crisis management processes as implemented in the Netherlands. As crisis management may be carried out differently in other countries, this research can be of more importance in the Netherlands than in other countries.
- Another limitation is that our research only had a sample size of 22 relief workers in total. Because we wanted to perform a quantitative research initially, the results derived from the questionnaires do not have a lot of statistical power as a non-parametric test was utilized.
- Also, with respect to the design of DIOS, we were only limited to the insights derived from network-centric warfare and a number of state-of-the-art CIMS solutions. As there are a lot of other systems available that can be used effectively for CIMS (e.g. GIS-systems, location-based systems, GPS trackers for vehicles etc.), this research was only carried out with a limited set of insights drawn from other systems.

Even though we only investigated a small part of improving crisis management as a whole, we still think that this research contributes significantly to current research on using network-centric systems in crisis management. Therefore, we pose several recommendations based on this research towards practitioners, such as relief agencies and policy makers in the Netherlands, and academics studying the field of information management in crisis situations.

## 10.3 Recommendations for further research

Having conducted this research, we now formulate 4 recommendations for further research in this area. We have split the recommendations into those for practitioners (e.g. relief agencies, policy workers and policy advisors) and for academics that examine the field of information management in crisis situations.

The following recommendations are meant for the practitioners in the Netherlands:

1. We recommend the Ministry of Internal Affairs of the Netherlands involve relief workers actively in developing and pre-testing a CIMS. Also, the ministry should take criticism and experiences of relief workers more into account by hosting feedback sessions in which the network-centric approach towards crisis management is discussed and evaluated. The Ministry must take into account that for implementing a network-centric CIMS that is effective, one needs the acceptance of all users.
2. We also recommend the Ministry of Internal Affairs involve all relief agencies in developing a CIMS that is interoperable. As these agencies are heterogeneous with respect to their information systems, procedures and authority structures, the development of a CIMS needs to happen in collaboration with each relief agency. The Ministry can for instance host collaboration sessions with representatives of all relief agencies for formulating acceptable requirements. In this way, each agency can give its preferences and the result may be more effective and acceptable for all agencies.

For researchers concerned with improving information management in crisis situations, we pose the following recommendations for further research:

1. Investigate further development of a fitting CIMS for crisis situations. Further research needs to be performed that leverages the advantages of both the network-centric and hierarchical approach. This can for instance be done by extending this research and trying to collaborate with other groups and organizations to come up with more requirements and design principles (e.g. collaborate with TNO, Ministry of Internal Affairs, Safety Regions and Municipalities).

2. Utilize more gaming simulation sessions with relief workers as an evaluation tool as we only had a sample size of 22 relief workers. As relief workers have the opportunity to use a CIMS in a simulated crisis situation, the CIMS can be improved based on relevant feedback from the actual users. Also, a gaming simulation session gives the participants the chance to experience what it is like to use such a system. Furthermore, generalizing results of all sessions becomes easier and has more power as several groups of relief workers are asked to participate.

## 10.4 Reflection

I will finish this chapter with a reflection on the work I delivered during this master thesis project. I will reflect upon the concepts I used in this research, the system I have built (DIOS), the gaming simulation and the results of the session with the participants. I will also focus on what I think of the possible use of network-centric systems in crisis situations in the future.

Throughout the literature review in this research, I used several concepts and constructs to define the research context of this thesis. The first two concepts that I analyzed were Information Quality (IQ) and System Quality (SQ). What struck me specifically was the wide range of dimensions that could be formulated for IQ and SQ. Initially, I could not determine which dimensions I should use for this research. Based on research of Bharosa et al., I managed to select several IQ and SQ dimensions to make this research more feasible, however reflecting back on these dimensions I can say that these lists are certainly not comprehensive. The use of IQ and SQ dimensions as performance criteria is however worthwhile in my opinion: IQ and SQ dimensions give designers and users a means to assess information and information systems in a structured way.

The next concepts I reflect upon are the hierarchical and network-centric approaches to information management. As I contributed to ongoing research, the question was raised how to coordinate information management in crisis situations. After some desk research, I came across two main approaches: the hierarchical approach and the network-centric approach. Reflecting back on the use of these two approaches, I think that I was too focused on just the information management processes that these approaches accommodate. I did not pay enough attention to the organizational and institutional arrangements surrounding these information management processes, while these approaches also give guidelines on how to arrange organizations and institutions. Despite my limited view on these two approaches, I could still use them to show the major differences and to test a fairly 'new' approach for information management in crisis situations. In my opinion, this research contributed to previous research by developing a CIMS based on a -for crisis management- 'new' approach and by evaluating such a CIMS so that insights can be derived for further research. I would recommend, even though I only hosted one evaluation session, to further research a hybrid form of a CIMS, leveraging the advantages of both the hierarchical and the network-centric approach.

Apart from reflecting upon the used concepts, I will now reflect on the design and the design process of DIOS. I utilized DIOS 1.0, developed by Dave Daas and Victor den Bak, as a starting point for DIOS 2.0 (the version used in the evaluation session). The design process was built up incrementally: we first had to decide on which objects would be used in the design and which functionalities should be supported. An important part in upgrading the user-friendliness of DIOS was incorporating AJAX technology. This however resulted in a version of DIOS that had to neglect a number of functionalities of DIOS 1.0. If I look back at the design of DIOS, I would say that both DIOS 1.0 and 2.0 have its advantages and I sincerely think that incorporating both versions would result in an even better CIMS.

Reflecting back on the design of the Master of Disaster Game, I was helped by the framework of Meijer that provided a structured way of designing a gaming simulation. Even though I have designed several other gaming simulations in the passed, I think the framework gives designers a means to structurally design a gaming simulation. With respect to the design of the gaming simulation, I regret the fact that we did not have the opportunity to test the gaming simulations several times due to the strict planning of this project. I think that if we tested the gaming simulation more thoroughly, preferably with relief workers, I think that the gaming simulation would be more robust and streamlined.

With respect to the results of the session, I was personally disappointed with the relatively low results on the IQ and SQ dimensions. Also, I did not take the number of respondents into account while designing the questionnaire. This resulted in using a non-parametric test (Wilcoxon) instead of a more powerful parametric test (e.g. Paired Samples T-test). Furthermore, the session experiences of a number of participants gave important insights on how they look at the concept of network-centric systems. At first, I did not take these important insights into account in my thesis, while these insights might be even more important than the scores on IQ and SQ dimensions. Reflecting back on the session results, I think that the results we got are valuable and add to the objective of this research. Still, only one gaming simulation session was hosted with professionals and to give a more comprehensive view of the relief workers with respect to network-centric systems, I would have hosted more sessions.

If I have to predict how the use of network-centric CIMS will develop in the future, I think that a combination of a network-centric and a hierarchical approach is the most thinkable scenario. I think this is mainly because of the trade-off between the hierarchical process structures in Dutch relief agencies and the advantages of a implementing a network-centric approach (e.g. shared situational overview and decentralized decision-making). I also believe that much standardization in organizations and information systems will be needed to deal with the heterogeneity of all relief agencies. However, standardization is not considered worthwhile by everyone because crisis situations do not occur every day and it might cost a lot of effort to implement standardization. It is for this reason that I think a central system, such as CEDRIC is gradually upgraded with several network-centric principles based on further research on how to design a CIMS. This research has contributed to the academic discussion on how to design a CIMS and I believe that further research in this field is definitely necessary because there are so many opportunities in improving information management considering the upcoming IT possibilities.

Reflecting back on my graduation project, I can sincerely say that I have learned a lot; not only with respect to crisis management and designing systems and gaming simulations, but also on how to cope with setbacks I did not foresee at the beginning. All in all, I think I have produced a decent report and I am proud to finish my study at TPM with this master thesis project as the finishing touch.

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# Appendix A: Scientific Article

# Exploring Hurdles in Using a Network-Centric Crisis Information Management System: Results from a Gaming Simulation

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**Abstract**

An emerging approach of managing information in crisis situations is a so-called network-centric approach. This approach originates from the field of military operations and is mainly focused on decentralized decision-making and allowing information sharing amongst all relief workers.
An interesting development is that Crisis Information Management Systems (CIMS) with a network-centric approach are gaining popularity and are vastly promoted in the Netherlands by the Ministry of the Interior. Yet, despite the promotion of network-centric CIMS, there is little known on hurdles relief workers can experience when using a network-centric CIMS. The objective of this paper is therefore to explore the hurdles in using a network-centric CIMS. To this end, we hosted a gaming simulation for a number of relief workers of the Netherlands.
The research approach consisted of designing a network-centric CIMS prototype, based on several network-centric principles found in literature. The next step was to develop a gaming simulation in which a crisis situation was simulated and the network-centric CIMS was utilized.
We hosted the gaming simulation at the Police Academy of the Netherlands and we had a multi-disciplinary sample of relief workers, including firemen, paramedics and policemen. Eventually, we derived seven main hurdles that relief workers experienced when making use of the network-centric CIMS. The main hurdles we observed were information overload, no clear definition of responsibilities and tasks for each relief worker and the mismatch between the network-centric CIMS and the hierarchical process structure amongst relief workers.

*Keywords:* crisis management, information management, CIMS, gaming simulation, net-centricity, disaster management

## 1. Introduction

In the event that a crisis takes place, the consequences can have a tremendous impact on society. This was clearly visible during the events of 9/11. Miscommunication and little information sharing caused that several firefighters were inside one of the towers when it was collapsing, while policemen had the information concerning the collapsing danger (De Bruijn 2006)

Repressing a crisis effectively has become an increasingly important issue after this man-made disaster, not only on the political agenda but also as a significant topic in science. Reflecting back on the 9/11 event, the importance of information became evident as the lack of information sharing caused several firefighters to pass away. Previous contributions in this field of science also state that in crisis situations crucial information is often lacking, not available, not shared adequately or delivered too late (Quarantelli 1988; Fisher 1998; Dawes, Creswell et al. 2004; Horan and Schooley 2007).

As such, an important challenge in repressing a crisis effectively is adequately managing information during a crisis. Ryoo and Choi confirm the importance of information management in crisis situations: *'at the core of disaster management lie the monumental tasks of* *collecting, distributing, processing and presenting disaster-related data'* (Ryoo and Choi 2006).

Traditionally, information management during crisis situations is done hierarchically (Bigley and Roberts 2001). A command and control structure is preserved between units of a public agency. In practice, this means that commanders only share information with other commanders. In turn, they pass this information on to their subordinates.

Yet, this approach towards information management has been criticized for several reasons. The following reasons are found in literature for condemning hierarchical information sharing systems in crisis situations (Bharosa, Janssen et al. 2009):

1. A hierarchically coordinated information system is not considered flexible (Drabek and McEntire 2003): flexibility of information systems is an important issue in crisis situations as several agencies need to work with the same system.
2. A hierarchical information system does not support emergent events and processes (t' Hart 1993): because of the very nature of crisis situations, hierarchical systems almost always fail as they cannot effectively deal with unforeseen and uncertain events.

Apart from this hierarchical approach towards information management, an emerging approach is the so-called network-centric approach. This approach originates from the field of military operations and is mainly focused on decentralized decision-making and allowing information sharing amongst all relief workers in order to increase the situational awareness of all militaries (Fewell and Hazen 2003; Stanovich 2006). A network-centric approach towards information management has also been promoted for use in crisis situations, also in the Netherlands (Stanovich 2006; Crisisplein.nl 2010).

Another point of interest in this matter is that information management processes, whether they are arranged hierarchically or network-centrically, need to be assisted in an effective way. Therefore, several scholars stress that information management processes need to be assisted by implementing a Crisis Information Management System (CIMS). CIMS can be used in assisting relief workers during information management processes (e.g. information acquisition, information validation and information distribution). Several examples of CIMS can be found in (Turoff, Chumer et al. 2004; Fahland, Glässer et al. 2007; Ianella, Robinson et al. 2007; Buffalo Computer Graphics 2009).

An interesting development is that CIMS having a network-centric approach are gaining popularity and are vastly promoted in the Netherlands by the Ministry of the Interior (Crisisplein.nl 2010). Yet, despite the promotion of network-centric CIMS, there is little known on hurdles relief workers can experience when using a network-centric CIMS.

The objective of this paper is therefore to explore the hurdles in using a network-centric CIMS. In this paper, we discuss a number of insights on these hurdles that came to pass during a gaming simulation session with relief workers from the Netherlands.

This paper is structured as follows: in the next section, background information is given on crisis management, information management and the concept of network-centric warfare. Subsequently, our research approach is given in section 3. Next, an overview is given of the CIMS we designed at Delft University of Technology. Then, the design of the gaming simulation will be discussed in section 5. Section 6 will lay out the results of the gaming simulation session with relief workers. Finally, several conclusions are drawn and recommendations for further research are given in section 7.

## 2. Background

In this section, some background information and theories are discussed in order to properly define the context. First, the concept of crisis management is discussed. Then, some relevant background information on information management will be discussed in the subsection afterwards. Then, the concept of network-centric warfare is discussed. This network-centric approach is gaining popularity in the military paradigm. The last part of this section will focus on exploring already seen hurdles in using a network-centric warfare approach.

### *2.1. Crisis Management*

Managing a crisis situation can prove to be a difficult task, as a crisis situation can be characterized as dynamic, unpredictable and error-sensitive (Bigley and Roberts 2001). Because several agencies also have to work together in order to manage a crisis, it becomes even more complicated to adequately respond to a crisis. These characteristics show that crisis management is a complex concept, yet several scholars have tried to define crisis management adequately. For instance, Rosenthal and 't Hart state that: *'crisis management involves making tough decisions in an environment of threat, urgency and uncertainty'* (Rosenthal and 't Hart 1991).

As this explanation of crisis management may be rather abstract, others describe crisis management as a set of 4 processes (Drabek and Hoetmer 1990; National Research Council 2007):

1. *Mitigation:* pro-actively minimizing the effects of a possible crisis on beforehand. Relief agencies can for instance take preventive healthcare measures and manage land zones near sea in order to minimize damage when a flooding occurs.
2. *Preparedness:* planning how to respond when a crisis occurs. Relief agencies often get prepared by performing realistic crisis exercises.
3. *Response:* in this phase, efforts are made to minimize the hazards created by a crisis. Relief agencies have to provide immediate assistance to save lives by providing emergency healthcare, shelter and transportation.
4. *Recovery:* recover the affected area. This can be done by for instance reconstructing buildings and by providing medical aftercare to victims.

In each of the four processes mentioned above, adequately working together is an important issue in order to guarantee effective crisis management. As various relief agencies have to collaborate in managing a crisis, it requires this complex network of actors to be well-aligned and efficient. It is therefore important to give some background information on the network of relief workers during a crisis situation. Consequently, the next section will discuss crisis response networks.

#### *2.1.1. Crisis Response Networks*

Characterizing a network of actors in a crisis situation is not unilateral since every crisis situation may require special expertise from different organizations. Yet, it is often seen as a task of the government, varying from local authorities to international departments, to manage a crisis. In most cases, a crisis also needs to be managed by a number of governmental authorities. One can think of the police department, the paramedics and the fire department. As these public agencies all have to work together to effectively repress the crisis, it is important to gain more insight in this network of actors. To this end, the figure below shows an example of an overview of information flows between relief agencies in a crisis situation. This overview is based on how information flows are managed during a crisis situation in the Netherlands.

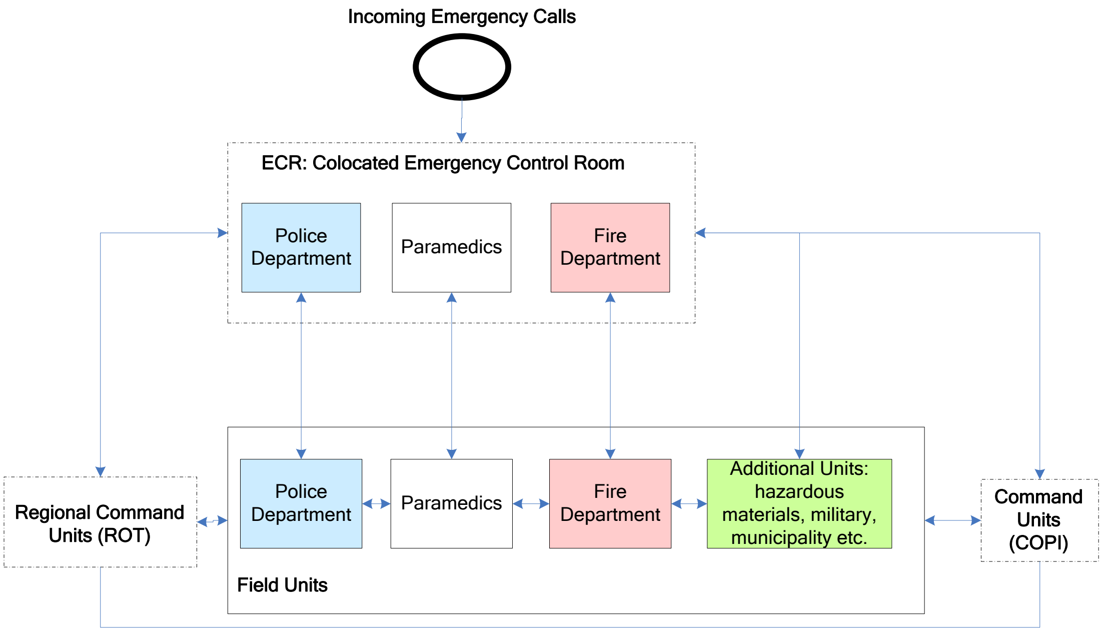


**Figure 1: An example of a crisis response network in the Netherlands (Based on Bharosa, Lee et al. 2010)**

Collaborating effectively during a crisis is a necessity, because wrong agreements and a lack of coordination may have large consequences. Therefore, it is evident that this network of relief agencies needs to be robust and well-aligned. There are however several aspects that increase the complexity of resolving a crisis for this network:

1. *Heterogeneity between relief agencies:* several agencies are involved in managing a crisis and each agency differs on several aspects from the others. The heterogeneity between these agencies is an aspect that further complicates effective crisis management: because in multi-agency coordination of disasters, each agency has its own processes, information, applications and technology (Bharosa, Lee et al. 2010), the efficiency and effectiveness of disaster response may be hampered.
2. *Crisis situations are no routine task:* it is often difficult to predict when and where a crisis situation will occur. Also, each crisis can have the need for different expertise. The problem of these kinds of situations is that they need are not a routine task for relief agencies as they do not occur on a daily basis for each agency. As Quarantelli points out, channeling information through an organization becomes more complex as officials cannot assume non-routine tasks in crisis situations (Quarantelli 1988).
3. *Fragmentation in a crisis response network:* there is often much fragmentation in a crisis response network also with respect to information (De Bruijn 2006): not every agency possesses *all* relevant information for effectively repressing a crisis. Yet, an integrated overview of all relevant information is considered necessary for effective crisis management.
4. *Interdependencies between relief agencies:* during a crisis situation, relief agencies often have to rely on each other's work. For instance, firemen and paramedics depend on each other while repressing a fire with several casualties. Networks are often characterized by these interdependencies (Koppenjan and Klein 2004; De Bruijn 2006). As such, interdependencies in a crisis response network might even be more of a critical aspect as disastrous consequences may occur.

Despite these complicating aspects of a crisis response network, the public agencies still have the important task of repressing a crisis as effectively as possible. High-quality information management plays a significant role in fulfilling this task (Ryoo and Choi 2006; Ianella, Robinson et al. 2007; Bharosa and Janssen 2008).

Therefore, we will go more into detail on information management and its relevance for crisis situations in the next section.

*2.2. Information Management*

To further frame the context in this research, an elaboration on the concept of information management is given in this section. Choo considers information management to be a set of six distinct processes within a given situation (Choo 1995):

1. Identifying information needs
2. Acquiring information
3. Organizing and storing information
4. Developing information products and services
5. Distributing information
6. Using information

These processes form a good starting point for explaining information management in crisis situations. However, as a crisis is characterized as a complex and dynamic process with a lot of unforeseeable events, additional information management processes are proposed by (Bharosa and Janssen 2008) and are already used by the Police Academy in the Netherlands:

1. Validating information: checking whether the information provided is the right information
2. Enriching information: in case information is incomplete or in-accurate, agencies should search for additional information

As already said in section 1, there are several ways to manage information during a crisis, of which a hierarchical information management structure is the most used in crisis situations (Bigley and Roberts 2001). However in the military domain, a network-centric approach is gaining popularity as the concept network-centric warfare is employed more progressively. Because a network-centric approach to information management in crisis situations is also becoming increasingly popular, we decided to elaborate on network-centric warfare and its characteristics in the next section to gain more insight.

*2.3. Network-Centric Warfare and network-centric information systems*

To manage information more effectively during crises, several governments consider the aptitude of applying a network-centric approach in crisis situations, including the Ministry of the Interior of the Netherlands (Crisisplein.nl 2010). In the military domain, a network-centric approach has already gained some recognition as we see that the concept of network-centric warfare (NCW) is being implemented increasingly (Cebrowski and Garstka 1998; Alberts, Garstka et al. 2002).

Perry et al. consider NCW to be 'the linking of platforms into one shared-awareness network in order to obtain information superiority, get inside the opponent's decision cycle and end conflict quickly' (Perry, Button et al. 2002).

Fewell and Hazen have reflected upon several definitions for network-centric warfare, including the definition of Perry, and they came with a more extensive description of the concept of NCW: *'Network-centric warfare is the conduct of military operations using networked information systems to generate a flexible and agile military force that acts under a common commander's intent, independent of the geographic or organizational disposition of the individual elements, and in which the focus of the war fighter is broadened away from individual, unit or platform concerns to give primacy to the mission and responsibilities of the team, task group or coalition'* (Fewell and Hazen 2003).

By utilizing networked information systems and allowing full information sharing by each user of the network, more shared situational awareness can be realized across all combat units. Reflecting on these definitions for NCW and the objective of this approach in the military, several network-centric characteristics for an information system can be derived:

**Table 1: Network-centric Characteristics**

| **Network-centric Characteristics** | **Explanation** |
|---|---|
| *Flattened hierarchical organization structure* | The hierarchical command and control structure becomes flattened as information becomes available in the same format on every |

| | |
|---|---|
| | organizational level |
| *Full information sharing* | Every node of the network (i.e. user) can share information with every other node (Fewell and Hazen 2003; Bharosa, Janssen et al. 2009) |
| *Decentralized decision-making* | Decision-making authority is distributed top-down to subordinate commanders |
| *Self-synchronization* | Organizing and synchronizing activities from bottom-up (Hutchins, Kleinman et al. 2001) |
| *Shared situational awareness* | Every user of the network has a shared overview of the situation at hand |
| *Interoperability* | Organizations and their information systems need to be interoperable (Stanovich 2006; Bharosa, Janssen et al. 2009) |

The table above gives a rough impression of what a network-centric approach stands for, based on insights from the military domain. As such, these characteristics are meant for military network-centric information systems. Yet, the characteristics might also serve as a solid basis for building a CIMS using a network-centric approach.

Even though there are several major differences between disaster response and military response, the characteristics above can still adopted in defining a network-centric approach in disaster response. A disaster response environment and a military environment both have the tasks of exerting command and control and building situational awareness (Stanovich 2006). Moreover, both environments can be typed by a complex and dynamic situation, with a lot of time pressure and possible threats for society (Bigley and Roberts 2001; Stanovich 2006). Therefore, one can use the insights derived in the field of NCW to design network-centric information systems suitable for disaster response.

With respect to military purposes, hierarchical information management systems are often criticized by the fact that they are inefficient and rigid (Bharosa, Janssen et al. 2009). A network-centric approach may have more potential because of its supposed benefits, such as more efficiency, agility and adaptability in information management (Fewell and Hazen 2003; Wilson 2007). Several other advantages of employing a network-centric approach in the military are also mentioned, such as increased responsiveness of units, lower risks and costs and increase combat effectiveness (Alberts, Garstka et al. 2002). Yet, various hurdles in using a network-centric warfare approach are also seen in the military paradigm. It is important to know which hurdles are already mentioned in current literature to get a complete picture of the consequences of adopting a network-centric approach. Therefore, in the next section, these hurdles are discussed in more detail.

### *2.4. Hurdles in following a network-centric warfare approach*

In this section, several hurdles in using a network-centric warfare approach are discussed. These hurdles contribute to a more critical view on network-centric approaches, such as NCW. As applying a network-centric approach is gaining popularity in crisis management, it is important to take note of possible drawbacks of using such an approach. Several scholars formulated a number of network-centric challenges in the military paradigm:

1. *Information Overload:* as more information becomes available for each user of a network-centric information system, the danger of information overload is apparent (Stanovich 2006; Wilson 2007)
2. *Unfiltered information:* as all information becomes available, it is difficult to distinguish processed intelligence from raw and unverifiable information (Stanovich 2006)
3. *A network-centric approach is at odds with effective command and control:* a network-centric approach ‘flattens’ a hierarchical process structure, which can lead to

counterproductive situations (Stanovich 2006).

4. *Excessive control from superior commanders:* commanders receive much more information, in a timely fashion. As commanders might think to have a complete picture of the incident, they may control their subordinates too much in their tasks (Stanovich 2006).
5. *Ignoring control from above:* as subordinate commanders now also can see the information intended for superior commanders, they might draw their own conclusions and ignore commands from above (Stanovich 2006).
6. *Networking for Networking's sake:* the value of a networked information system for gathering real-time information is immense. Yet, there is a danger that this network will then be used as an information channel instead of for its intended purpose, namely command and control of response efforts (Barnett 1999). Utilizing the network might become an end, instead of a means for a more effective command and control (Stanovich 2006).

Despite the formulation of these network-centric hurdles, the potential of network-centric information systems for military purposes is still recognized in literature (Alberts, Garstka et al. 2002; Perry, Button et al. 2002). The question is however whether this success of network-centric information systems would also arise in crisis response situations. As Stanovich also points out, the hurdles mentioned above may be the starting point for exploring the impact of a network-centric approach towards command and control and information systems of emergency response (Stanovich 2006).

Yet, the use of network-centric information management systems in crisis situations is hardly discussed in literature and there is little known on hurdles relief workers from several agencies can experience in using a network-centric CIMS. Therefore, the objective of this paper is to identify these hurdles for relief workers and thus contributing to the academic discussion of designing an adequate CIMS. We continue this paper with explaining the approach we followed in this research to fulfill this objective.

## 3. Research Approach

The first step in this research was to design a CIMS based on the network-centric characteristics mentioned in the previous section. We also adopted the guidelines for network-centric warfare systems, as given by the DoD. These DoD guidelines are primarily leveraging the use of shared web services and Service Oriented Architectures (DoD 2007).

After we designed a network-centric CIMS prototype, we decided to build a gaming simulation in which a crisis situation was replicated. To illustrate what a gaming simulation stands for, Duke and Geurts define a gaming simulation as follows: *'a special type of model that uses gaming techniques to model and simulate a system. A gaming simulation is an operating model of a real-life system in which actors in roles partially recreate the behavior of the system'* (Duke and Geurts 2004).

We have chosen to follow a gaming simulation approach in this research for several reasons:

1. Gaming simulations can be used to study the behavior of the participants (Meijer 2009). Because we are interested in the experiences of relief workers, a gaming simulation is a suitable approach
2. A gaming simulation is a controlled and safe environment in which systems can be evaluated without real-life consequences (Peters 2008).
3. Gaming simulations can be used to give life and relevance to descriptive material (Neral and Ray 1995; Lowry 1999). Therefore, a gaming simulation might be more effective compared to interviews and presentations as gaming simulations are more interactive and often more fun.

Both the network-centric CIMS prototype and the gaming simulation were tested several times with students and academic personnel. Eventually, we evaluated the use of a network-centric CIMS with professional relief workers during a gaming simulation session at the Police

Academy of the Netherlands. We continue to elaborate on the network-centric CIMS in the next section of this paper.

## 4. DIOS: Disaster Interagency Orchestration System

In this research, we designed a network-centric CIMS prototype at Delft University of Technology. We called the system DIOS, which stands for Disaster Interagency Orchestration System. The design of the system is based on several network-centric characteristics derived from the military concept of network-centric warfare. The premise is that a network-centric information system may lead to improved information management and better situational awareness during a crisis. DIOS consists of three layers as shown in Figure 2: a presentation layer, an application layer and data layer. In the subsections below, each layer is further described.

### *4.1. Presentation Layer*

The presentation layer of this system stands for the part of the application that users directly interact with. In other words, it is that part of the application that presents the system to the user. In the presentation layer, DIOS consists of one main website that has 4 distinct parts:

1. *Map and Weather information:* in the first part, the map of the crisis scene can be loaded together with the current time and weather information. To give an impression of the DIOS application, a screenshot is given in Figure 3.
2. *Dashboard:* the dashboard shows the latest information concerning relevant information for crises (e.g. casualties, bystanders, dangers and information requests)
3. *Input:* this part of the website gives the user the possibility to input data into the system. This is done in a structured manner where several tabs are used for several different information objects
4. *Information Tables:* whereas the dashboard only shows the latest information available for each type of information, the information tables keep track of all information entries into the system, providing a full 'information system memory' for each crisis.

In the presentation layer, we used AJAX technology to enhance the user experience of relief workers. AJAX stands for *Asynchronous JavaScript and XML* and is actually a set of several technologies that can be used in developing web applications (Garrett 2005). AJAX technology allows a web application to be more interactive by enabling partial-page updates, which means that parts of a webpage can be updated without having to refresh the whole page, which is usually done by pressing the F5 button. This enhancement gives the user a much richer experience with web applications (Garrett 2005).

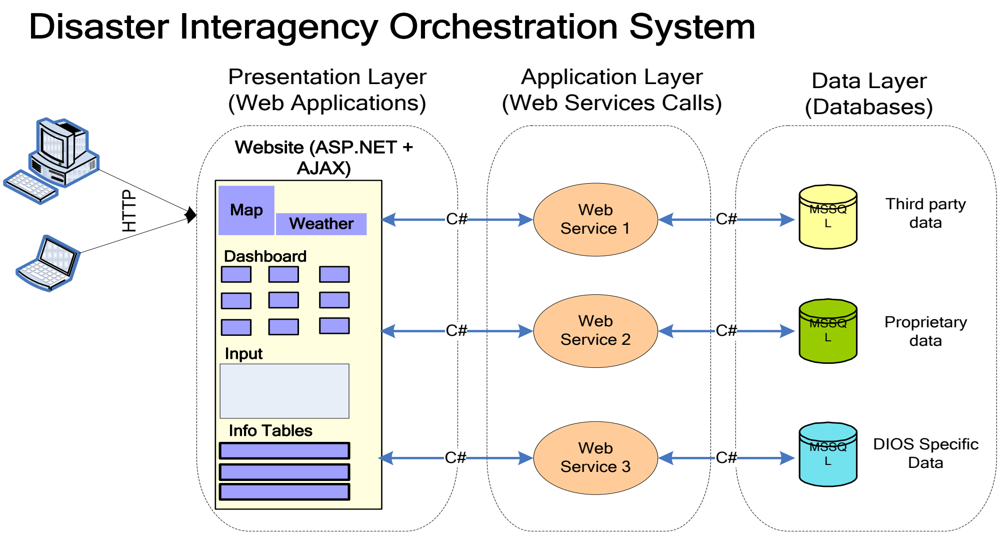


**Figure 2: DIOS – Layered Technical Architecture**

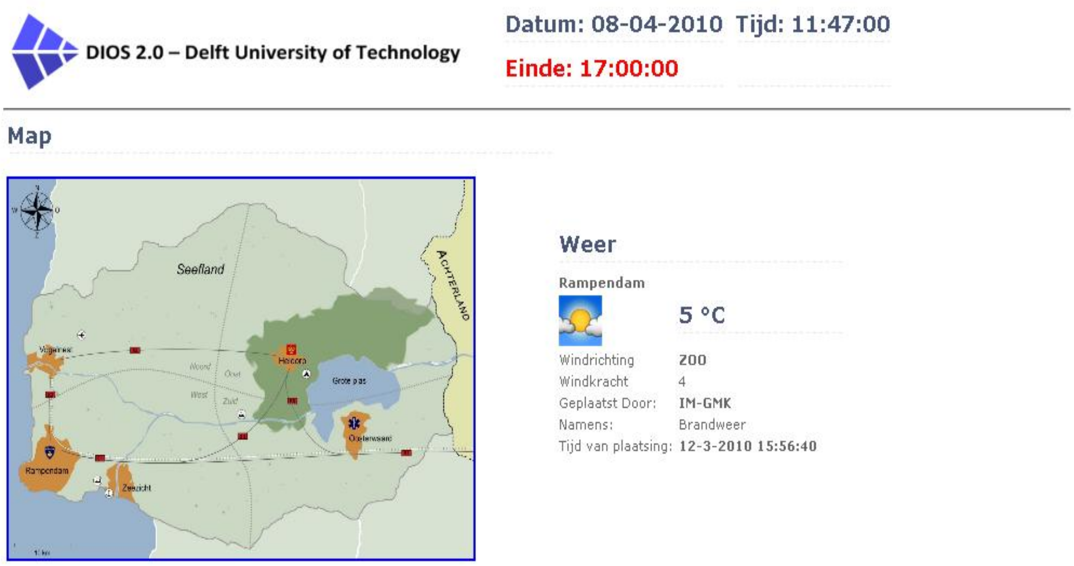


**Figure 3: DIOS – Presentation Layer**

*4.2. Application Layer*

The application layer of DIOS consists of several web services that can be used for modifying, inserting or selecting data. These web services are called by commands coming from the presentation layer. As web services are used in this CIMS prototype, the design is easily extensible and can be used with different presentation layers. Web services are as a matter of fact loosely coupled (Erl 2007), which makes them suitable for systems that need to be interoperable. In this case, interoperability is necessary as CIMS need to work along several relief agency systems.

*4.3. Data Layer*

The data layer consists of a Microsoft SQL Server, which operates separately next to the web server on which the presentation layer is running. The SQL Server contains one database with all specific data of DIOS. There was no use of third-party data in this prototype, as it was too risky to depend on relatively unknown service providers during the gaming simulation. Yet, the use of third-party data in DIOS is easy to implement due to the use of web services in the application layer.

The network-centric characteristics mentioned in the previous section are utilized as guidelines for this CIMS design. We made sure that DIOS is an interoperable system, allowing decentralized decision-making. Furthermore, every user can post and consult information at any time, thereby allowing information sharing throughout the whole command and control structures.

We used DIOS specifically as the network-centric CIMS prototype for the following reasons:

1. It is a unique CIMS because of its network-centric design, based on characteristics derived from the military field of science. As network-centric systems are increasingly being promoted for use, the results of the evaluation of DIOS can contribute significantly to state-of-the-art in CIMS developments.
2. DIOS builds on previous research from Delft University of Technology. For this practical reason, DIOS was chosen because of a whole development process on beforehand.
3. In case further research is done, DIOS is particularly suited for this purpose because of the design. Using a layered approach web services make DIOS very modular and easily adaptable.

The next section will further detail on the gaming simulation. In this gaming simulation DIOS is used as the CIMS prototype. We particularly were interested in the experiences relief workers had in using DIOS.

## 5. Gaming Simulation: Master of Disaster

Apart from the CIMS prototype we designed, a gaming simulation was also developed. With this gaming simulation, we wanted to explore the experience relief workers have in using a net-centric CIMS. The gaming simulation consists of several elements of which the most important are discussed in the sections below.

### *5.1. Roles*

The Master of Disaster Game is a gaming simulation that simulates the processes of information management in a disaster situation. The roles in a gaming simulation can be divided into roles for participants and roles for game facilitators (Meijer 2009).

#### *5.1.1. Facilitator Roles*

Facilitators have to make sure the gaming simulation takes place in good order. To help facilitators in accomplishing this, several facilitator roles are defined in the table below.

**Table 2: Roles for Facilitators**

| | |
|---|---|
| *Mailman* | The mailman will deliver messages between several roles. This is part of the representation of an information management system in round 1. |
| *Journalist* | The journalist wants to gain as much relevant information on the disaster as possible and asks commanders for information. |
| *Observers* | The goal of the observers is to observe the participants as good as possible with help of an observation protocol. |

#### *5.1.2. Participant Roles*

The roles for participants are divided into 4 groups with each group having a specific task in this gaming simulation. These roles are based on realistic roles used in the Netherlands for crisis repression.

**Table 3: Roles for Participants**

| Group | Roles |
|---|---|
| *Emergency Control Room (ECR)* | 1. ECR – Police<br>2. ECR – Paramedics<br>3. ECR – Fire Department |
| *Commando Place Incident (CoPI)* | 1. CoPI – Chairman<br>2. CoPI – Information Manager<br>3. CoPI – Police Commander<br>4. CoPI – Paramedics Commander<br>5. CoPI – Fire Dpt. Commander<br>6. CoPI – Local Representative |
| *Municipal Crisis Center (MCC)* | 1. MCC – Mayor<br>2. MCC – Information Manager<br>3. MCC – Police Commander<br>4. MCC – Paramedics Commander<br>5. MCC – Fire Dpt. Commander<br>6. MCC – Municip. Crisis Manager |
| *Field Workers (Field)* | 1. Field – Police Officers<br>2. Field – Paramedics<br>3. Field – Fire Fighters |

### *5.2. Loads*

Loads can be defined as the values of all variables in the design of the gaming simulation (Meijer 2009). A load can also be described as a scenario. In this section, two loads are discussed: Load A (for round 1) and Load B (for round 2). For both loads, a fictional safety region is designed, called Seefland. In this safety region, the city of Rampendam is chosen as the location where the disasters will take place.

*5.2.1. Load A: Fire at a business complex*

Load A is about a fire at a business complex in Rampendam. At this business complex, there are two do-it-yourself stores situated. These shops have explosive and toxic material in their warehouses, which can lead to disastrous consequences for the environment surrounding Rampendam. In this load, participants have to work without a CIMS. Communication between teams is done with the use of forms and a mailman.

*5.2.2. Load B: Fire at a university campus*

In Load B, a fire at a university campus in Rampendam is simulated. The architecture faculty of the University of Rampendam caught fire by accident. The great danger here is that the architecture faculty borders on the chemistry lab of the Faculty of Chemistry. In this lab, there are many poisonous and explosive materials stored. There is also a collapsing danger of the Faculty of Architecture. In this load, participants are able to use the CIMS we have developed for this session.

*5.3. Situation*

The situation stands for all variables that surround the gaming simulation session, but are not part of the design (Meijer, 2009). One can think of the venue, the participants and the space in which the gaming simulation is hosted.

**Table 4: Master of Disaster Game - Situation**

| **Situational Variable** | **Session** |
|---|---|
| *Date* | Friday 12 March 2010 |
| *Duration* | 1:30 PM – 4:30 PM |
| *Location* | Ossendrecht, Netherlands |
| *Venue* | Police Academy of the Netherlands |
| *Participants* | Police Academy Students: relief workers from different agencies, such as police officers, paramedics and firemen |
| *# Participants* | 24 |

We decided to limit the session to three hours to avoid that participants would not get distracted or tired of the session. The session structure looks as follows:

1. *Introduction:* facilitators inform the participants on how the gaming simulation will take place. All role descriptions are given and participants have time to read through it.
2. *Round 1:* The gaming simulation starts with simulating a disaster situation in Rampendam and it is up to the participants to manage this disaster effectively and efficiently. The participants can use Microsoft Word and Gmail accounts to share information.
3. *Evaluation of Round 1:* participants take part in a short evaluation session of round 1 in which improvement points are defined for the next round.
4. *Break*
5. *Round 2:* Again, a crisis situation is simulated in Rampendam, yet participants can now make use of the CIMS we developed.
6. *Evaluation of round 2:* participants take part in a more extensive evaluation session of round 2 in which we discussed the experience participants had while using the CIMS.
7. *Concluding remarks and awards:* the facilitators conclude the session with a small award ceremony for the best players in the gaming simulation

The next section will discuss the results of the gaming simulation session. In the evaluation session of round 2, we could identify several hurdles with respect to using a network-centric CIMS.

## 6. Findings from the gaming simulation with relief workers

In this section, we discuss the findings from the gaming simulation session with the 24 relief workers at the Police Academy of the Netherlands. A number of interesting findings were made regarding the use of a network-centric information system. Based on the experiences professionals had, the next section will address the hurdles in the use of a CIMS. Afterwards, we go on with the experiences of the relief workers with respect to the session itself. It turned out that these session experiences played a crucial role in the experiences of the participants with the network-centric CIMS.

*6.1. Identified Hurdles*

After round 2 of the gaming simulation session, an evaluation session was held to discuss the use of DIOS. We held an open discussion with participants, so that they felt they could give an honest opinion on the use of a CIMS. The result was a number of hurdles they came across when they were using DIOS.

**Table 5: Identified Hurdles in using network-centric CIMS**

| Identified Hurdles | Explanation |
|---|---|
| *No clear agreements on the meeting process* | Currently, commanders have a meeting each 15 minutes in which they share information and make decisions to repress the crisis. While using a network-centric CIMS, these meetings were ongoing and as there was new information posted continuously, commanders could not retain a structured meeting. |
| *No clear defined tasks for each relief worker* | It was unclear who had the task of posting information into the system. Because many participants are often not authorized to share information with everyone, it caused confusion among them. Participants were not used to this type of information sharing and they missed prescribing procedures. |
| *No clear responsibilities in the use of DIOS* | Participants were uncertain on who would bear responsibility for the posted information. They believed that it was difficult to know who can be accounted for which piece of information. In the current situation, all commanders are responsible, but they also are the ones sharing and verifying information. |
| *No approval mechanisms for posting information* | Commanders missed the functionality of overruling or approving new entries of information, which means that officers with a higher rank can overrule and/or approve information in case this is necessary. The commanders deem this overruling mechanism necessary, they are responsible for the outcome of the crisis situation. |
| *Information overload* | The network-centric system caused that a lot more information was shared than in a common situation. Therefore, several participants found it difficult to maintain an overview of the situation when there is so much continuously changing information. This information overload was initially captured by the information tables of DIOS, yet participants were more focused on analyzing the information available on the information dashboard. |
| *Mismatch between network-centric CIMS and process structure* | Participants also found it fairly difficult to *use* DIOS as it did not comply with the way of working they were used to. A relief worker clarified this problem as follows: *'This is an attempt to incorporate a network-centric information system in a hierarchical process structure. This leads to a mismatch.'* |
| *Supply of too much irrelevant information* | A lot of participants had the feeling that they received too much irrelevant information for their tasks. For instance, firemen received information specifically meant for policemen. This also is due to the heterogeneity in tasks between the relief agencies. |

These hurdles show several similarities with NCW hurdles found in the military paradigm. Examples are the information overload issue, the mismatch between a hierarchical process structure and a network-centric system and the obscurity of responsibilities in using a network-centric system. Yet, other crisis-specific hurdles are also identified, such as the supply of irrelevant information due to the heterogeneity of the organizations and the need for clear agreements on the meeting processes during a crisis. These new insights, based on user experiences, can be used effectively in further research on how to assist information management in crisis situations with help of a CIMS.

The hurdles mentioned above are of value for the disaster response community, yet they are based on only one session with relief workers. Besides, these relief workers also had their opinion on the session itself; these experiences may also explain why relief workers have formulated these hurdles. Therefore, we discuss the session experiences of the participants in the next section.

*6.2. Session Experiences*

During the gaming simulation, quite a number of relief workers retained a somewhat indifferent feeling afterwards. Some interesting findings were made that may explain this feeling and its effect on the found hurdles of the previous section. These findings are based on the experiences of the relief workers regarding the network-centric CIMS and the gaming simulation.

An important finding that came to pass in the evaluation session was that several relief workers were reluctant to use a network-centric CIMS on beforehand. This could be explained by the political pressure by the Ministry of the Interior of the Netherlands. Some relief workers retained the feeling that network-centric CIMS were actively imposed by the Ministry of the Interior in their relief agency, which made the relief workers possibly reluctant to work with these kinds of CIMS. Maybe because of this disinclined look towards network-centric systems, a few relief workers were initially of opinion that we were promoting our network-centric CIMS as well.

Another result that became evident was the mismatch in expectations of the relief workers and the academic researchers. The relief workers had in mind that a workshop would be given in which they would receive several lectures on network-centric information systems while we hosted a gaming simulation with the goal of exploring the experiences of relief workers.

As we conducted the gaming simulation with a heterogeneous group of relief workers, a lot of relief workers also were of opinion that they experienced difficulties in collaborating effectively. As each relief worker was used to its own way of working, tasks and responsibilities, the use of network-centric CIMS caused some confusion and misalignment on which tasks are the most important and who needs to take responsibility for which action.

This study not only shows results with respect to the hurdles participants experience in using a network-centric CIMS, but also points out that several relief workers in the Netherlands have a reluctant stance towards the concept of network-centric CIMS itself. This result can have a significant impact on the acceptance of network-centric information systems for crisis management in the Netherlands as some of the users may not be willing to use such a system, but still have to. The final section will draw several conclusions with respect to the hurdles we identified.

**7. Conclusions**

In this paper, we identified and presented several hurdles that relief workers experienced in using a network-centric CIMS. These hurdles came to pass during a gaming simulation session with 24 relief workers at the Police Academy of the Netherlands. By utilizing a gaming simulation session, the experiences of participants with using the CIMS could easily be observed.

Relief workers mainly had difficulties regarding unclear responsibilities, tasks and agreements with the CIMS. Furthermore, they experienced an information overload and supply of much irrelevant information when this network-centric system was utilized. Finally, the relief workers also differentiated a mismatch between the CIMS and the process structure and, maybe as a result, they felt there was a lack of overruling mechanisms for posting information by subordinate commanders.

Reflecting back on the gaming simulation session, participants retained a somewhat disinclined feeling towards the use of network-centric systems. We argue that this is mainly due to the political pressure and the active promotion of network-centric systems by the

Ministry of the Interior of the Netherlands. This attitude towards network-centric systems can have a significant impact on the acceptance of network-centric information systems for crisis management in the Netherlands as some of the users may not be willing to use such a system, but still have to.

The research presented in this paper was only limited to one gaming simulation session with one sample of professionals. Therefore, we recommend using gaming simulations extensively with relief workers to test and improve the CIMS. These sessions can incorporate the valuable feedback of professionals. Besides performing more gaming simulations, we recommend to further develop a more adequate CIMS based on the insights of this research.

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# Appendix B: Application Code

In this appendix, the application code of DIOS 2.0 is shown and briefly discussed. All code was programmed using the Microsoft Visual Web Developer 2008 Express Edition IDE. This developer environment was easy in use for programming ASP.NET websites and C# programs. Visual Web Developer has for instance an auto-completion mode for already made classes. Figure 44 is an example of how the IDE looks like.

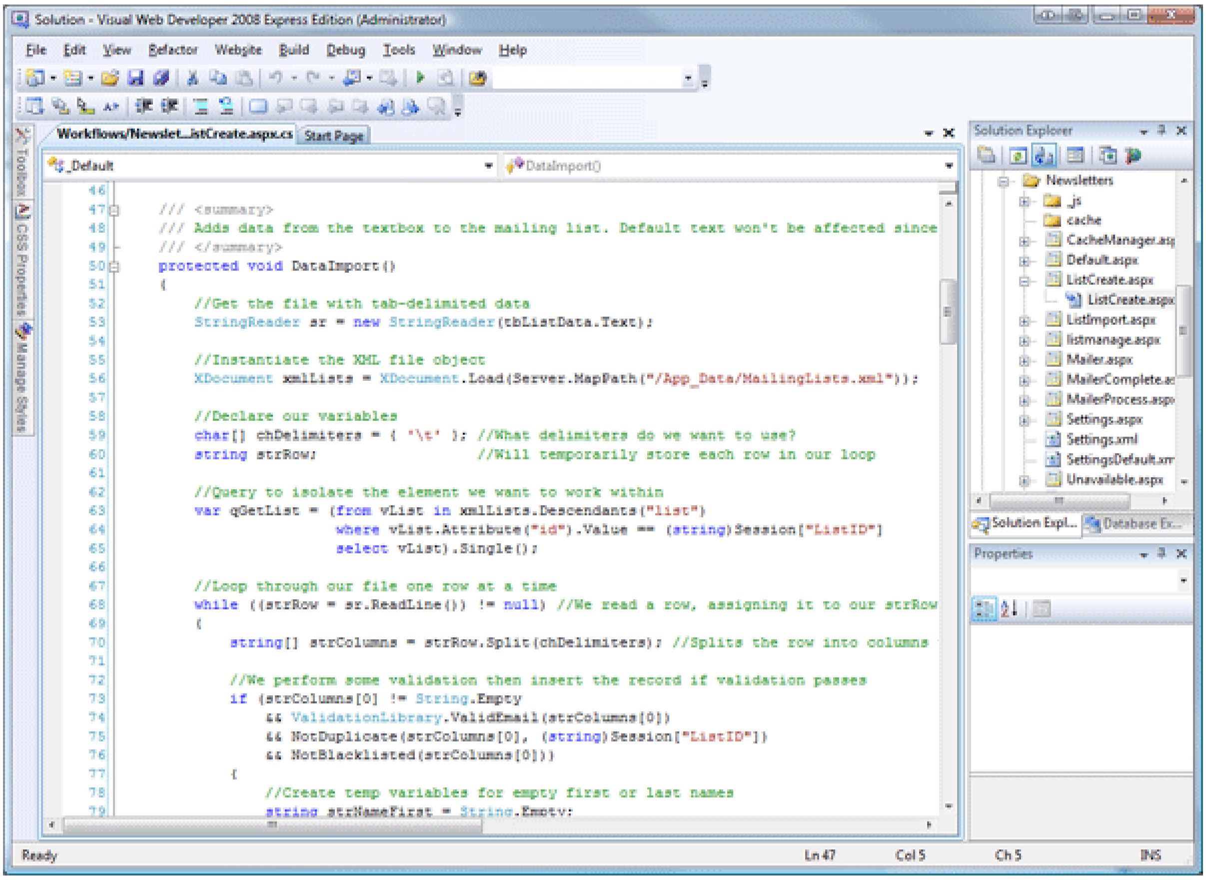

Figure 44: Microsoft Visual Web Developer 2008 Express Edition IDE

As DIOS 2.0 was coded into one single website, the code given below is only limited to that website. This website in question is called DIOS.aspx, which indicates that it is an ASP.NET website (because of the .aspx postfix). Not all code of the website is given as this contains almost 40 pages of code. Only a limited amount of code is given, primarily to show the structure of the file.

```
<%@ Page Language='C#' AutoEventWireup='true'  CodeFile='DIOS.aspx.cs' Inherits='_Default' %>

<%@ Register Assembly='AjaxControlToolkit' Namespace='AjaxControlToolkit' TagPrefix='asp' %>

<%@ Register Assembly='System.Web.Ajax' Namespace='System.Web.UI' TagPrefix='asp' %>

//Start of the Website

<! DOCTYPE html PUBLIC '-//W3C//DTD XHTML 1.0 Transitional//EN'
'http://www.w3.org/TR/xhtml1/DTD/xhtml1-transitional.dtd'>

<html xmlns='http://www.w3.org/1999/xhtml'>
//Start of the Head

<head runat='server'>
    <link href='DIOSStyleSheet.css' rel='stylesheet' type='text/css' />
```

```
<title>DIOS Versie 1.0 - TU Delft</title>
</head>

//Start of the Body
<body>
    <form id='form1' runat='server'>

        //Scriptmanager needed for AJAX implementation
        <asp:AjaxScriptManager ID='AjaxScriptManagerDIOS' runat='server'>
        </asp:AjaxScriptManager>

//Header of the website
<div id='headerdiv'>
            <table>
                <tr>
                    <td>
                        <img alt='' src='images/dios-logo-final.png'
                            style='width: 450px; height: 68px' /></td>
                    <td class='style1'>
                         </td>
                    <td> /*Date and Time*/
                        <asp:UpdatePanel ID='DateTime_UpdatePanel' runat='server' >
                            <ContentTemplate>
                                <asp:Timer ID='DIOS_Timer' runat='server' Interval='1000'
  ontick='DIOS_Timer_Tick'>
                                </asp:Timer>
                                <table width: '200px'>
  <tr>
      <td>
          <h2>
                                Datum:
                                <asp:Label ID='DatumLabel' runat='server' Text=''></asp:Label>
          </h2>
      </td>

      <td>
          <h2>
                                Tijd:
                                <asp:Label ID='TijdLabel' runat='server' Text=''></asp:Label>
          </h2>
      </td>
      <td>
           </td>
  </tr>
  <tr>
      <td>
          <h3>
              Einde: 17:00:00</h3>
      </td>
      <td>
          <h2>
               </h2>
      </td>
  </tr>
                                </table>
                            </ContentTemplate>
                        </asp:UpdatePanel>
                    </td>
                </tr>
                </table>
    <hr />
    </div>

        //Start of the Content DIV with Dashboard
        <div id='contentdiv'>
```

```
        <asp:UpdatePanel ID='UpdatePanel1' runat='server'>
            <ContentTemplate>
                <table>
                    <tr>
                        <td class='style12' colspan='2'>
                            <h2>Dashboard</h2> <br />
           /*Map*/<a href='RampendamGroot.aspx''><img alt=''
src='images/Rampendam_klein_v2.jpg'
                                style='width: 430px; height: 300px' /></a></td>
                        <td class='style12'>
                            /*Weather*/<asp:UpdatePanel ID='Weer_UpdatePanel' runat='server'>
                                <ContentTemplate>
  <table class='style2'>
      <tr>
          <td colspan='2'>
              <h2>
                  Weer</h2>
          </td>
      </tr>
      <tr>
          <td colspan='2'>
              <b>Rampendam</b></td>
      </tr>
      <tr>
          <td class='style3'>
            <img alt='' src='images/partly_cloudy.png' style='width: 40px; height: 40px'
/></td>
          <td class='style5'>
              <h2>
                                     <asp:Label ID='Weer_Temp_Label'
runat='server'></asp:Label>
                  °C</h2>
          </td>
      </tr>
      <tr>
          <td class='style3'>
              Windrichting</td>
          <td class='style5'>
              <asp:Label ID='Windrichting_Label' runat='server' style='font-weight:
700'></asp:Label>
          </td>
      </tr>
      <tr>
          <td class='style3'>
              Windkracht</td>
          <td class='style5'>
              <asp:Label ID='Windkracht_Label' runat='server'></asp:Label>
          </td>
      </tr>
      <tr>
          <td class='style3'>
              Geplaatst Door:</td>
          <td class='style5'>
              <asp:Label ID='Weer_GD_Label' runat='server' style='font-weight:
700'></asp:Label>
          </td>
      </tr>
      <tr>
          <td class='style3'>
              Namens:</td>
          <td class='style5'>
              <asp:Label ID='Weer_N_Label' runat='server'></asp:Label>
          </td>
      </tr>
      <tr>
          <td class='style3'>
```

```
              Tijd van plaatsing:</td>
          <td class='style5'>
              <asp:Label ID='Weer_Tijd_Label' runat='server' style='font-weight:
700'></asp:Label>
                        <td>/*Start of the Dashboard*/
                            <asp:DetailsView
                                ID='Gevaren_DetailsView' runat='server'
AutoGenerateRows='False'
                                CellPadding='4' DataSourceID='Gevaren_Dash_SqlDataSource'
ForeColor='#333333'
                                GridLines='None' HorizontalAlign='Justify' Width='250px'>
                                <FooterStyle BackColor='#5D7B9D' Font-Bold='True'
ForeColor='White' />
                                <CommandRowStyle BackColor='#E2DED6' Font-Bold='True' />
                                <RowStyle BackColor='#F7F6F3' ForeColor='#333333' />
                                <FieldHeaderStyle BackColor='#E9ECF1' Font-Bold='True' />
                                <PagerStyle BackColor='#284775' ForeColor='White'
HorizontalAlign='Center' />
                                <Fields>
  <asp:BoundField DataField='Creatie' HeaderText='Creatie'
      SortExpression='Creatie' />
  <asp:BoundField DataField='Type' HeaderText='Type' SortExpression='Type' />
  <asp:BoundField DataField='Prioriteit' HeaderText='Prioriteit'
      SortExpression='Prioriteit' />
  <asp:BoundField DataField='Brongebied' HeaderText='Brongebied'
      SortExpression='Brongebied' />
  <asp:BoundField DataField='Effectgebied' HeaderText='Effectgebied'
      SortExpression='Effectgebied' />
                                </Fields>
                                <HeaderStyle BackColor='#5D7B9D' Font-Bold='True'
ForeColor='White' />
                                <EditRowStyle BackColor='#999999' />
                                <AlternatingRowStyle BackColor='White' ForeColor='#284775' />
                            </asp:DetailsView>
                            <asp:SqlDataSource ID='Gevaren_Dash_SqlDataSource' runat='server'
                                ConnectionString='<%$ ConnectionStrings:ConnectionStringDIOS
%>'
                                SelectCommand='SELECT [Creatie], [Type], [Prioriteit],
[Brongebied], [Effectgebied] FROM
[Gevaren] ORDER BY [Creatie] DESC'>
                            </asp:SqlDataSource>
                        </td>
                    </tr>
                    <tr>
                        <td>
                             </td>
                        <td>
                             </td>
                        <td>
                             </td>
                    </tr>
                </table>
            </ContentTemplate>
        </asp:UpdatePanel>


    </div>
    <hr />
       //Start of the Input Output DIV
       <div id='inputputdiv'>
        <table class='style7'>
       //Fill in Information
            <tr><td><h2>Informatie Invoeren</h2></td></tr>
            <tr>

                <td class='style11'>
```

```
                    <asp:TabContainer ID='DIOS_Input_TabContainer' runat='server'
ActiveTabIndex='3'
                        Height='263px' Width='675px'>
                        <asp:TabPanel runat='server' HeaderText='GRIP' ID='GRIP_TabPanel'>
                            <HeaderTemplate>
                                GRIP
                            </HeaderTemplate>
                            <ContentTemplate>
                                <asp:Panel ID='GRIP_InputPanel' runat='server'
CssClass='TabPanel'>
  <table>
      <tr>
          <td>
              GRIP:
          </td>
          <td>
              <asp:DropDownList ID='GRIP_DropDownList' runat='server'>
                  <asp:ListItem>0</asp:ListItem>
                  <asp:ListItem>1</asp:ListItem>
                  <asp:ListItem>2</asp:ListItem>
                  <asp:ListItem>3</asp:ListItem>
                  <asp:ListItem>4</asp:ListItem>

              </asp:DropDownList>
          </td>
      </tr>
      <tr>
          <td>
              Geplaatst Door:</td>
          <td>
              <asp:DropDownList ID='GRIP_GD_DropDownList' runat='server'>
                  <asp:ListItem>IM-CoPI</asp:ListItem>
                  <asp:ListItem>IM-GVS</asp:ListItem>
                  <asp:ListItem>IM-GMK</asp:ListItem>
                  <asp:ListItem>IM-Veld</asp:ListItem>
              </asp:DropDownList>
          </td>
      </tr>
      <tr>
          <td>
              Namens:
          </td>
          <td>
              <asp:DropDownList ID='GRIP_N_DropDownList' runat='server'>
                  <asp:ListItem>Politie</asp:ListItem>
                  <asp:ListItem>Brandweer</asp:ListItem>
                  <asp:ListItem>GHOR</asp:ListItem>
                  <asp:ListItem>Gemeente</asp:ListItem>
                  <asp:ListItem>Extern</asp:ListItem>
              </asp:DropDownList>
          </td>
      </tr>
      <tr>
          <td>
              Betrouwbaarheid:
          </td>
          <td>
              <asp:DropDownList ID='GRIP_B_DropDownList' runat='server'>
                  <asp:ListItem>Laag</asp:ListItem>
                  <asp:ListItem>Gemiddeld</asp:ListItem>
                  <asp:ListItem>Hoog</asp:ListItem>
              </asp:DropDownList>
          </td>
      </tr>
      <tr>
          <td>
```

```
               </td>
          <td>
              <asp:Button ID=‘GRIP_Button’ runat=‘server’ onclick=‘GRIP_Button_Click’
                  Text=‘OK’ />
          </td>
      </tr>
  </table>
                                </asp:Panel>
                            </ContentTemplate>
                        </asp:TabPanel>
                         <asp:TabPanel ID=‘Extern_TabPanel’ runat=‘server’ HeaderText=‘Externe
Informatie’>
                            <ContentTemplate>
                                <table class=‘style7’>
  <tr>
      <td>
          Externe informatie kan via dit scherm opgevraagd worden. Klik op de categorieen
          hieronder voor meer informatie.</td>
  </tr>
  <tr>
      <td>
          <b><a href=‘javascript:windowOpenGS()’>1. Gevaarlijke Stoffen</a></b></td>
  </tr>
  <tr>
      <td>
          <b><a href=‘javascript:windowOpenOL()’>2. Opvanglocaties</a></b></td>
  </tr>
  <tr>
      <td>
          <b><a href=‘javascript:windowOpenFotos()’>3. Foto&#39;s</a></b></td>
  </tr>
  <tr>
      <td>
          <b><a href=‘javascript:windowOpenKaarten()’>4. Universiteit</a></b></td>
  </tr>
                                </table>
                            </ContentTemplate>
                        </asp:TabPanel>
                    </asp:TabContainer>
                     </td>

            </tr>
            </table>

    <hr />
    </div>
       //Start of the Output DIV - Information Tables
       <div id=‘outputdiv’>

        <table class=‘style7’>

            <tr>
                <td class=‘style11’>
                    <h2>
                        Informatie Tabellen</h2>
                </td>
            </tr>
            <tr>
                <td class=‘style11’>
                     </td>
            </tr>
            <tr>
                <td class=‘style11’>
                    <table class=‘style7’>
                        <tr>
                            <td>
```

```
                    <asp:Panel ID='GRIP_HeaderPanel' runat='server'
CssClass='collapsePanelHeader'>
                        <asp:Image ID='GRIP_Header_Image' runat='server'
ImageUrl='~/images/expand_blue.jpg' />
                         GRIP - Klik voor informatie...
                    </asp:Panel>
                            </td>
                        </tr>
                        <tr>
                            <td>

                    //The Collapsible Panels for Information
                    <asp:Panel ID='GRIP_ContentPanel' runat='server' CssClass='collapsePanel'>
                        <asp:UpdatePanel ID='GRIP_UpdatePanel' runat='server'>
                            <ContentTemplate>
                                <asp:GridView ID='GRIP_GridView' runat='server'
    AutoGenerateColumns='False' DataSourceID='GRIP_SqlDataSource' AllowPaging='True'
AllowSorting='True' CellPadding='4'
                      ForeColor='#333333' GridLines='None' PageSize='5'
  style='color: #FFFFCC'>
  <RowStyle BackColor='#F7F6F3' ForeColor='#333333' />
  <Columns>
      <asp:BoundField DataField='Creatie' HeaderText='Creatie'
            SortExpression='Creatie' />
      <asp:BoundField DataField='GRIP' HeaderText='GRIP' SortExpression='GRIP' >
      <ItemStyle BackColor='#FFFFCC' Font-Bold='True' ForeColor='#FF3300' />
      </asp:BoundField>
      <asp:BoundField DataField='GeplaatstDoor' HeaderText='GeplaatstDoor'
            SortExpression='GeplaatstDoor' />
      <asp:BoundField DataField='Namens' HeaderText='Namens'
            SortExpression='Namens' />
      <asp:BoundField DataField='Betrouwbaarheid' HeaderText='Betrouwbaarheid'
            SortExpression='Betrouwbaarheid' />
  </Columns>
  <FooterStyle BackColor='#5D7B9D' Font-Bold='True' ForeColor='White' />
  <PagerStyle BackColor='#284775' ForeColor='White' HorizontalAlign='Center' />
  <SelectedRowStyle BackColor='#E2DED6' Font-Bold='True' ForeColor='#333333' />
  <HeaderStyle BackColor='#5D7B9D' Font-Bold='True' ForeColor='White' />
  <EditRowStyle BackColor='#999999' />
  <AlternatingRowStyle BackColor='White' ForeColor='#284775' />
                                </asp:GridView>
                                <asp:SqlDataSource ID='GRIP_SqlDataSource' runat='server'
    ConnectionString='<%$ ConnectionStrings:ConnectionStringDIOS %>'

  SelectCommand='SELECT [Creatie], [GRIP], [GeplaatstDoor], [Namens], [Betrouwbaarheid]
FROM [GRIP] ORDER BY [Creatie] DESC'>
                                </asp:SqlDataSource>
                            </ContentTemplate>
                        </asp:UpdatePanel>
                    </asp:Panel>
                                <asp:CollapsiblePanelExtender
ID='GRIP_CollapsiblePanelExtender' runat='server'
                                TargetControlID='GRIP_ContentPanel'
ExpandControlID='GRIP_HeaderPanel'
CollapseControlID='GRIP_HeaderPanel' Collapsed='true'
                                ImageControlID='GRIP_Header_Image'
CollapsedImage='~/images/expand_blue.jpg'
ExpandedImage='~/images/collapse_blue.jpg' SuppressPostBack='true'>
                                </asp:CollapsiblePanelExtender>


                            </td>
       </tr>
    </div>
```

```
    <hr />
    <div id='footer'>2010 - All rights reserved. Property of Delft University of
Technology.</div>
    <div id='ex'>
        <br />
        <br />
    </div>
    </form>
    <p> </p>
</body>
</html>
```

# Appendix C: Gaming Simulation Materials

In this appendix, all materials used for the gaming simulation session are discussed. To simulate a disaster and to conceive it correctly within a gaming simulation, there are a number of essential components required. The following components were used: role descriptions, forms, start information and messages. An example of each component will be shown here below. As the session was played at the Police Academy of the Netherlands, all documentation below is in Dutch.

<table>
<tr><td colspan="2">Team Sitrap<br>Team: Tijd: ….-……</td></tr>
<tr><td>Locatie</td><td>Meteo</td></tr>
<tr><td colspan="2">Slachtoffers</td></tr>
<tr><td colspan="2">Risico’s en gevaren</td></tr>
<tr><td colspan="2">Besluiten</td></tr>
</table>

Figure 45: Master of Disaster Game - Team SITRAP

# Kolom SITRAP

**StartTijd:** ☐ : ☐

**Uw Kolom:** ☐ Politie ☐ Brandweer ☐ GHOR

**Uw Team** ☐ Veld ☐ CoPI ☐ GVS ☐ GMK

**Aan uw collega in:**
☐ Veld ☐ CoPI ☐ GVS ☐ GMK

**Tijd van aankomst:** ☐ : ☐

Lokatie

Weer

Slachtoffers

Risico’s en gevaren

Besluiten

Figure 46: Master of Disaster Game - Column SITRAP (Dutch: Kolom SITRAP)

## Informatie vraag en antwoord formulier

| | |
|---|---|
| **Van:** ☐ Veld ☐ CoPI ☐ GVS ☐ GMK | **Aan:** ☐ Veld ☐ CoPI ☐ GVS ☐ GMK |
| **Kolom:** ☐ Politie ☐ Brandweer ☐ GHOR | **Kolom:** ☐ Politie ☐ Brandweer ☐ GHOR |

Vraag over:

☐ De locatie ☐ Het weer ☐ De slachtoffers ☐ De risico's en gevaren ☐ De besluiten

Vraag

**Tijd bij vraagstelling:** ☐ : ☐

Antwoord

**Tijd bij beantwoording:** ☐ : ☐

Figure 47: Master of Disaster Game - Information Request and Response Form

# Bericht

AAN: VELD - BRW
**DATUM:** 12-03-2010
**TIJD:** 13:45

Een medewerker van de Leenbakker meldt dat twee bejaarden in het gebouw waren en dat deze volgens hem nog niet naar buiten zijn gelopen. Het is zaak om deze twee mensen te vinden nu de brand nog niet zo groot is in de Leenbakker!

Figure 48: Master of Disaster Game - Message

# Start Info – Brand Universiteit Rampendam

| | |
|---|---|
| **VAN:** | Gemeenschappelijke Meldkamer (GMK) |
| **AAN:** | **VELD – Chef van Dienst Politie** |
| **DATUM:** | 12-03-2010 |
| **TIJD:** | 15:15 |

### *GRIP*

| | |
|---|---|
| **GRIP** | 2 |
| **Betrouwbaarheid** | Hoog |

### *Locatie*

Faculteit Bouwkunde
Newtonweg 5
3122DE
Rampendam
Betrouwbaarheid: Hoog

### *Omstanders*

350 studenten van de Universiteit
Locatie: Faculteit Bouwkunde
De omstanders zijn **in gevaar**
Betrouwbaarheid: Hoog

### *Capaciteit*

Tot de beschikking:
4 Politiewagens
8 Agenten
Betrouwbaarheid: Hoog

### *Gevaren*

Gevaar: **Brand**, Prioriteit Gemiddeld
Brongebied: Faculteit Bouwkunde
Effectgebied: Campus Universiteit
Betrouwbaarheid: Hoog

**Figure 49: Master of Disaster Game – Start Information**

# 3. Rolbeschrijving Officier van Dienst Brandweer (OVD-B)

## Uw rol

In het spel bent u de tactische leidinggevende binnen de brandweer (rode) kolom. Bij rampen van GRIP 1 en hoger wordt u opgeroepen om zitting te nemen in het Commando Plaats Incident Team (COPI).

U hebt gedurende de ramp een aansturende en leidinggevende functie tegenover de brandweerfunctionarissen in het veld. Daarnaast vervult u een coördinerende functie samen met Politie en GHOR en een adviserende functie naar de leider COPI. U houdt zich vooral bezig met zaken zoals effectbestrijding, waarschuwen van de bevolking, gevaar/gas meting en ontsmetting.

## Uw taken

- Meewerken aan het opstellen van een situatie rapport (team-sitrap) dat door de Informatiemanager wordt doorgestuurd naar de GVS
- Iedere 20 minuten een kolom-sitrap doorsturen naar de Commandant Brandweer in de GVS via de postbode
- De informatie die u van het Veld en de GVS ontvangt delen met uw team

## Werkwijze en Interactie

**U ontvangt informatie van:**

- *De Commandant Brandweer in de GVS (in de vorm van een kolom-sitrap)*
- *De Veldfunctionaris Brandweer in het VELD (in de vorm van een kolom-sitrap)*
- *De GMK Brandweer (Meldkamer)*
- *De informatiemanager in de COPI (in de vorm van een team-sitrap)*

**U levert na overleg in de COPI informatie aan:**

- *De Commandant Brandweer in de GVS (in de vorm van een kolom-sitrap)*

U kunt gebruik maken van de informatie verzoekformulieren indien u meer informatie binnen uw kolom nodig heeft.

Figure 50: Master of Disaster Game - Role Description

# Appendix D: Questionnaires

In this appendix, the questionnaires of this research are shown. The questionnaires are in Dutch as the questionnaires were handed out at the Police Academy of the Netherlands.

---

## Master of Disaster - Vragenlijst voor Spelronde 1

Beste deelnemer,

Wij willen u vragen om deze vragenlijst invullen, als onderdeel van deze spelronde. De resultaten van deze vragenlijst zullen alleen worden gebruikt voor verder wetenschappelijk onderzoek naar de knelpunten voor informatie- en systeemkwaliteit tijdens rampenbestrijding.

Alvast bedankt voor het willen invullen van de vragenlijst!

**Deel A. Algemene vragen**

1. Voor welke organisatie werkt u?

□ a. Brandweer
□ b. Gemeente
□ c. GHOR
□ d. Politie
□ e. Waterschappen
□ f. Anders, namelijk………………………………………

2. Hoeveel jaar werkt u al voor deze organisatie?

□ a. 0 tot 1 jaar
□ b. 1 tot 3 jaar
□ c. 3 tot 5 jaar
□ d. 5 tot 10 jaar
□ e. 10 tot 20 jaar
□ f. meer dan 20 jaar

3. In welke van de volgende teams heeft u in de praktijk deelgenomen?

□ a. Regionale Beleids Team
□ b. COPI (COmmando Plaats Incident)
□ c. Veld
□ d. Gemeentelijke Veiligheidstaf
□ e. Meldkamer
□ f. Anders, namelijk ……………………………

4. Hoe vaak hebt u al meegedaan tijdens een daadwerkelijke GRIP situatie in de praktijk (GRIP 1 en hoger)?

□ a. 0 keer
□ b. 1 tot 5 keer
□ c. 5 tot 10 keer
□ d. 10 tot 15 keer
□ e. 15 tot 20 keer
□ f. meer als 20 keer

5. In welke van de volgende teams nam u deel gedurende het spel?

□ a. COPI (COmmando Plaats Incident)
□ b. GVS (Gemeentelijke Veiligheidsstaf)
□ c. Veld - Brandweer
□ d. Veld- Politie
□ e. Veld - GHOR
□ f. Meldkamer - Brandweer
□ g. Meldkamer - Politie
□ h. Meldkamer –GHOR

**Deel B. Evaluatie van de eerste spelronde**

De volgende vragen betreffen de eerste spelronde en zijn geformuleerd als stellingen.

**In hoeverre bent u het eens met de volgende stellingen?**

| | **Totaal Oneens** | | **(omcirkel uw keuze)** | | | | **Totaal Eens** |
|---|---|---|---|---|---|---|---|
| 1. De eerste spelronde was goed georganiseerd. | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 2. Het scenario van de eerste spelronde was realistisch. | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 3. De structuur (volgorde) van de eerste spelronde was duidelijk. | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 4. Ik kon op basis van mijn rolbeschrijving mijn taken in het spel goed vervullen. | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 5. Mijn rolbeschrijving in het spel komt overeen met mijn dagelijkse rol. | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 6. Mijn spelersboekje gaf mij voldoende informatie voor het kunnen deelnemen aan de eerste spelronde. | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 7. Het gebruiken van Sitraps om informatie te delen tussen de verschillen teams komt overeen met de werkelijkheid. | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 8. De afhankelijkheden tussen de deelnemende teams werd conform de realiteit in het spel nagespeeld. | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 9. De organisatoren hebben op een realistische wijze de informatie uitwisselingsprocessen tijdens crisissituaties gesimuleerd. | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 10. Over het algemeen was de eerste spelronde leerzaam. | **1** | 2 | 3 | **4** | 5 | 6 | **7** |

**Deel C. Evaluatie van de informatiekwaliteit**

Tijdens de eerste ronde van het spel heeft u aan de hand van situatie rapporten informatie van anderen ontvangen en informatie naar anderen verstuurd. U kunt de kwaliteit van de ontvangen informatie bepalen aan de hand van verschillende informatie kwaliteit dimensies, zoals de juistheid, volledigheid en tijdigheid.

**In hoeverre bent u het eens met de volgende stellingen omtrent de informatie kwaliteit tijdens de eerste spelronde?**

| | **Totaal Oneens** | | **(omcirkel uw keuze)** | | | | **Totaal Eens** |
|---|---|---|---|---|---|---|---|
| 1. Over het algemeen was de informatie die met mij werd gedeeld up-to-date. *<IQ timeliness1>* | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 2. Over het algemeen was de informatie die met mij werd gedeeld correct. *<IQ correctness1>* | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 3. Over het algemeen was de informatie die met mij werd gedeeld volledig. *<IQ completeness1>* | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 4. Ik kreeg teveel informatie van de anderen. *<IQ overload1>* | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 5. De informatie die ik van anderen ontving was relevant (direct bruikbaar voor de uitvoering van mijn taken). *<IQ relevancy1>* | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 6. Die informatie die ik van anderen ontving was consistent (niet in tegenstelling tot de informatie die ik al had). *<IQ consistency1>* | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 7. De Kolom-sitrap bevatte verouderde informatie. *<IQ timeliness2>* | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 8. De Kolom-sitrap bevatte foutieve informatie. *<IQ correctness2>* | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 9. De Kolom-sitrap bevatte onvolledige informatie. *<IQ completeness2>* | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 10. Ik ontving onvoldoende (niet genoeg) informatie. *<IQ overload2>* | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 11. Door de steeds veranderende situatie ontving ik informatie die niet meer actueel was. *<IQ timeliness3>* | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 12. Veel van de informatie die ik had ontvangen was onjuist. *<IQ correctness3>* | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 13. Vaak ontbrak het nodige detail in die informatie die anderen met mij deelden. *<IQ completeness3>* | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 14. In verhouding met wat ik aan informatie nodig had was de hoeveelheid informatie die anderen met mij deelden te veel. *<IQ overload3>* | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 15. Ik ontving informatie die ik niet nodig had voor het uitvoeren van mijn taken. *<IQ relevancy2>* | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 16. Ik ontving overbodige informatie. *<IQ relevancy3>* | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 17. De informatie die ik had was inconsistent met de informatie van de anderen in mijn team *<IQ consistency2>* | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 18. Ik zou graag van anderen willen weten hoe betrouwbaar de informatie is die ze met mij delen. *<Func_ feedback 1>* | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 19. Het was voor mij onduidelijk of de informatie die ik had ontvangen betrouwbaar was. *<Func_feedback2>* | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 20. Ik had het gevoel dat de overige deelnemers over andere informatie beschikten dan ik *<IQ_consistency2>.* | **1** | 2 | 3 | **4** | 5 | 6 | **7** |

**Deel D. Evaluatie van de systeemkwaliteit**

In de eerste ronde heeft u gebruik gemaakt van een hiërarchisch informatie systeem om informatie te kunnen ontvangen en delen. Dit informatie systeem valt te ontleden in een tweetal hoofdcomponenten: (1) formulieren, (2) een postbode (als vervanger voor C2000). U kunt u de kwaliteit van dit informatie systeem op basis van diverse kwaliteitsindicatoren beoordelen.

**In hoeverre bent u het eens met de volgende stellingen betreffende de systeemkwaliteit?**

| | **Totaal oneens** | | **(omcirkel uw keuze)** | | | | **Totaal eens** |
|---|---|---|---|---|---|---|---|
| 1. Het informatiesysteem gaf mij onmiddellijk alle informatie die ik nodig had. *<SQ Responsetime1>* | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 2. Via het informatiesysteem kon ik snel aan de informatie komen die ik nodig had. *<SQ_InfoAccesability1>* | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 3. Ik moest te lang wachten op informatie ik had aangevraagd. *<SQ Responsetime3>* | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 4. Ik kon rekenen op het informatiesysteem voor informatie. *<SQ reliability1>* | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 5. Het informatie systeem was eenvoudig te gebruiken. *(SQ Ease of use1)* | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 6. Het informatiesysteem bood mij toegang tot informatie (bijv. opvanglocaties) die buiten het bereik van mijn organisatie ligt. *<SQ_InfoAccesability1* | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 7. Via het informatie systeem had ik direct toegang tot de informatie die ik nodig had. *<Func_accesability2* | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 8. Het informatiesysteem notificeerde mij indien veranderingen in de crisissituatie waren opgetreden *<Func_ eventNotification1>*. | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 9. Dankzij het informatiesysteem had ik continu een totaal overzicht van alle informatie die ik nodig had. *<Func_ aggregation2>* | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 10. Veranderingen in basisinformatie (geo, meteo etc) waren onmiddellijk te zien in het informatiesysteem. *<Func_ eventNotification2>*. | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 11. Het informatiesysteem gaf mij inzicht in de betrouwbaarheid van informatie. *<Func_ feedback 3>* | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 12. Het informatie systeem bood mij een geaggregeerd (totaal) beeld van de crisissituatie. *<Func_ aggregation1>* | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 13. Het informatie systeem liet real-time (onmiddellijk) de veranderingen in de crisissituatie zien *<Func_EventNotification3>*. | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 14. Met dit informatie systeem was het eenvoudig om de geheugen (opgebouwde kennis van de situatie) te behouden *<Func_ Memory1>*. | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 15. Met dit informatie systeem was het eenvoudig om foto's of andere kaartinformatie te delen *<Func_ Multi-mediaexchange>*. | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 16. Met dit informatie systeem kon ik eenvoudig al mijn collega's (ook van de andere kolommen) van informatie voorzien <Func_Infosharing1> | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 17. Met dit informatie systeem kon ik eenvoudig al mijn collega's (ook van de andere kolommen) om informatie verzoeken. <Func_Infosharing2> | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 18. Ik ben tevreden over het huidige informatiesysteem. *<SQ_Satisfaction1>* | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 19. Ik vind het prima om dit hiërarchische informatiesysteem te blijven gebruiken in crisissituaties. *<SQ_Satisfaction2>* | **1** | 2 | 3 | **4** | 5 | 6 | **7** |

**Deel E. Indien u nog andere suggesties of opmerkingen heeft naar aanleiding van de eerste speelronde kunt u die hieronder opschrijven.**

Bedankt voor het invullen van de vragenlijst!

# Master of Disaster - Vragenlijst voor Spelronde 2

### Deel A. Evaluatie van de tweede spelronde

De volgende vragen betreffen de tweede spelronde en zijn geformuleerd als stellingen. In hoeverre bent u het eens met de volgende stellingen?

| | **Totaal Oneens** | | | | | | **Totaal Eens** |
|---|---|---|---|---|---|---|---|
| 1. De tweede spelronde was goed georganiseerd. | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 2. Het scenario van de tweede spelronde was realistisch. | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 3. Het scenario van de tweede spelronde was anders dan van de eerste spelronde. | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 4. De structuur (volgorde) van de tweede spelronde was duidelijk. | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 5. Mijn spelersboekje gaf mij voldoende informatie voor het kunnen deelnemen aan de tweede spelronde. | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 6. Over het algemeen was de tweede spelronde leerzaam. | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 7. Ten opzichte van de eerste spelronde was het makkelijker om informatie te delen in de tweede spelronde. | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 8. In de tweede spelronde hadden we betere situatie rapporten dan in de eerste spelronde. | **1** | 2 | 3 | **4** | 5 | 6 | **7** |

**Deel B. Evaluatie van de informatiekwaliteit**

Tijdens de tweede spelronde heeft u aan de hand van het DIOS Systeem informatie van anderen ontvangen en informatie naar anderen verstuurd. U kunt de kwaliteit van de ontvangen informatie bepalen aan de hand van verschillende informatie kwaliteit dimensies, zoals de juistheid, volledigheid en tijdigheid.

**In hoeverre bent u het eens met de volgende stellingen omtrent de informatiekwaliteit tijdens de tweede spelronde?**

| | **Totaal Oneens** | | | | | | **Totaal Eens** |
|---|---|---|---|---|---|---|---|
| 1. Over het algemeen was de informatie die met mij werd gedeeld up-to-date. *<IQ timeliness1>* | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 2. Over het algemeen was de informatie die met mij werd gedeeld correct. *<IQ correctness1>* | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 3. Over het algemeen was de informatie die met mij werd gedeeld volledig. *<IQ completeness1>* | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 4. Ik kreeg teveel informatie van de anderen. *<IQ overload1>* | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 5. De informatie die ik van anderen ontving was relevant (direct bruikbaar voor de uitvoering van mijn taken). *<IQ relevancy1>* | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 6. Die informatie die ik van anderen ontving was consistent (niet in tegenstelling tot de informatie die ik al had). *<IQ consistency1>* | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 7. De Kolom-sitrap bevatte verouderde informatie. *<IQ timeliness2>* | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 8. De Kolom-sitrap bevatte foutieve informatie. *<IQ correctness2>* | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 9. De Kolom-sitrap bevatte onvolledige informatie. *<IQ completeness2>* | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 10. Ik ontving onvoldoende (niet genoeg) informatie. *<IQ overload2>* | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 11. Door de steeds veranderende situatie ontving ik informatie die niet meer actueel was. *<IQ timeliness3>* | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 12. Veel van de informatie die ik had ontvangen was onjuist. *<IQ correctness3>* | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 13. Vaak ontbrak het nodige detail in die informatie die anderen met mij deelden. *<IQ completeness3>* | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 14. In verhouding met wat ik aan informatie nodig had was de hoeveelheid informatie die anderen met mij deelden te veel. *<IQ overload3>* | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 15. Ik ontving informatie die ik niet nodig had voor het uitvoeren van mijn taken. *<IQ relevancy2>* | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 16. Ik ontving overbodige informatie. *<IQ relevancy3>* | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 17. De informatie die ik had was inconsistent met de informatie van de anderen in mijn team *<IQ consistency2>* | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 18. Ik zou graag van anderen willen weten hoe betrouwbaar de informatie is die ze met mij delen. *<Func_ feedback 1>* | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 19. Het was voor mij onduidelijk of de informatie die ik had ontvangen betrouwbaar was. *<Funck feedback 2>* | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 20. Ik had het gevoel dat de overige deelnemers over andere informatie beschikten dan ik *<IQ consistency2>.* | **1** | 2 | 3 | **4** | 5 | 6 | **7** |

**Deel C. Evaluatie van de systeemkwaliteit**

In de tweede spelronde heeft u gebruik gemaakt van een netcentrische informatie systeem (DIOS) om informatie te kunnen ontvangen en delen. In dit Netcentrische informatie systeem is de bedoeling dat iedereen real-time informatie kan delen in een centraal overzicht. U kunt u de kwaliteit van DIOS op basis van diverse kwaliteitsindicatoren beoordelen.

**In hoeverre bent u het eens met de volgende stellingen betreffende de systeemkwaliteit?**

| | **Totaal oneens** | | | | | | **Totaal eens** |
|---|---|---|---|---|---|---|---|
| 1. DIOS gaf mij onmiddellijk alle informatie die ik nodig had. *<SQ Responsetime1>* | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 2. Via DIOS kon ik snel aan de informatie komen die ik nodig had. *<SQ_InfoAccesability1>* | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 3. Ik moest te lang wachten op informatie ik had aangevraagd. *<SQ Responsetime3>* | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 4. Ik kon rekenen op DIOS voor informatie. *<SQ reliability1>* | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 5. DIOS was eenvoudig te gebruiken. *(SQ Ease of use1)* | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 6. DIOS bood mij toegang tot informatie (bijv. opvanglocaties) die buiten het bereik van mijn organisatie ligt. *<SQ_InfoAccesability1* | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 7. Via het DIOS had ik direct toegang tot de informatie die ik nodig had. *<Func_accesability2* | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 8. DIOS notificeerde mij indien veranderingen in de crisissituatie waren opgetreden *<Func_ eventNotification1>*. | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 9. Dankzij DIOS had ik continu een totaal overzicht van alle informatie die ik nodig had. *<Func_ aggregation2>* | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 10. Veranderingen in basisinformatie (geo, meteo etc) waren onmiddellijk te zien in DIOS. *<Func_ eventNotification2>*. | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 11. DIOS gaf mij inzicht in de betrouwbaarheid van informatie. *<Func_ feedback 3>* | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 12. DIOS bood mij een geaggregeerd (totaal) beeld van de crisissituatie. *<Func_ aggregation1>* | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 13. Het DIOS liet real-time (onmiddellijk) de veranderingen in de crisissituatie zien *<Func_EventNotification3>*. | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 14. Met DIOS was het eenvoudig om de geheugen (opgebouwde kennis van de situatie) te behouden *<Func_ Memory1>*. | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 15. Met DIOS was het eenvoudig om foto's of andere kaartinformatie te delen *<Func_ Multi-media exchange>*. | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 16. Met DIOS kon ik eenvoudig al mijn collega's (ook van de andere kolommen) van informatie voorzien <Func_Infosharing1> | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 17. Met DIOS kon ik eenvoudig al mijn collega's (ook van de andere kolommen) om informatie verzoeken. <Func_Infosharing2> | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 18. Ik ben tevreden over DIOS. *<SQ_Satisfaction1>* | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 19. Ik vind het prima om dit netcentrische informatiesysteem te gaan gebruiken in crisissituaties. *<SQ_Satisfaction2>* | **1** | 2 | 3 | **4** | 5 | 6 | **7** |

**Deel D. Evaluatie van de systeemfunctionaliteiten**

DIOS kent enkele specifieke functionaliteiten die de informatiekwaliteit en systeemkwaliteit moeten waarborgen. Voorbeelden van deze functionaliteiten zijn het kunnen beoordelen van de informatie betrouwbaarheid en het opbouwen van een dynamische situatie beeld. In hoeverre bent u het eens met de volgende stellingen betreffende de systeemfunctionaliteiten?

| | Totaal oneens | | (omcirkel uw keuze) | | | | Totaal eens |
|---|---|---|---|---|---|---|---|
| 1. De manier waarop informatie in DIOS is gecategoriseerd behoedt mij voor informatie overload (Func_category→IQ info amount) | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 2. Het kunnen opzoeken van derde partij/externe informatie via DIOS versnelde het informatiedelings proces (Func_thirdparty1→info sharing speed) | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 3. Het dashboardoverzicht van laatst toegevoegde informatie in DIOS versnelde het informatiedelings proces (Func_dashboard→info sharing speed) | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 4. Met DIOS kon ik sneller informatie delen binnen mijn team (infosharingspeed_team level) | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 5. Met DIOS kon ik sneller informatie delen met mijn kolom (infosharingspeed_organizational level) | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 6. Doordat iedereen in het netwerk alle informatie in DIOS konden zien hadden wij sneller een gedeeld beeld van de situatie (Func_NetworkSitrap→ Situational Awareness) | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 7. Via DIOS zijn wij sneller gekomen tot een gedeeld beeld van de situatie (Situational Awareness) | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 8. Dankzij de vermelde betrouwbaarheid van de geplaatste informatie in DIOS konden wij als team sneller door de veelheid aan informatie (Funct_Rating→ IQ amount of infosharingSpeed??) | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 9. Ik zou graag de door anderen geplaatste informatie willen beoordelen op de betrouwbaarheid (Func_Rating) | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 10. De opgebouwde bibliotheek van informatie DIOS zorgde ervoor dat we geen belangrijke informatie kwijtraakten (Func_Memory→IQ relevancy) | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 11. De real-time veranderingen in de informatievelden van DIOS zorgen ervoor dat ik op de hoogte bleef van veranderingen in de crisis situatie (Funct_eventNotification → Situational awareness) | **1** | 2 | 3 | **4** | 5 | 6 | **7** |
| 12. Met DIOS kon ik alle belangrijke informatie terugvinden. (Func_Memory) | **1** | 2 | 3 | **4** | 5 | 6 | **7** |

**Deel E. Indien u nog andere suggesties of opmerkingen heeft naar aanleiding van de tweede speelronde kunt u die hieronder opschrijven.**

**Indien u een samenvatting van dit onderzoek wenst te ontvangen, kunt u hieronder uw e-mailadres opschrijven.**

Bedankt voor het invullen van de vragenlijst!

# Appendix E: SPSS Codebook

In this appendix, the codebook of the data file will be discussed. In this codebook, variables retrieved from the questionnaires will be explained by showing the variable name and label, the used value labels and the measurement level of the question.

Questionnaire 1 and 2 are divided into six parts. Each part will separately be discussed in the sections below.

| Part | Description | Q1 | Q2 |
|---|---|---|---|
| **A. General Questions** | Demographics of the respondents | X | |
| **B. Evaluation of the Game Round** | 8-10 questions concerning the gaming simulation itself | X | X |
| **C. Evaluation of Information Quality** | 20 questions on the assessment of information quality | X | X |
| **D. Evaluation of System Quality** | 19 questions on the assessment of system quality | X | X |
| **E. Evaluation of system functionalities** | 12 questions on the assessment of the propositions of DIOS | | X |
| **F. Suggestions and Comments** | Open fields for comments | X | X |

## Part A: General Questions

| Variable Name | Variable Label | Value Labels | Measurement Level |
|---|---|---|---|
| **R1_A_ORGANIZATION** | Of which organization are you an employee? | 1 = Fire Department<br>2 = Police<br>3 = Paramedics<br>4 = Municipality<br>5 = Water Authority<br>6 = Other, namely | Nominal |
| **R1_A_WORKYEARS** | How many years do you work for this organization? | 1 = 0-1 years<br>2 = 1-3 years<br>3 = 3-5 years<br>4 = 5-10 years<br>5 = 10-20 years<br>6 = >20 years | Ordinal |
| **R1_A_WORKTEAMS** | Which of the following teams have you participated in practice? | 1 = Regionaal BT<br>2 = CoPI<br>3 = Veld<br>4 = GVS<br>5 = Meldkamer<br>6 = Other, namely | Nominal |
| **R1_A_NRGRIP** | How many times have you already participated in a real GRIP situation (GRIP 1 and higher)? | 1 = 0 times<br>2 = 1-5 times<br>3 = 5-10 times<br>4 = 10-15 times<br>5 = 15-20 times<br>6 = > 20 times | Ordinal |
| **R1_A_GAMETEAM** | In which of the following teams did you take part during the game? | 1 = CoPI<br>2 = GVS<br>3 = Veld-BRW<br>4 = Veld-POL<br>5 = Veld-GHOR<br>6 = GMK-BRW<br>7 = GMK-POL<br>8 = GMK-GHOR | Nominal |

## Part B: Evaluation of the Game Round

| Variable Name | Variable Label | Value Labels | Measurement Level |
|---|---|---|---|
| **R1_GAME_ORGANIZED** | The first round was well organized | 1 = Strongly Disagree<br>2 = Disagree<br>3 = Slightly Disagree<br>4 = Neutral<br>5 = Slightly Agree<br>6 = Agree<br>7 = Strongly Agree | Nominal |
| **R1_GAME_REALISM** | The scenario of the first round was realistic | 1 = Strongly Disagree<br>2 = Disagree<br>3 = Slightly Disagree<br>4 = Neutral<br>5 = Slightly Agree<br>6 = Agree<br>7 = Strongly Agree | Interval |
| **R1_GAME_STRUCTURE** | The structure of the first round was clear | 1 = Strongly Disagree<br>2 = Disagree<br>3 = Slightly Disagree<br>4 = Neutral<br>5 = Slightly Agree<br>6 = Agree<br>7 = Strongly Agree | Interval |
| **R1_GAME_TASKS** | Based on my role description, I could fulfill my tasks well in the game | 1 = Strongly Disagree<br>2 = Disagree<br>3 = Slightly Disagree<br>4 = Neutral<br>5 = Slightly Agree<br>6 = Agree<br>7 = Strongly Agree | Interval |
| **R1_GAME_ROLE** | My role description in the game matches my daily role | 1 = Strongly Disagree<br>2 = Disagree<br>3 = Slightly Disagree<br>4 = Neutral<br>5 = Slightly Agree<br>6 = Agree<br>7 = Strongly Agree | Interval |
| **R1_GAME_GAMEBOOK** | My game book gave me enough information to take part in the first round | 1 = Strongly Disagree<br>2 = Disagree<br>3 = Slightly Disagree<br>4 = Neutral<br>5 = Slightly Agree<br>6 = Agree<br>7 = Strongly Agree | Interval |
| **R1_GAME_INFOSHARING** | Using Sitraps to share information between different teams reflects the reality | 1 = Strongly Disagree<br>2 = Disagree<br>3 = Slightly Disagree<br>4 = Neutral<br>5 = Slightly Agree<br>6 = Agree<br>7 = Strongly Agree | Interval |
| **R1_GAME_DEPENDENCIES** | The dependencies between the teams in the game were in line with reality | 1 = Strongly Disagree<br>2 = Disagree<br>3 = Slightly Disagree<br>4 = Neutral<br>5 = Slightly Agree<br>6 = Agree<br>7 = Strongly Agree | Interval |
| **R1_GAME_INFOPROCESSES** | The organizers have simulated the crisis information exchange processes realistically | 1 = Strongly Disagree<br>2 = Disagree<br>3 = Slightly Disagree | Interval |

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|---|---|---|---|
| | | 4 = Neutral<br>5 = Slightly Agree<br>6 = Agree<br>7 = Strongly Agree | |
| **R1_GAME_INSTRUCTIVE** | In general, the first round was instructive | 1 = Strongly Disagree<br>2 = Disagree<br>3 = Slightly Disagree<br>4 = Neutral<br>5 = Slightly Agree<br>6 = Agree<br>7 = Strongly Agree | Interval |

## Part C: Evaluation of Information Quality

| Variable Name | Variable Label | Value Labels | Measurement Level |
|---|---|---|---|
| **R1_IQ_TIMELINESS_1** | In general, the information shared with me was up to date. | 1 = Strongly Disagree<br>2 = Disagree<br>3 = Slightly Disagree<br>4 = Neutral<br>5 = Slightly Agree<br>6 = Agree<br>7 = Strongly Agree | Nominal |
| **R1_IQ_CORRECTNESS_1** | In general, the information shared with me was correct. | 1 = Strongly Disagree<br>2 = Disagree<br>3 = Slightly Disagree<br>4 = Neutral<br>5 = Slightly Agree<br>6 = Agree<br>7 = Strongly Agree | Interval |
| **R1_IQ_COMPLETENESS_1** | In general, the information shared with me was complete. | 1 = Strongly Disagree<br>2 = Disagree<br>3 = Slightly Disagree<br>4 = Neutral<br>5 = Slightly Agree<br>6 = Agree<br>7 = Strongly Agree | Interval |
| **R1_IQ_OVERLOAD_1** | I got too much information from others | 1 = Strongly Disagree<br>2 = Disagree<br>3 = Slightly Disagree<br>4 = Neutral<br>5 = Slightly Agree<br>6 = Agree<br>7 = Strongly Agree | Interval |
| **R1_IQ_RELEVANCY_1** | The information I received from others was relevant (directly usable for my duties) | 1 = Strongly Disagree<br>2 = Disagree<br>3 = Slightly Disagree<br>4 = Neutral<br>5 = Slightly Agree<br>6 = Agree<br>7 = Strongly Agree | Interval |
| **R1_IQ_CONSISTENCY_1** | The information I received from others was consistent | 1 = Strongly Disagree<br>2 = Disagree<br>3 = Slightly Disagree<br>4 = Neutral<br>5 = Slightly Agree<br>6 = Agree<br>7 = Strongly Agree | Interval |
| **R1_IQ_TIMELINESS_2** | The Kolom sitrap contained outdated information | 1 = Strongly Disagree<br>2 = Disagree<br>3 = Slightly Disagree<br>4 = Neutral | Interval |

| | | | |
|---|---|---|---|
| | | 5 = Slightly Agree<br>6 = Agree<br>7 = Strongly Agree | |
| **R1_IQ_CORRECTNESS_2** | The Kolom sitrap contained erroneous information | 1 = Strongly Disagree<br>2 = Disagree<br>3 = Slightly Disagree<br>4 = Neutral<br>5 = Slightly Agree<br>6 = Agree<br>7 = Strongly Agree | Interval |
| **R1_IQ_COMPLETENESS_2** | The Kolom sitrap contained incomplete information | 1 = Strongly Disagree<br>2 = Disagree<br>3 = Slightly Disagree<br>4 = Neutral<br>5 = Slightly Agree<br>6 = Agree<br>7 = Strongly Agree | Interval |
| **R1_IQ_OVERLOAD_2** | I received not enough information | 1 = Strongly Disagree<br>2 = Disagree<br>3 = Slightly Disagree<br>4 = Neutral<br>5 = Slightly Agree<br>6 = Agree<br>7 = Strongly Agree | Interval |
| **R1_IQ_TIMELINESS_3** | With the ever changing situation, I received information that no longer was actual | 1 = Strongly Disagree<br>2 = Disagree<br>3 = Slightly Disagree<br>4 = Neutral<br>5 = Slightly Agree<br>6 = Agree<br>7 = Strongly Agree | Interval |
| **R1_IQ_CORRECTNESS_3** | Much of the information I had received was incorrect | 1 = Strongly Disagree<br>2 = Disagree<br>3 = Slightly Disagree<br>4 = Neutral<br>5 = Slightly Agree<br>6 = Agree<br>7 = Strongly Agree | Interval |
| **R1_IQ_COMPLETENESS_3** | Information that others shared with me often lacked the necessary details | 1 = Strongly Disagree<br>2 = Disagree<br>3 = Slightly Disagree<br>4 = Neutral<br>5 = Slightly Agree<br>6 = Agree<br>7 = Strongly Agree | Interval |
| **R1_IQ_OVERLOAD_3** | The amount of information that others shared with me was too much compared to what I needed | 1 = Strongly Disagree<br>2 = Disagree<br>3 = Slightly Disagree<br>4 = Neutral<br>5 = Slightly Agree<br>6 = Agree<br>7 = Strongly Agree | Interval |
| **R1_IQ_RELEVANCY_2** | I received information I did not need to perform my duties | 1 = Strongly Disagree<br>2 = Disagree<br>3 = Slightly Disagree<br>4 = Neutral<br>5 = Slightly Agree<br>6 = Agree<br>7 = Strongly Agree | Interval |
| **R1_IQ_RELEVANCY_3** | I received unnecessary information | 1 = Strongly Disagree<br>2 = Disagree<br>3 = Slightly Disagree<br>4 = Neutral | Interval |

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|---|---|---|---|
| | | 5 = Slightly Agree<br>6 = Agree<br>7 = Strongly Agree | |
| **R1_IQ_CONSISTENCY_2** | The information I had was inconsistent with the information of others in my team | 1 = Strongly Disagree<br>2 = Disagree<br>3 = Slightly Disagree<br>4 = Neutral<br>5 = Slightly Agree<br>6 = Agree<br>7 = Strongly Agree | Interval |
| **R1_F_FEEDBACK_1** | I would like to know of others how reliable the information was they share with me | 1 = Strongly Disagree<br>2 = Disagree<br>3 = Slightly Disagree<br>4 = Neutral<br>5 = Slightly Agree<br>6 = Agree<br>7 = Strongly Agree | Interval |
| **R1_F_FEEDBACK_2** | It was unclear to me whether the information I had received was reliable | 1 = Strongly Disagree<br>2 = Disagree<br>3 = Slightly Disagree<br>4 = Neutral<br>5 = Slightly Agree<br>6 = Agree<br>7 = Strongly Agree | Interval |
| **R1_IQ_CONSISTENCY_3** | I had the feeling that the other participants had more information than me | 1 = Strongly Disagree<br>2 = Disagree<br>3 = Slightly Disagree<br>4 = Neutral<br>5 = Slightly Agree<br>6 = Agree<br>7 = Strongly Agree | Interval |

## Part D: Evaluation of System Quality

| Variable Name | Variable Label | Value Labels | Measurement Level |
|---|---|---|---|
| **R1_SQ_RESPONSETIME_1** | The information system immediately gave me all the information I needed. | 1 = Strongly Disagree<br>2 = Disagree<br>3 = Slightly Disagree<br>4 = Neutral<br>5 = Slightly Agree<br>6 = Agree<br>7 = Strongly Agree | Nominal |
| **R1_SQ_ACCESSIBILITY_1** | Through the information system I could quickly get the information I needed | 1 = Strongly Disagree<br>2 = Disagree<br>3 = Slightly Disagree<br>4 = Neutral<br>5 = Slightly Agree<br>6 = Agree<br>7 = Strongly Agree | Interval |
| **R1_SQ_RESPONSETIME_2** | I had to wait too long on information I had requested | 1 = Strongly Disagree<br>2 = Disagree<br>3 = Slightly Disagree<br>4 = Neutral<br>5 = Slightly Agree<br>6 = Agree<br>7 = Strongly Agree | Interval |
| **R1_SQ_RELIABILITY_1** | I could count on the information system for delivering information | 1 = Strongly Disagree<br>2 = Disagree<br>3 = Slightly Disagree<br>4 = Neutral<br>5 = Slightly Agree | Interval |

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|---|---|---|---|
| | | 6 = Agree<br>7 = Strongly Agree | |
| **R1_SQ_EASEOFUSE_1** | The information system was easy to use | 1 = Strongly Disagree<br>2 = Disagree<br>3 = Slightly Disagree<br>4 = Neutral<br>5 = Slightly Agree<br>6 = Agree<br>7 = Strongly Agree | Interval |
| **R1_SQ_ACCESSIBILITY_2** | The information system offered me access to external sources of information (e.g. victim reception centers) | 1 = Strongly Disagree<br>2 = Disagree<br>3 = Slightly Disagree<br>4 = Neutral<br>5 = Slightly Agree<br>6 = Agree<br>7 = Strongly Agree | Interval |
| **R1_SQ_ACCESSIBILITY_3** | Through the information system I had direct access to the information I needed | 1 = Strongly Disagree<br>2 = Disagree<br>3 = Slightly Disagree<br>4 = Neutral<br>5 = Slightly Agree<br>6 = Agree<br>7 = Strongly Agree | Interval |
| **R1_F_EVENTNOTIFICATION_1** | The information system notified me when changes in the crisis had occurred | 1 = Strongly Disagree<br>2 = Disagree<br>3 = Slightly Disagree<br>4 = Neutral<br>5 = Slightly Agree<br>6 = Agree<br>7 = Strongly Agree | Interval |
| **R1_F_AGGREGATION_1** | With the information system I had a continuous overview of all the information I needed | 1 = Strongly Disagree<br>2 = Disagree<br>3 = Slightly Disagree<br>4 = Neutral<br>5 = Slightly Agree<br>6 = Agree<br>7 = Strongly Agree | Interval |
| **R1_F_EVENTNOTIFICATION_2** | Changes in basic information (location, weather etc) were immediately seen in the information system | 1 = Strongly Disagree<br>2 = Disagree<br>3 = Slightly Disagree<br>4 = Neutral<br>5 = Slightly Agree<br>6 = Agree<br>7 = Strongly Agree | Interval |
| **R1_F_RELIABILITYINDICATION_1** | The information system gave me insight into the reliability of information | 1 = Strongly Disagree<br>2 = Disagree<br>3 = Slightly Disagree<br>4 = Neutral<br>5 = Slightly Agree<br>6 = Agree<br>7 = Strongly Agree | Interval |
| **R1_F_AGGREGATION_2** | The information system offered me an overall picture of the crisis | 1 = Strongly Disagree<br>2 = Disagree<br>3 = Slightly Disagree<br>4 = Neutral<br>5 = Slightly Agree<br>6 = Agree<br>7 = Strongly Agree | Interval |
| **R1_F_EVENTNOTIFICATION_3** | The information system showed real-time changes in the crisis | 1 = Strongly Disagree<br>2 = Disagree<br>3 = Slightly Disagree<br>4 = Neutral<br>5 = Slightly Agree | Interval |

| | | | |
|---|---|---|---|
| | | 6 = Agree<br>7 = Strongly Agree | |
| **R1_F_MEMORY_1** | This information system maintained the memory (accumulated knowledge of the situation) of the crisis | 1 = Strongly Disagree<br>2 = Disagree<br>3 = Slightly Disagree<br>4 = Neutral<br>5 = Slightly Agree<br>6 = Agree<br>7 = Strongly Agree | Interval |
| **R1_F_MULTIMEDIA_1** | With this information system, it was easy to share photos or map information | 1 = Strongly Disagree<br>2 = Disagree<br>3 = Slightly Disagree<br>4 = Neutral<br>5 = Slightly Agree<br>6 = Agree<br>7 = Strongly Agree | Interval |
| **R1_F_INFOSHARING_1** | With this information system I could easily provide all my colleagues (also from other columns) of information | 1 = Strongly Disagree<br>2 = Disagree<br>3 = Slightly Disagree<br>4 = Neutral<br>5 = Slightly Agree<br>6 = Agree<br>7 = Strongly Agree | Interval |
| **R1_F_INFOSHARING_2** | With this information system I could easily request all my colleagues (also from other columns) for information | 1 = Strongly Disagree<br>2 = Disagree<br>3 = Slightly Disagree<br>4 = Neutral<br>5 = Slightly Agree<br>6 = Agree<br>7 = Strongly Agree | Interval |
| **R1_SQ_SATISFACTION_1** | I am satisfied with the current information system | 1 = Strongly Disagree<br>2 = Disagree<br>3 = Slightly Disagree<br>4 = Neutral<br>5 = Slightly Agree<br>6 = Agree<br>7 = Strongly Agree | Interval |
| **R1_SQ_SATISFACTION_2** | I think it's fine to continue to use this hierarchical information system in crisis situations | 1 = Strongly Disagree<br>2 = Disagree<br>3 = Slightly Disagree<br>4 = Neutral<br>5 = Slightly Agree<br>6 = Agree<br>7 = Strongly Agree | Interval |

## Part E: Evaluation of system functionalities (propositions)

| Variable Name | Variable Label | Value Labels | Measurement Level |
|---|---|---|---|
| **R2_F_CATEGORIZATION** | The way information is categorized in DIOS protected me from information overload. | 1 = Strongly Disagree<br>2 = Disagree<br>3 = Slightly Disagree<br>4 = Neutral<br>5 = Slightly Agree<br>6 = Agree<br>7 = Strongly Agree | Nominal |
| **R2_F_THIRDPARTY** | The ability to search through external information via DIOS accelerated the information sharing process | 1 = Strongly Disagree<br>2 = Disagree<br>3 = Slightly Disagree<br>4 = Neutral<br>5 = Slightly Agree<br>6 = Agree | Interval |

| | | | |
|---|---|---|---|
| | | 7 = Strongly Agree | |
| **R2_F_DASHBOARD** | The dashboard overview of last added information in DIOS accelerated the information sharing process | 1 = Strongly Disagree<br>2 = Disagree<br>3 = Slightly Disagree<br>4 = Neutral<br>5 = Slightly Agree<br>6 = Agree<br>7 = Strongly Agree | Interval |
| **R2_F_SHARINGSPEED_TEAM** | With DIOS I could quickly share information with my team | 1 = Strongly Disagree<br>2 = Disagree<br>3 = Slightly Disagree<br>4 = Neutral<br>5 = Slightly Agree<br>6 = Agree<br>7 = Strongly Agree | Interval |
| **R2_F_SHARINGSPEED_ORG** | With DIOS I could quickly share information with my column | 1 = Strongly Disagree<br>2 = Disagree<br>3 = Slightly Disagree<br>4 = Neutral<br>5 = Slightly Agree<br>6 = Agree<br>7 = Strongly Agree | Interval |
| **R2_F_NETWORKSITRAP** | Because everyone in the network could see information in DIOS, we had a faster shared picture of the situation | 1 = Strongly Disagree<br>2 = Disagree<br>3 = Slightly Disagree<br>4 = Neutral<br>5 = Slightly Agree<br>6 = Agree<br>7 = Strongly Agree | Interval |
| **R2_F_SITUATIONAWARENESS** | Through DIOS we quickly came to a shared picture of the situation. | 1 = Strongly Disagree<br>2 = Disagree<br>3 = Slightly Disagree<br>4 = Neutral<br>5 = Slightly Agree<br>6 = Agree<br>7 = Strongly Agree | Interval |
| **R2_F_RATING_1** | Thanks to reliability notions of the posted information in DIOS we accelerated the information sharing process | 1 = Strongly Disagree<br>2 = Disagree<br>3 = Slightly Disagree<br>4 = Neutral<br>5 = Slightly Agree<br>6 = Agree<br>7 = Strongly Agree | Interval |
| **R2_F_RATING_2** | I would like to rate the information posted by others on reliability | 1 = Strongly Disagree<br>2 = Disagree<br>3 = Slightly Disagree<br>4 = Neutral<br>5 = Slightly Agree<br>6 = Agree<br>7 = Strongly Agree | Interval |
| **R2_F_MEMORY_2** | The built library of information in DIOS meant that we did not lose any important information | 1 = Strongly Disagree<br>2 = Disagree<br>3 = Slightly Disagree<br>4 = Neutral<br>5 = Slightly Agree<br>6 = Agree<br>7 = Strongly Agree | Interval |
| **R2_F_EVENTNOTIFICATION_4** | The real-time changes in information fields DIOS ensured that I was aware of changes in the crisis situation | 1 = Strongly Disagree<br>2 = Disagree<br>3 = Slightly Disagree<br>4 = Neutral<br>5 = Slightly Agree<br>6 = Agree | Interval |

| | | | |
|---|---|---|---|
| | | 7 = Strongly Agree | |
| **R2_F_MEMORY_3** | With DIOS I could find all my information relevant for my job | 1 = Strongly Disagree<br>2 = Disagree<br>3 = Slightly Disagree<br>4 = Neutral<br>5 = Slightly Agree<br>6 = Agree<br>7 = Strongly Agree | Interval |

For the suggestions and comments section of the questionnaires, no codebook has been made as these statements are often not coded into groups.