Coordination and its ICT support in Crisis Response: confronting the information-processing view of coordination with a case study

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Abstract

Coordinating the response of multiple agencies during a large-scale crises is a challenge. Using the information-processing view of coordination, a case study is presented in which dependencies, coordination mechanisms, coordination approaches, and supporting information and communication technologies (ICTs) are explored in crisis response exercises. The findings suggest that although current practices and ICT support favor coordination standards and hierarchy, emergent coordination, which is also present, is not adequately addressed and there is opportunity for improvement.

1. Introduction

In the event of a crisis, such as a large-scale emergency or a natural disaster, a network of response agencies (police, fire, medical services, and others) may be deployed to handle the situation. The speed and accuracy with which these agencies become aware and take action is critical for the crisis to be contained or controlled, and both speed and accuracy depend on effective coordination. In crisis response, coordination may involve joint decision-making, resource sharing, information exchange, and schedule alignment. According to the information-processing view (to use Galbraith's term as an overarching label), coordination is about resolving or managing dependencies between activities. This can be traced back to the organizational design theories of March and Simon (1958) [1], Galbraith (1974) [2], and Mintzberg (1979) [3], and more recently to the work of Malone and Crowston (1994) [4]. This view is also generally attached to notions of problem-solving, goal-seeking, and decision-making by rationally bounded agents.

During a crisis or emergency, many of the logistical problems are not caused by lack of resources, but by failure to coordinate their distribution [5]. This challenge of coordinating resource distribution becomes harder if we take into account that the network of response agencies changes as the phases of emergency response evolve [6]. This difficulty is just an example of the complexity of coordinating a crisis response effort. Thus, the study of coordination and the improvement of its practices and the technology that supports them has been a concern for crisis response practitioners and researchers. Indeed, by better supporting coordination in crisis response, lives can be saved and negative impact on critical infrastructure can be reduced.

This motivation guides the research objective within which this case study is embedded. Namely, improving coordination effectiveness and efficiency with the support of information and communication technologies (ICT) in the domain of crisis response. The first part of this objective is to improve the way in which distributed groups of people or organizations go about coordinating their activities, resulting in a faster, more cost effective and more appropriate way of conducting inter-dependent efforts. The second part addresses the use of ICT as a system of tools and services to support coordination. As will later be argued in this paper, it has been found that ICT can offer (and has offered) the means for improving coordination effectiveness and efficiency and much of this work has been carried out in the domain of crisis response, which bring us to the third component of the general objective, which relates to the application domain. This research focuses on the domain of crisis or emergency response, since this setting presents many challenging and rich characteristics for studying and improving coordination issues. These characteristics include: the complexity and unpredictable nature of a large-scale crisis, the heterogeneous nature of the responders, the critical requirements of speed and accuracy (for saving lives, protection the environment or restoring normalcy), and the difficulty in agreeing upon and combining the individual actions of response units and agencies to achieve a globally effective and efficient response. Also, the numerous information systems and ICT tools that have been developed for emergency response, some of which will be mentioned later on, indicate the opportunities for ICT in this domain.

This case study specifically addresses the following question: *How can the dominant understanding of coordination be confronted with the practices of crisis response and the ICTs that support these practices, in order to contribute to an improved understanding and support?* This study assumes the information-processing view of coordination, presented above, to be the dominant understanding. The way in which we approach

this question is by reporting on a case study of emergency response exercises in the Port of Rotterdam.

We will focus on examining the relationship between dependencies, coordination mechanisms, and approaches, as core constructs of the information-processing view of coordination. We will examine the extent to which these constructs are present and/or sufficient for explaining coordination in crisis response, and the role that ICT plays as support for coordination viewed in this framework. In doing so, we will suggest opportunities for improving or extending this view in order to better understand coordination processes and consequently improving the way in which they can be supported with ICT.

The paper proceeds in §2 with the description of the case setup and units of analysis. In §3 the findings of the case are presented. §4 contains additional findings. In §5 a discussion of the findings is presented and §6 concludes.

2. The Case

Much of the research in crisis response is limited by the difficulty to plan and control real-world inquiries. Studies of simulacra, records of past responses, or simulations are common ways of dealing with this. Smith and Dowell [7], for example, conduct a case study after a train crash in the UK to explore distributed decision-making and coordination in emergency response. Shen and Shaw [8] used the American Incident Command Systems (ICS) as a case to explore coordination dependencies and mechanisms, together with IT capabilities. Bigley and Roberts [9] also studied the ICS, using a fire department as case and, although they didn't explicitly address coordination, they analyzed the ICS as a basis for organizational design of high-reliability organizations (HROs). Another case was conducted by van Laere [10] in the Amsterdam Police Force, using the information-processing view of coordination, as well as taking into consideration ICT use.

In this paper we report the results of a case study in crisis (or emergency) response exercises in the Port of Rotterdam. The study involved observation of planned exercises with emergencies of different magnitude. All emergencies involved scenarios where the incident originated within the context of the Port and for which a multidisciplinary response was necessary. Although the five exercises observed were different in size, they all involved several physically spread actors, which is why the study was complemented with interviews and documents to supplement the limited point of view.

2.1. Case context

This case study can be classified, following Yin (2003), as single-embedded [11] and, following Stake (1995), as instrumental [12]. It is single, as opposed to multiple, since it did not aim at generalizing new hypothesis or categorically contrasting cases, but rather at empirically confronting and enhancing existing theoretical notions; in this case, those related to coordination. The case is embedded, as opposed to holistic, because it involved multiple units of analysis, which will be presented in the next subsection. Finally, the case was also instrumental because the issues explored exceed the case exclusively. This is in opposition to an intrinsic case in which the aim is to learn exclusively about the case.

The opportunity to observe crisis response exercises in the Port of Rotterdam offered an interesting setting for exploring coordination issues. Mainports are a strategic link in global supply chains and can fuel the economy of countries like The Netherlands, where the Port of Rotterdam contributes around 8% of its GDP and remains the largest in Europe [13]. The need for continuity, reliability and compliance with safety regulations, among others, make crisis response a critical issue for the Port. An emergency may affect not just the Port operations, but the whole logistics infrastructure of The Netherlands, Germany and other countries, as well as posing a threat to an area that can be heavily populated. In addition, large-scale emergencies or crises call for the participation of several regional agencies, which may including police, port authority, medical services, fire department, hazardous materials experts, and government officials.

2.2. Units of analysis

The units of analysis investigated in this case study are related to the research question presented in the introduction. We frame the units of analysis within the information-processing view of coordination, which we assume to be the dominant current understanding.

Dependencies. First, we ask what is coordinated during crisis response. To answers this we go back to the already mentioned definition of coordination: managing dependencies between activities. According to Malone and Crowston [4], those dependencies can be: managing a resource flow between activities (D1); managing the fit when multiple activities produce a single resource (D2); and managing sharing of the same resource (D3).

Coordination mechanisms. Second, we ask how the dependencies are coordinated in practice. To answer this we use coordination mechanisms as the unit of analysis.

Coordination mechanisms are the methods or tools to manage dependencies [4][14]. This is how coordination gets done. Unfortunately, there is no fixed list of mechanisms, since they can be of multiple nature. However, it is possible to attach one or more coordination mechanism to each dependency, resulting in a many-to-many relationship between dependencies and mechanisms. Examples of coordination mechanisms (which express their diversity) are: algorithms for coordinating workflow activities [15], goal setting for coordinating business networks [16], schedules for coordinating medical personnel [17], markets or strategic alliances for coordinating supply chains [18], and implementations of the Generalized Partial Global Planning (GPGP) approach for coordinating agents in a multi- agent information system for emergency medical services [19]. Further examples are listed by Malone and Crowston [20][21], who proposed a set of coordination mechanisms (also called processes) to deal with dependencies, which resulted in a handbook linking the appropriate mechanisms for each dependency (e.g. a fit dependency can be managed by having a design).

Coordination approaches. After matching the dependencies with coordination mechanisms, a third unit of analysis to consider is which coordination approach the mechanisms belong to. The information-processing view of coordination generally considers three different approaches, which can be found in Galbraith [2] or on a more recent account, in Gosain *et al*. [22]. The first approach is *coordination by standards* (A1), which can also be found in literature as coordination by rules, or by programs, or by plans. Within this approach coordination is achieved by following a predefined plan or standard (e.g. a workflow). The second approach is *coordination by mediation* (A2), also known as coordination by hierarchy. In this approach, coordination among two activities or actors is achieved through the mediation of a third actor or organizational unit, typically one level up in the hierarchy, but also including boundary spanners as mediators. The third approach is *coordination by mutual adjustment* (A3), also denominated as coordination by goals or by feedback. In this approach, individual responses are negotiated and adapted according to the responses of others. It should be noted that coordination approaches can also be viewed as abstract coordination mechanisms; for example, in Malone and Crowston [4], markets and centralized decision-making are mentioned as coordination mechanisms, but standardization, supervision and mutual adjustment are also mentioned as general coordination mechanisms; furthermore, "coordination processes", such as scheduling, task decomposition, and (again) standardization are also mentioned. This implies that there is no definitive distinction between coordination mechanisms or approaches (or indeed processes). However, the three approaches used here (A1, A2, A3) are often used and imply an understanding that coordination is first tackled by designing formal structures (rules, schedules, division of labor) then, as task or environmental uncertainty increase, coordination moves towards less formal interpersonal liaisons [23]. In this case study, we use coordination approaches as higher-level categories for coordination mechanisms.

ICTs supporting coordination. In general, ICT is seen by many as a way to enhance, support of reduce the cost of coordination [4][24]. This argument has also been recognized in the domain of crisis response [25][26]. For example, according to Turoff *et al*. [25], technology that supports dynamic formation of groups can help solve the coordination problem in crisis response. In this case study, after finding coordination mechanisms, we look at ICTs that support them, this is our fourth unit of analysis. As with mechanisms, there is no predefined set of categories for ICTs which can effectively be applied in this context. This is due to the variety of supporting technologies that are available for crisis response; among these we have: geographic information systems [27][28], decision-support systems [6][29], knowledge management systems [30][31], workflow management systems [32], and telecommunication technologies [33].

2.3. Method

This case study was conducted through observation of crisis response exercises in the Port of Rotterdam. Since no recording of the exercises was allowed, the observations were written down, some pictures were taken and informal interviews and verbal contact was carried out with several responders, from police officers, to crisis managers, to exercise organizers, always determined by the proximity and willingness of these individuals.

First observation: April 12, 2006, "Safe Harbour". This rehearsal had the main goal of performing a full-scale test of the new C2000 communication system (described later on). In it, approximately 300 people were participating around two incidents. On the first incident, the police were entrusted with crowd control due to hooligan activity on a ferry. Also, an explosion was supposed to happen and a real fire was staged as a result. Actors were hired to perform as either victims or hooligans to add realism. As part of the exercise, a simulation tool was used to support various processes and tasks in preparing, executing and evaluating. The observation took place in the 21st floor of the World Port Center. This meant observation of centralized command, rather than on-site response. In the room there were around 15 people (from different emergency services) with access to individual computers, in addition to two

large screens in the front, a large map of the Harbour and 4 boards on the walls. There was also a TV that is usually used as a news feed. The observation focused on radio and computer-based communication between responders and central command. In addition, some officers were in charge of checking the correspondence between the planned sequence of events and the events unfolding on site; talking to these officers during the exercise offered a global view, despite the limited point of view of the central command.

CoPI training workshop observations: Oct. 19- Nov. 17, 2006. Throughout these workshops, responders from the Fire Brigade, the Police, the Medical Services (GHOR), and other disciplines (hazmat, environmental, port authority and industrial representatives) exercised crisis response, focusing on the CoPI (Commando Plaats Incident) team. This team is a central aspect of crisis response in The Netherlands and consists of a multidisciplinary (typically involving fire, police, medical services and port authority) response team, which is formed after an incident is reported. Representatives from all involved disciplines gather inside a specially equipped vehicle to gain situation awareness, make decisions and provide operational leadership for the response by coordinating the activities within and between their agencies. Two scenarios were designed for these exercises, one involved a fire in a ship, which included VIP personnel to add priority to the decision-making process. The other was an explosion at an industrial compound involving an important number of potential victims. In total, four sessions were observed both from within the CoPI vehicle and close to it, giving an overview of on-site response activities.

Besides the observations, others sources of data were also considered. When possible, informal interviews on site were done. On the first exercise all questioning was done to a crisis manager from the Port and to a leader from the medical services team, present in the Wolrd Port Center, to get a sense of activity close to the incident. During the CoPI exercises, questions were asked of a police officer, an information manager, a crisis manager from the port, and a port officer in charge of communications, these were all questions improvised according to events in the exercise. Sometimes, they would comment on the exercise, without being asked.

After the exercises, an additional semi-formal interview with a Crisis Manager from the Port (CMP) was conducted (anonymity was requested). Some answers are worth summarizing. When we asked about the ICTs used during an emergency, as opposed to those in daily routine, the CMP pointed out that not only is there a difference on the ICTs, but also in the type of work that responders do: “they are not used to sitting down and writing things in a computer”. However, the CMP stressed the importance of introducing standard, unified, highly visual supporting technologies. The CMP also pointed out that conflicts seldom arise in the Port due to a long-lasting cooperation culture, led by the Fire Department, and perhaps influenced by the Dutch polder (consultation) model and by the fact that the Port is faced relatively frequently with critical incidents, such as oil spills. It is also worth noting that the CMP emphasized command over coordination and highlighted the need to have a structured pre-defined hierarchy in order to prevent hesitation, adding that “knowing each other is one of the biggest emphasis in crisis management.”

A final source of data was a set of documents related to crisis response in the Port. Of special interest were the GRIP (Coordinated Regional Incident Management Procedure) level description [34] and the Crisis Management Plans of the Rotterdam-Rijnmond Region. The GRIP levels describe the organizational structure and tasks that should be executed once an incident requires a multidisciplinary response in The Netherlands. It starts at GRIP 1 when it can be locally controlled by a CoPI team (further discussed later on), then scales up to GRIP 2 when the incident spreads (a regional team is setup starting in this level), GRIP 3 when there is a serious threat to the population, or GRIP 4 when the incident involves more than one municipality.

3. Findings

Findings of this case study are presented according to the units of analysis previously presented.

3.1. Dependencies

The three basic dependencies presented earlier were investigated in the case.

Flows (D1). Two relevant flow dependencies were found:

D1.1 Information flows. During a crisis response, information is generated by events related to the incident or by agents participating in the response. Not all agents have access to all information at the same time, which is why information must flow from a producer to a consumer. An example of this is voice communication and messages which need to flow through radio, phone, the C2000 system, e-mail, or through the Multiteam system (later discussed). Such messages include reporting incidents, asking information about the incident from responders close to the site or distributing decisions among a group in order to take action. Another example is embedded in the GRIP response procedure

indicating how response units in the operation environment should handle communication lines and how they should feed information to the management environment; this is basically represented with arrows connecting organizational units.

D1.2. Task flows. During the response some tasks are prerequisite of other tasks and so they must be carried out in a certain order. An example of this during the exercises is different from what would happen in a real emergency, because (at the management level) there is previous knowledge of how the incident will develop chronologically. During an actual emergency, the flow between tasks is contingent on the type and size, especially when it is multi-incident. It is not possible to design a fixed sequence of tasks. In the first exercise, the incident events were planned in detail and executed accordingly with the aid of a simulator. Each event planned was run by the simulator, projected on screens and enacted (apparently very closely from what we were told) on the site of the fictitious emergency. In the smaller scale CoPI exercises, there were scripts guiding the development of the incidents, but there was room for changing the order or adding new events during the enactment. In fact, there were two basic scripts but each exercise using the same script was different from the others (although not too much). These scripts were basically spreadsheets with events relevant to the different agencies, color coded according to discipline. Thus, the first column represented time, a red column showed events relevant to the fire service, a blue column for the police, and a green column for the medical services. Only team leaders had access to this script and responders were supposed to be unaware of it.

Fits (D2). Three fit dependencies were found:

D2.1. Fit of multiple agents making a single decision. During an emergency, decisions need to be made quickly, under pressure and with limited information. Often, they must be made between more than one agent, since actions will affect the response network and the incident itself. Although the final word with regards to decisions is typically the responsibility of a single agent, it involves joint discussion or consultation. An example of this is decision-making inside the CoPI, which is a trailer set up for the first multidisciplinary team to coordinate the response close to the incident site. Decision-making is a group effort, but is the responsibility of the Operational Leader. Once situational awareness is reached and first actions are put in effect, they restart discussions to assess the situation once more and revise the action plan. Typically, the CoPI team would be setup after 10 minutes, then discussion would start and a few minutes later action would be taken. Once action was underway, discussion would restart to adjust the response. Another example is when the GRIP level reaches 4; this means that the incident has extended beyond a single municipality. Decisions now affect a broader area and must be made by more than one mayor (with the advise of senior response agents). This was not seen in the exercise, but is documented in the GRIP procedure.

D2.2. Fit of multiple agents providing information to the public. Regardless of the incident, an important aspect of the response is how the response team will communicate with the press and the general public. There are conflicting requirements (confidentiality, security, public safety, and transparency), and there may be incompleteness or discrepancies if more than one agent discloses information. An example: all GRIP levels specify a single informant (typically a Police Officer) as liaison between the press and the response team. At one point, we observed a police officer talking to the press (also part of the exercise) and describing a limited version of what was going on. The press described the incident as an enormous chaos, highlighting the presence of VIP personnel. Once the short interview was over, the police officer came to me showing excitement and nervousness after what she said was her first interview ever.

D2.3. Fit of multiple agents coming up with a single picture of the incident using a Geographic information system (GIS). GIS are often used as visual information systems to get and register information related to the incident. Some of the information will be relatively fixed (maps, satellite images) or automatically updated (weather information, sensor information), but other will be fed by users during the response. If there is more than one user and the GIS is distributed, then conflicts should be prevented while aiming for as much completeness and detail as possible. An example of this was observed when a GIS system was used with an information manager as master user in the CoPI and the Central Command users as slaves (no updating). The reason for this is initially to provide the central command with visual information close to the incident, but as the person setting up the GIS told us, sometimes it is also needed that someone farther away can ad data, because they have a larger area of vision and they can use this to validate the data visualized by more than one user.

Sharing (D3). Two sharing dependencies were found in the case:

D3.1. Sharing of communication channels. An example of this is when the C2000 or radio users share a limited amount of communication channels.

D3.2. Sharing of physical response resources. A critical issue in a crisis response is sharing a limited amount of physical resources. The same resource may have to be used in different locations or by different agents. An example is access and use of the CoPI trailer, since it should fit the people, the maps, the laptops, the boards, the communication devices, all in the same space. In a few exercises the CoPI trailer was so full that some participants (some of which wouldn't be inside the CoPI in an actual emergency) had to stand outside. For further exercises they restricted access to prevent this.

3.2. Coordination mechanisms

For each dependency, there are corresponding coordination mechanisms.

Information flow (D1.1). In the radio and C2000 systems, broadcast is used. For the GRIP levels, a command-and-control hierarchy is defined.

Task flow (D1.2). During the training exercises, scripts or simulated workflows serve as basis for task flow. During a real emergency, teams are expected to follow the GRIP procedure, where task flows are defined by hierarchical decision-making.

Decision-making fit (D2.1). In every GRIP scale, at the operational level an operational leader guides decision-making (typically the Fire Chief). Maps and boards help with the group decision-making process on site, and GIS or simulation can be ICTs that support this. When GRIP 4 is reached, a single coordinating mayor has the final word for inter-municipal decisions. The main philosophy is to have a command and control, rank-based process of decision-making.

Public information fit (D2.2). At each GRIP scale there is a single informant whose role it is to inform the public. In addition, emergency TV and radio broadcasts may be put into effect; SMS messages, sirens, Teletext and Call Center can also be used.

Single situation assessment fit in GIS (D2.3). For exchange between multiple GIS platforms, metadata standards can be used. For disambiguation of incident related information, icons are used (not text). It is also possible to integrate partial GIS views into a global view of the incident.

Communication channel sharing (D3.1). A well-known mechanism for handling channel sharing is sequencing (each one speaks at a time); however, it is also possible (specifically in C2000) to make use of a red button which gives priority in using the channel. Personal judgment is the basis for the use of the button.

Physical resource sharing (D3.2). As in other domains, there are several mechanisms that can be employed to share resources of a physical nature. Among these, we find: sequencing of tasks, priority in access and decision-making as the basis for resource assignment. They can all be used simultaneously for different resources.

3.3. Coordination approaches

All three information-processing coordination approaches were present during the exercises.

Standardization (A1). Coordination in crisis response can be done through standards and plans but only on a limited basis. This is in part due to the fact that standards can be designed and applied by discipline, but will differ between disciplines, and responses of large-scale crises or emergencies are interdisciplinary. Scripts (simulated or not) during exercises are an example of this (D1.2). The GRIP procedure itself is a plan; although it only gives the general structure, tasks and responsibilities, not how or when to execute them (D1.2). Metadata standards and icons for GIS or other information systems are another example (D2.3).

Mediation (A2). This is the most used approach and a central aspect of the command-and-control approach. The use of broadcast (in C2000, radio, TV, sirens, SMS, and Teletext; also in the public information liaison and existence of a Call Center) from a central source is an example (D2.2). Hierarchical decision-making (D2.1) is another example (also when resulting in sequencing or priority decisions). The presence of leaders at the operational (e.g. CoPI leader) and managerial (e.g. coordinating mayor) level is another instance of this (D2.1). The use of centralized, single-user devices (maps, boards) and information systems (GIS, simulation) is also mediation.

Mutual adjustment (A3). This type of coordination, although not the most favored, can occur at local small-scale interaction among responders and result in task sequencing or prioritizing. When devices and information systems are used by multiple-users in a distributed fashion it can also occur (e.g. when integrating partial GIS views: D2.3). When responders individually decide to enter a communication sequence or use the priority button, it could be seen as mutual adjustment (D3.1).

3.4. ICTs supporting coordination

Many ICTs are present in the Port of Rotterdam. In fact, some argue that the myriad of systems, devices and

information make integration and efficiency during the crisis response more difficult. In one exercise we observed a responder carrying around a radio, a map, and a board to write on; as he was walking towards the CoPI for its initial formation, he fumbled from carrying all this, dropped his phone to the ground and himself and another responder had to stop, pick it up, reorganize and continue. Later that day, one officer expressed his desire to integrate all existing technologies and devices into a single PDA, rather than carrying around a mobile phone, a radio, a laptop, maps, pen and paper, while wearing protective gear. Furthermore, of all the systems available, only a few where used critically (mobile phone and radio) while others remained secondary, despite their sophistication. One officer argues that regardless of which technology is in use, its adoption is conditioned by the fact that responders use it frequently – this can be improved through these types of training exercises.

Some individual systems used in the exercises were:

1. Telecommunications: C2000 (www.c2000.nl). This is a nation-wide communication system, which offers inter-agency communication services over a radio network that is supported by a fixed backbone. The main components from which the system exists are walkie-talkies and car phones and the system provides gateways to link to the phone network. During the exercises, it is used for communication, like a radio, including broadcast of emergency-related information. Part of the motivation for using C2000, which is related to coordination, is offering a standard way of communicating for all response agencies to avoid problems of coverage, channels or lack of inter-communication possibilities. In addition, it should make it easier to integrate to other systems, such as Multiteam.

2. Multipurpose: Multiteam (www.multiteam.info). According to its documentation, this system has been developed on the basis of the GRIP levels described earlier. All available MultiTeam modules form an integrated process for coordinated disaster management. MultiTeam supports different agencies by exchanging messages and documents through contact lists and with links to other applications (e.g. GIS). Multi-team is individually accessed through an Internet browser, making it platform-independent and low on computational resource needs. Within the case exercises it was not always used. According to an agent acting as information manager, the value of MultiTeam is that it has been agreed upon by all agencies in The Netherlands. Apart from not being used in every exercise, when we observed its use closelyon one of the exercises, only three messages were exchanged: one to indicate the CoPI team was operational, another to indicate that the incident had escalated from GRIP 1 to GRIP 2, and another to ask details of the incident (which never got a reply, as we discuss later on).

3. GIS: Google-maps based system. Geographic information systems are a fundamental part of modern crisis management systems. Their ability to represent the affected area and enable information sharing to reach common awareness is recognized the world over. In Rotterdam, although there is not yet a single GIS for all agencies, they use sophisticated maps in the Port Authority to track vessels, containers and harbor elements. This information, coupled with population, weather, gas clouds, among others, is useful during an emergency. In the first exercise, GIS is used to show interactive (fictitious) information around the exercise area. In the CoPI training workshops, a Google Maps-based GIS was used (not on every exercise). One of the main purposes, which contributes to coordination, is gaining a common visual situational awareness and observe the development of the incident in terms of positioning of response units or direction of a gas cloud, for instance. A crisis manager from the port said “when you visualize it, you don’t need to communicate about it”. This was the case in the exercises, but not focused on GIS, which were used marginally. Instead, most discussion inside the CoPI was guided by pointing at or drawing over paper maps of the Port and of the industrial compound where the incident took place. Words detailing events and arrows detailing access and evacuation routes are examples of the types of information scribbled over the maps.

4. Simulation: CrisisSim (www.crisissim.com). According to its documentation, this system supports preparation, management and evaluation of command posts or live exercises. In preparation, script and observation checklists are created digitally. During the exercise, CrisisSim is used to manage the storyline by sending event triggers to participants and instructing the exercise staff at remote locations. Observation results are collected digitally during the exercise. After the exercise, the Evaluation Module offers review functionality. Simulation during the first exercise is used, according to a Port Officer, as a “kind of document workflow” which allows enactment of the scenario. On the first large-scale exercise, the simulation events were projected onto a screen, but the font was so small and the screen so full that no one really was paying any attention to it, until it finally got changed for a projection of Multiteam.

4. Additional Findings

Other findings of the case could arguably be placed outside of the information-processing framework.

Role-based coordination [23] challenges the information-processing view of coordination, suggesting that roles are fundamental, especially in temporary organizations. For example, by thanking, admonishing and using humor, participants learn and negotiate the role structures which are only partially known prior to the group interaction. In this case study, roles are recognized first through the network of acquaintances (enforced through training exercises) and second by the use of uniforms. Visibility of status is also enacted through uniforms and in technology through profiles in MultiTeam. Also, the role of "information manager" inside the CoPI trailer is critical in relation to ICT-based coordination as it is responsible for feeding and reviewing the systems available, unloading the team so they focus on discussion and decision-making.

Practice-based coordination [35] also challenges the information-processing view of coordination by stressing that coordination is emergent as well as structured and that sometimes (e.g. in fast-response organizations) it is desirable that emergent coordination occurs to deal with an abnormal trajectory. Expertise coordination (based on knowledge, rather than standards or authority) and dialogic coordination (which may challenge the structure when someone detects a potentially wrong decision) practices are included. In this case, in every GRIP level, the role of the Fire Chief will always be central. However, according to the changing incident, the coordination structure may be altered when different expertise is required. For instance, a chemical expert may be called in at first as an observer with no active role, but as soon as a gas cloud forms his expertise becomes central for the decision-making process. These changes in structure, according to expertise, require flexibility and the existence of mature communities of practice, both within the areas of expertise and spanning across the different disciplines.

Emergent behavior has been found and studied in crisis response for a long time [36][37] and continues to be studied empirically [27][31][38]. Role-based and practice-based coordination could be seen as emergent, but other types of emergent coordination can also be found in the case. During the exercise involving MultiTeam, a message was sent by the information manager to the CoPI, because the leader of the medical services, physically present, asked him to do so (inquiring whether a hazardous or biological substance was present on the incident site). This is outside the normal procedure, first because this MultiTeam user is not supposed to be there in a real emergency. Second, the message was sent due to a verbal suggestion. Third, the reply never came. However, the information manager told us there was a reply, but it happened outside the scope of Multi-team, through radio. This mix between "talking" and using Multi-team is not desirable for the standard response, but it shows that in real-life some people will tend to look for efficient ways to coordinate, even if they fall outside the standards or hierarchy.

5. Discussion

The findings of this study allowed confronting current understanding of coordination with actual practices. Dependencies proved to be an appropriate starting point for the study of coordination. Coordination mechanisms, on the other hand, can be an ambiguous concept since there is not a limited set and several mechanisms can be used simultaneously (sometimes in a conflicting manner) for the same dependency.

With regards to coordination approaches, we found that although in several cases a specific mechanism could be classified in more than one approach (for instance, sequence and priority can obey a plan or be decided upon by a hierarchical process) it seemed that mediation was the dominating approach. Also, as stated before, it is still not clear how to define the level of granularity that distinguishes a coordination mechanism from an approach, although both concepts are used in literature (sometimes to refer to the same notion).

As asked in our initial study question, this case was focused on exploring whether the information-processing view is necessary and sufficient to study coordination and improve its effectiveness and efficiency with ICT in the domain of crisis response. This view of coordination can be simplified into the idea that coordination mechanisms change in a structured manner from standards into mediation when following a plan is no longer possible and only resorting to mutual adjustment when the other two are no longer possible. This preference on standards and hierarchy goes hand in hand with the military traditions and training requirements of crisis response agencies, but as others have pointed out [23][35][36] it may result in neglecting or not adequately or explicitly supporting other forms of coordination.

Although in this case study we present some additional findings outside the information-processing categories, they could arguably be placed under mutual adjustment, but this might imply an agreement with the general assumptions of the information-processing view (e.g. the existence of a common goal).

With regards to the supporting ICTs, this study, as others, found contradicting ideas. Sometimes technology may hamper rather than support crisis response. Especially when it requires additional effort from the responders, as opposed to unloading them cognitively; thus, the study supports the claim that effectiveness is

dependent on frequent use of the tools, even if they are designed for infrequent situations. Another consequence is the preference of using well-known and more simple technologies, rather than sophisticated tools. It also appears that most ICTs reflect the preference on mediation and standard coordination approaches, but this could of course be a reflection of a preference of the responders, rather than something forced by design. In the case of Multiteam, however, the emphasis on standards and hierarchy, which is part of the GRIP procedure, is said to have influenced the design. This can also be seen by looking, for example, at the influence that the information-processing view of coordination has had in designing coordination algorithms for multiagent systems and workflow management systems.

In terms of information systems (IS) development, coordination in crisis response is a challenge because it is not a classic office setting; it requires a flexible and creative understanding of ICT support. Another issue is trying to design IS for a process that cannot be predefined to deal with an unknown situation. Nonetheless, it is also a rich ground for new understandings of IS design and use, and a fertile ground for new ideas on how to cope with non-routine situations in all types of organizations.

6. Conclusions

This case study aimed at confronting current understanding of coordination with crisis response practices. By using the information-processing view of coordination we explored dependencies, mechanisms and approaches that are present during crisis response in the case of a set of crisis response exercises in the Port of Rotterdam. In addition, some of the ICTs that support coordination were also considered. The findings suggest that current practices favor standardization and mediation (hierarchy), while mutual adjustment is less favored. However, mutual adjustment, along with other types of coordination that can be considered as emergent (such as role-based and practice-based) were also present, regardless of whether they are preferred or not. One officer at the Port went so far as to say that besides standards and hierarchy, no other form of coordination was used. Therefore, both the dominant view of coordination and the ICT that supports coordination practices do not completely support or acknowledge alternative coordination behaviors. As a consequence, we suggest that rather than neglecting these coordination styles, they should be explained and supported.

In the future, we will explore the place of emergent coordination within the information-processing dominated theory of coordination. In the light of the conceptual improvements this could offer, we will develop a framework to enable better ICT support for coordination in crisis response. The next step will be to use simulation to explore different types of coordination in a specific crisis scenario.

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