Integrating technology in crisis response using an information manager: first lessons learned from field exercises in the Port of Rotterdam

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ABSTRACT

Integrating information technology (IT) in crisis management networks is a difficult and long-term endeavor. First responders must establish situational awareness and take decisions under time pressure with incomplete information. Partly, this can be mitigated by adopting more advanced IT, however practice shows that adoption is hampered because of the required change in routines and procedures. We believe that we can moderate a change in routines and stimulate the adoption of technology by introducing a new role: the information manager (IM). This paper presents some results of the first round of field observations. The main conclusion is that the IM is instrumental where it concerns, speeding up the process of establishing situational awareness and improving the information structures. In order to further improve the production of situational awareness we suggest that further research should address the issues of the internalization of process guidelines and enhancing the adaptability of information systems.

Keywords: crisis management, operational command, situational awareness, information manager

INTRODUCTION

Recent crisis response operations in London, Madrid and Schiphol have again underlined the problem of establishing quick situational awareness in and between multidisciplinary response teams. Exercises, such as Bonfire in Amsterdam, reveal that the key factor for achieving effective crisis response is having the right information available at the right time and right place (Helsloot, 2005). Information is often viewed as the main ingredient for achieving situational awareness in rescue teams (Smith, 2000, Turoff, 2004). In this context, situational awareness refers to "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future" (Endsley, 1988). As pointed out by smart (Smart, 1977), a crisis can be characterized by factors such as stress, surprise, restricted amount of time for response and threats to high priority goals. While the first responders (policemen, firemen, medical staff etc) are confronted with very complex and often unexpected tasks, situational awareness is needed within the shortest timeframe possible to decide what would be the most effective actions (Endsley, 2003, Appelman, 2005). More specifically, commanders of the various crisis management teams (that aim to coordinate the actions of the first responders in the field) find it very hard to create a joint operational picture, make decisions and define actions in the early stages of a crisis.

Proponents of information technology (IT) have suggested using multiple advanced IT solutions in order to support the establishment of situational awareness in the early staged of a crisis. A number of intelligent IT applications and devises are proposed in the literature (Burghardt, 2004, Sawyer, 2004). While the advantages of such innovative information and communication technologies may seem obvious (Rinkineva, 2003), our observation of exercises and our involvement in the organization of exercises and experiments over the past 2 years show that such innovative IT is not adopted even if offered for free.

Nevertheless, it is clear from other domains, like the public defense sector, that IT can be usefully employed in times of crisis. Considering the fact that the crisis management networks we focus on (collaboration of police, fire department etc) follow a less hierarchical command structure and are less advanced in their adoption of technology, we believe a different technology integration approach needs to be taken than in the military and private sector. Hence, the main goal in the approach elucidated in this paper is to ensure that integration *of advanced IT systems in crisis management decision-making teams also leads to sustained and effective use.*

Our preliminary analysis and the people responsible for professionalizing crisis management operations suggested that there is a need for the introduction of an information manager (IM) in crisis-response teams. Such a team member, who is an officer in non-crisis situations, should have access to more advanced IT, that is able to support a group in achieving situational awareness, during decision-making and improve administration.

This paper reports on the first observations of crisis response teams that were introduced to new technology without prior instruction. This is part of the change management approach: the IT exposure phase, in which technologies are selected for testing and training because they are considered likely additions in the near future. We concern ourselves here with two main questions: *was the information that the systems provided was used in the group process and how did the information manager and group leader interact?*

This paper proceeds by relating our work to previous research. This is followed by a contextualization of the embedded case, including an analysis of the multi-actor environment and the information structure during crisis management exercises. After presenting the research setting, the paper continues with an elaboration on the adapted research approach. Then we discuss our preliminary findings considering the role of the IM in relation to the introduced technology. Finally, the paper presents some points for discussion and the main conclusions of this research.

RELATED WORK

There have been several attempts to understand and predict IT adoption in organizations (Davis, 1993, Karahanna, 1999). However, in the domain of crisis management, very little has been published on the acceptance and adoption of IT. There seems to be more focus on developing advanced IT than on effectively integrating basic technology in crisis management processes. In our view, concepts used in models such as the Technology Acceptance Model (TAM) are more suitable for describing the acceptance and adoption of IT in a setting where which decision-makers are the users of the proposed IT (e.g. IT for managers). While TAM does take into account the set of system design features, this model does not consider the special characteristics (stress, time pressure, uncertainty etc) inherent to crises. Moreover, Legris et al (2003) state that the TAM is based on examining the adoption of office automation technology instead of IT for process support.

In our understanding of crisis management processes, multiple organizations and decision-making levels are formed during a crisis, with the first responder being the end-user and not the decision-maker. Accordingly, stimulating the acceptance and adoption of IT (for instance by means of top-down regulations and procedures) in crisis management does not mean the relief workers will actually use the tools. Moreover, introducing advanced IT usually implies reengineering established processes. Current group processes have taken years of training and people are hesitant to change current routines and often unable to alter behavior when they function under stress. Building on concepts such as acceptance and adoption, we prefer to use the term 'IT integration' which opts for a more sustained and effective use of IT by means of frequent practice. As we are more interested in the long term integration of IT in response processes, the frequency of use (practice) is also an important adoption stimulus.

BACKGROUND: CRISIS DECISION-MAKING AT THE PORT OF ROTTERDAM

Amongst the world's largest seaports, the Port of Rotterdam (PoR) is about 10500 ha[1]. An estimated 1600 different companies operate in this major harbor area. Every day enormous quantities of chemicals and other hazardous materials are imported, transferred and stored at the Port of Rotterdam. Handling such substances implies potential catastrophes for humans and infrastructure in the area.

When an incident is reported to the central command and intelligence room, multiple public agencies are prompted and gather to form a response team, called a CoPI (Commando Place Incident). The organizations, represented by one or more teams, include:

[1] Source: www.portofrotterdam.nl

- The Rotterdam fire brigade
- The Rotterdam police force
- The Rotterdam Port Authority
- Medical and ambulance workers (GHOR)
- The Municipality of Rotterdam
- Eventual experts/ company managers in the area

We want to stress that the listed organizations work autonomously in day to day operations. This also means that these organizations have their own information and communication resources. While there are major steps taken towards the standardization of the communication technology (C2000), the information systems (applications, databases etc) of these organizations are not integrated. This means that there is no cross-departmental information exchange. So, the commanders of these organizations can only retrieve information via their own control rooms.

Research setting

During crisis situations, the listed organizations physically come together in order to collectively coordinate the first responders in the field. For each crisis the commanders of these organizations joined to form CoPI teams. CoPI members are commanders of the fire brigades, police, ambulance, hazardous materials specialists, and press. The head of CoPI is the fire brigade commander (HOvD). CoPI members meet at a centralized location, usually a specially equipped vehicle. In addition, representatives of companies in the danger zone join the CoPI team with information such as building construction, material data etc. The following figure provides an illustration.

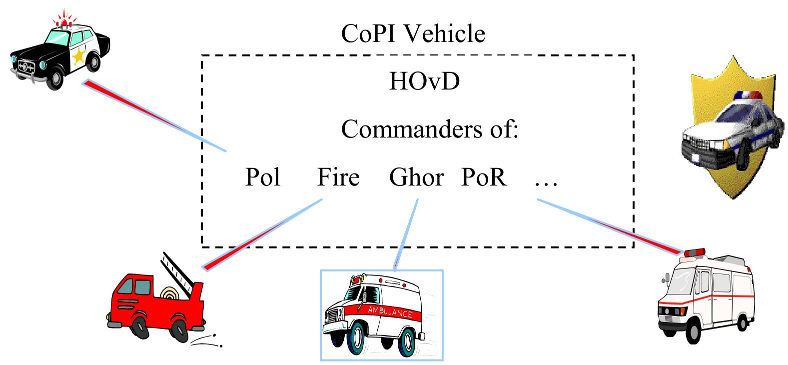

Figure 1: General crisis response decision-making scheme used at the PoR

The CoPI team should be read as a local disaster response team. The representatives (8-10) meet at the site in a local command centre. The core tasks of a CoPI team are (Appelman & Driel, 2005):

- Coordination of the deployment of disaster mitigation units in the area.
- To guide and direct the operational execution of all involved teams.
- To take measures aimed at the prevention of more casualties.
- Provision of information about the repression of the disaster to a higher-level Regional Operational Team (RegOT).
- Request for potential for support from RegOT.

The decision-making regime for crisis management is defined in the Coordinated Regional Incident-Management Procedure (GRIP). GRIP has four alarm levels, corresponding to increased levels of severity in risk, and becomes active for incidents involving hazardous materials, large-scale technical emergency response, or any other accident where at least one of the CoPI members calls for a coordinated response to an incident (Mendonça, 2001). Level 1 are considered (routine) incidents requiring no collective decision-making between responding organizations. GRIP level 2 events entail small scale disaster requiring collaboration between multiple stakeholders. GRIP level 3&4 are considered large scale disasters in which the municipality majors are required to take strategic decisions.

The Information problem within the research setting

In order to make effective decisions rapidly, timely and accurate information on the crisis situation is necessary. The type of information, its format, quality and detail can differ for each situation. Many scholars in the field of crisis management have already pointed out the problem of retrieving the right information during chaotic circumstances. Some scholars are more specific than others, discriminating between information overload (Smart, 1977, Iastrebova, 2006), information heterogeneity (Shadbolt, 2006) and information dynamics (Huberman, 2004).

The incapability of retrieving the right information at the right time is a central problem. Retrieving the right information at the right time is an obvious need and source of concern in crisis management and is can be related with coordination possibilities. Underlying technology to deal with a lack of information can be based on information retrieval techniques and information personalization in particular. The challenge for the developers of advanced technology is inherent to the information problem in which there is both a need for accurate information, a difficulty in getting it on time, but also an overwhelming amount of available, heterogeneous sources of potential data.

During crisis, changes in information processing abilities throughout the organization also contribute to reduced efficiency in making decisions. Under crisis induced stress, the number of communication challenges used for collection and distribution of information between the decision unit and the rest of the organization is reduced. This is part of the result of the tendency toward centralization and the debilitating impact of a high volume of information competing for the attention of fewer decision makers (Smart & Vertinsky, 1977). At the team level reduced efficiency can come about because of recognition primed decision making. Too early and based on too little low quality information decisions are made that might feel intuitively right but have been based on wrong assumptions of cause and effect.

It is therefore that previous research (Mendonça, 2001) points to the need to support crisis decision makers in responding to real-time events in situations requiring either modification or creation of courses of action. Methods for providing these types of support should be embedded in decision support tools and should be based on an understanding of cognitive-level processes involved (Mendonca, 2001).

Current information flows and technology used

Currently, CoPI teams collaborate in face-to-face settings supported by relatively sparse access to information sources. The main networks used are radio Porto phones and mobile phone networks that connect the different members of the team to their respective Emergency Control Centers (ECC). This is vulnerable and inefficient, direct access to information sources would allow for more rapid retrieval. Moreover, according to current procedures, all forms of voice communication should be turned of during CoPI meetings. This is not an unwise precaution because too much distraction leads to lower focus and productivity. The focus of a CoPI team is: to construct a joint operational picture that can be communicated to other levels and to take appropriate actions according to the constructed operational picture. Each representative has a mobile phone and some, e.g. chemical advisors, carry books with them. Information is captured and a joint operational picture codified in flip-over's attached to a wall. Detailed maps of the area are available in the local command center. At times, a list with actions is written down and check marked upon return to the local command centre when actions are completed.

Introduced technology

In the eight experiments we conducted, each time one of the three local command centers was equipped with a touch screen laptop that that was equipped with a GIS-application, which continuously synchronized with a server. Hosting of the server which synchronizes the services between the clients is offered by the defense technology operator (DTO). The connection between the client (IM with touch screen laptop) and the server was established using a mobile connect UMTS data card. The connection allowed for a variable internet speed, varying between a maximum of 384 Kbps downlink, and 64 Kbps uplink. The GIS application is developed by an independent commercial software developer called CityGIS. However, the CityGIS application forms only one part of the technology service which is introduced.

A second application which was introduced was a GasMal Simulator that projected the hazard zone on the CityGIS application. This GasMal application was developed by TNO Delft. Both the CityGIS application and the GasMal application are installed and run on the touch screen laptop. Installing and running the application on the touch screen laptops is an explicit service design choice, in order to deal with the limited internet bandwidth provided by the mobile connect UMTS data card. Hence, such a laptop can be considered a thick client which is connected to server. We now turn to how we observed the first teams that were exposed to new technology and welcomed a new team member; the information manager. In fact, we could refer to the IM as an information broker, as he/she makes a selection of relevant information.

The following figure provides an impression of one experiment in which the IM was given access to the CityGIS application.

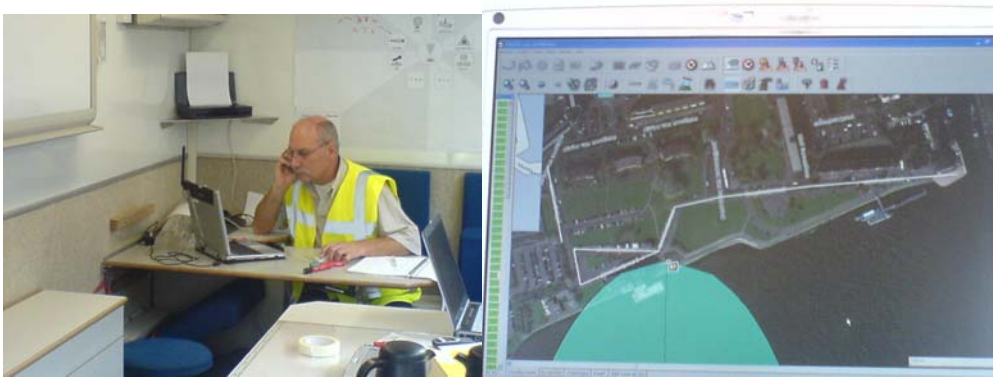

Figure 2: The information manager (left) using the CityGIS application (right)

Related to the timeliness of information is the quality of information (Horan, 2005). The IM finds himself in unique position in the CoPI vehicle. While following incoming information presented by the commanders of the relief working organizations, the IM can monitor the quality (in terms of accuracy and speed) of the information projected by the CityGIS application, he receives feedback that would otherwise be unavailable to the team.

For this research we use the classification of coordination as 'coordination by feedback', proposed by (Dynes, 1977). Coordination by feedback takes place in Emergency Operations Centers where decision makers must be prepared to make decisions based on feedback they receive from the field (Mendonça, 2001). The envisaged role of IM is to manage the flows of information and present information to a group that helps them during the phases of creating situational awareness and decision making. When the local commanders are out in the field the IM interacts with the group leader, scans for new information, and updates simulations and action-lists. He coordinates by giving feedback based on information.

RESEARCH APPROACH

Keeping in mind that our goal is to ensure integration *of advanced IT systems in crisis management decision-making teams that should leads sustained and effective use* in crisis management decision-making teams, we adapted an action research approach because it allows us to take both active roles (research planning and design) and passive roles (observation phase) as researchers during the experiments. Action research is an iterative process involving researchers and practitioners acting together on a particular cycle of activities, including problem diagnosis, action intervention, and reflective learning (Avison, 1999). This type of research combines theory and practice (and researchers and practitioners) through change and reflection in an immediate problematic situation. The strength of this approach is the in-depth and first hand understanding the researcher obtains. Conversely, a weakness is the potential lack of objectivity stemming from the researcher's stake in effecting a successful outcome for the client organizations (Benbasat, 1987)

The findings presented in this paper can be classified as a 'slice' out of a longitudinal case study into technology integration that started in 2004 by one of the researchers involved. We chose to present the material here in case study format because of the data richness (Yin, 2003). We deemed it important to write a paper that is accessible as possible because we hope it is read by professionals, scientists as well as policy-makers.

We suggested to decision makers to use technologies in a small number of teams that would take part in a 2-day exercise. Additionally, we advocated a comprehensive Change Management Approach, dubbed Crisis Management Studio (CMS), containing elements of Knowledge Management, Innovation and Institutionalization of learning.

Taking a bottom up approach, we investigated the structure and direction of information flows during eight crisis response exercises.

The two data-gathering techniques used were observation and handing out a questionnaire. The intention was to do a field –experiment that entailed training for the CoPI leader as well as the Information Manager. They would be instructed to direct the team via a process engineering approach labeled Collaboration Engineering. It was suddenly canceled and we had to resort to observation and being part of a compound questionnaire that participants were not obliged to fill in. Some observations were doing while being present at the local command centre, some while watching an audio-video link and some by participant observation. One of the authors was in this case a participant that simulated, with others, High-end Control.

During a period of four days (October 19 and 20, November 3 and December 1, 2006) eight runs of disaster scenarios were evaluated. We have observed one run each day. The scenarios were different for each day. The scenario for day one included a major gas leak at the Unilever Factory in Vlaardingen. The scenario for the second day was based on multiple explosions in a major cruise ship. The following table elaborates the two scenarios in more detail.

Table 1: Scenarios

	Day 1 and day 3	Day 2 and day 4
Scenario	Disturbance of public order combined with a possible toxic spill producing a gas cloud at Unilever premises	Cruise ship explosion, members of the royal family are on board and need to be evacuated.
Crisis elements	Toxic gas, possible hostile people on premises, evacuation	Fire, VIPs, surrounding ships and inhabited areas
Grip level (ultimately)	2	3

Data collection

For this research, data was collected by multiple means. Ideally, evidence from two or more sources converges to support the research findings (Benbasat, 1987). The methods used were direct observation and semi-structured interviews. Direct observation implies absorbing and noting details, actions, or subtleties of the field environment. The findings from the observations were compared with the results from the interviews. After we wrote down our observations, we verified our own observations by exchanging notes and informal evaluations with other research team members and held informal (telephone) interviews with other researchers that were present.

The following topics were used in these semi- structured interviews:

- access (to information and technology),
- quality of observation,
- use of techniques (mind mapping),
- use of technology
- structure/flow of group process,
    - actions group leader,
    - actions information manager,
    - interaction group leader and IM
    - interaction team members

Our main findings based on this list are discussed in the final sections of this paper.

Data analysis

In the introduction, two main questions were introduced. From these questions we indicated appropriated units of analysis. For research question 1, the unit of analysis was the interaction between the IM and the information system. For research question 2, the unit of analysis was the interaction between the IM and the HOVD. Data analysis was conducted in a qualitative manner.

The analysis of case data depends heavily on the integrative powers of the researcher. Multiple researchers can capture greater richness of data and rely more confidently on the accuracy of the data (Benbasat, 1987). Therefore, we worked as three research partners, so that some level of comparison and triangulation could be achieved with interpreting the findings.

FINDINGS

Our research interest was focused according to the two main questions raised in the introduction of this paper. First, we wanted to investigate how the information provided by the introduced IT (CityGIS) could was used in the CoPI decision making process. As the introduction of IT was ensured via the introduction of the IM role, the focus could shift as towards how the IT could be used it in an effective way. Seven out of the eight times, we observed that initially, the IM did not use the CityGIS application but paid more attention to the group process, until he/she was confronted with a developing gas/fire cloud on the laptop screen. The danger zone (depicted in a green cloud on top of the location) provided the IM with information on the location and direction of the hazardous gas or spreading fire, which was rapidly changing. The direction and scale of the event was simulated using a model.

The second question we raised in the introduction was on the interaction between the IM and the CoPI-leader. In six of the eight experiments, the IM wrote up some basic attributes about the danger (location, wind speed, direction) on a whiteboard, after discovering the gas layer projected on the area map. Listing these attributes immediately drew attention of the commanders in the CoPI vehicle. In one case, one commander even asked the IM about the reliability of the information, as he had a different perception of the location and magnitude of the dangerous gas leak. It should be noted that during the CoPI session all communication with the outside first responders and the control room is disabled, so that there are no disruptions during the sessions.

The obvious danger in this approach is that eventual updates on the danger area (e.g. gas cloud scale and direction) may not be considered by the commanders during the sessions. By writing up the incoming information on the whiteboard, the IM centralized the information coming in without interrupting the CoPI session. A more detailed communication pattern between the CoPI-leader and the IM develops, especially during the time that the commanders are in the field, leaving the CoPI leader and the IM in the vehicle. As the CoPI-leader had no actual view of the situation, he consulted the IM who had access to a dynamic picture of the area, providing the CoPI-leader with a more detailed view on the situation as it developed.

DISCUSSION

From a technology oriented perspective, we state that there is a technology push in the field of crisis management, which requires the current processes to be adapted to the characteristics of IT. In practice, this strategy fails because first responders are highly specialized in a specific set of processes, independent of advanced technology. In other words, the end-users will not adopt IT if it does not fit with their process goals. In the experiments discussed in this paper, one approach for dealing with the discrepancy between demand and supply is introducing a role, the information manager.

As current technologies fall short in supporting complex and dynamic processes, we advocate the introduction of the IM, who's trained in the extraction of specific information from an advanced technology resource. For that to become true we need concepts that describe the bare essentials of a group process and the way in which members should be instructed to perform the actions that lead to situational awareness. If we can do that we will not only have found a way to measure competencies, we will also know what to transfer to participants in a very concise way. In this way group processes can be drilled and the relative skill with which new routines can be performed can be observed more objectively[2] and we can show progress to the teams involved; they can actually see how good they get. From a competency perspective, we therefore advocate further research into ways that lead to objective measurements of competencies.

However, from a coordination theory perspective, this information manager is yet another layer between the CoPI and the required information, fulfilling the role of an intermediary. Even though the introduction of this role proved to help in establishing situation awareness, we believe that this is just a preliminary solution. This because the IM is

[2] An approach that meets these requirements is collaboration engineering that has defined building blocks for group processes irrespective of the technology used. First experiments suggest that command during the repression or mitigation is still possible in a distributed fashion when instructed with Thinklet prompts, and is just as quick, if not quicker, then in a face-to face setting.

human, and in the tension of a crisis is very limited in his/her ability to rapidly access, filter and orchestrate information to the commanders and first responders. We believe that the extra layer of the IM could be obsolete if the information systems used would be more adaptive in orchestrating information according to the needs of the different actors and in accordance with the situational demands of the crisis. That is something needed in a world where most evaluations of crisis management exercises or real disaster mitigations always conclude that it could have been done better.

CONCLUSION

This paper presents the preliminary findings of an ongoing research. Central in this paper is the need for and use of a new role in crisis management operations. In the introduction, we stated that the current approach of implementing advanced IT in crisis management operations faces much resistance, especially on the operational level. Accordingly, our goal was to ensure integration *of advanced IT systems in crisis management decision-making teams that should leads sustained and effective use* in crisis management decision-making teams. In order to achieve this objective, we adapted an action research approach during eight CoPI experiments in the Port of Rotterdam. In order to collect rich data on site, we used direct observations and semi-structured interviews as research instruments. Based on the research questions, we indicated two main units of analysis: the interaction between the IM and the introduced IT; and the interaction between the IM and the CoPI-leader. Our findings show that after some hesitation, the IM does use the data from the information system to improve situational awareness. Related to the second unit of analysis, we found that while the commanders of the crisis management organizations were busy discussing repressive measures, the IM was able to monitor rapidly changing situations in the CoPI vehicle and report findings to the CoPI-leader. The feedback provided by the IM proved to be very helpful in achieving situational awareness during the experiments. Even though the experimental setting of the exercises differs from real crises, we believe that the findings of our research are applicable for real crisis management Based on observations and interviews in eight experiments, we argue that alternative approach, suggesting first responders should initially get acquainted with advanced IT by frequent use in an un-mandatory manner, promises to be more successful. The key ingredient to this bottom up formula was the development of a new role, IM.

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