
DRAWING THE LINE
JEROEN WOLBERS
CROSS-BOUNDARY COORDINATION PROCESSES IN EMERGENCY MANAGEMENT

Drawing the Line

Cross-boundary Coordination Processes in Emergency Management

Reading committee

prof. dr. David Allen	University of Leeds, United Kingdom
prof. dr. Myriame Bollen	Netherlands Defense Academy
prof. dr. Paul Carlile	Boston University, United States of America
prof. dr. John Lammers	University of Illinois, United States of America
prof. dr. Alfons van Marrewijk	VU University Amsterdam, The Netherlands

Cover design and layout:	Esther Ris, proefschriftomslag.nl
Printed by:	Ridderprint BV, the Netherlands
ISBN:	978-94-92332-03-5

VRIJE UNIVERSITEIT

Drawing the Line

Cross-boundary Coordination Processes in Emergency Management

ACADEMISCH PROEFSCHRIFT

ter verkrijging van de graad Doctor aan
de Vrije Universiteit Amsterdam,
op gezag van de rector magnificus
prof. dr. V. Subramaniam,
in het openbaar te verdedigen
ten overstaan van de promotiecommissie
van de Faculteit der Sociale Wetenschappen
op donderdag 7 januari 2016 om 13.45 uur
in de aula van de universiteit,
De Boelelaan 1105

door
Jeroen Jan Wolbers
geboren te Naarden

promotor: prof. dr. P. Groenewegen
copromotor: dr. ir. F. K. Boersma

Table of Contents

1. A day to remember

Wednesday February 25th, 2009. It was around 9.30AM on a gloomy morning when we arrived at the train station of Haarlem. I was travelling together with fellow researchers Kees Boersma and Pieter Wagenaar to an interview appointment around 10AM with a field commander at the fire station in Haarlem, safety region Kennemerland. We were in the data collection phase for our research project on use of information technology in emergency management (see: Boersma, Wagenaar and Wolbers 2012). The fire station was quite a walk from the train station, so we decided to take a cab. We enjoyed the opportunity of going to the field once more, to hear the experiences of a field commander in a lively region that had recently gained the responsibility for emergency response to Schiphol Airport.

It was around 30 minutes into the interview –we were discussing the role of the up-scaling procedures with the field commander– when he abruptly stopped talking. His pager alarm triggered.

10:31:33 25-02-09 PRIO 1 UGS A PELIKAANWEG LUCHTHAVEN SCHIPHOL LUCHTVAART INCIDENT SCHIPHOL **(VOS: 6)** (INC: 09) [344 171 349 346 342 748 198 563 574 590 584 195 594 194 193]

"So… a VOS6, he stated remarkably calm. "*A VOS6 is something serious…"* He remained silent for about half a minute, after which he continued his explanation: *"VOS6 stands for aviation accident at Schiphol Airport. Category 6 means the plane has actually crashed and has between 50-250 persons on board. If you don't mind, it's probably best to end the interview"*. He excused himself and promptly left the room, heading towards the crash site in the role of field commander.

We just witnessed the start of the response to, what would later be regarded as, one of the largest aviation disasters the Netherlands has known. Turkish Airlines Boeing 737-800, flight 1951, stalled on the final approach to runway 18R of Schiphol Airport. The pilots failed to respond adequately after losing too much airspeed caused by a defect radio altimeter. The aircraft crashed into a ploughed field just before the runway, near highway A9. Unfortunately, nine people (including the three pilots) lost their lives and 86 were wounded, of which 25 serious and 55 sustained minor injuries.

10:36:05 25-02-09 PRIO 1 UGS A PELIKAANWEG LUCHTHAVEN SCHIPHOL LUCHTVAART INCIDENT SCHIPHOL (VOS: 6) (INC: 09) **(GRIP: 3 schiphol)**

Back at the fire station people were rapidly walking down the hallway. The GRIP3 level of the Dutch upscaling protocol had been activated, calling Tactical- (Incident Commanders) and Strategic Commanders (Mayor and Regional Commanding Officers) to various incident command rooms. We could hear bits and pieces of anxious conversations in the hallway, *"Shall I come along?"* and *"Do you have any information yet?"* Blue light flashes and the sound of sirens filled the surroundings, while we witnessed the largest deployment of emergency vehicles I had ever seen. Fire engines, ambulances, and other special geared trucks pulled out from the fire station.

While we witnessed the start of a massive emergency response operation from the main fire station in Haarlem, the calmness of the field commander had struck me. I wondered: how are that many different emergency response units able to coordinate in such a challenging environment? This question triggered my creative leap and would remain the central focus of my PhD research. At a later stage, when I was better informed by the theoretical debate, I transformed my initial question into the following main research question: *how do emergency responders coordinate the response operation across the boundaries of their organizations in fast paced environments?*

Several months later the first evaluation reports appeared, applauding the professionalism of the response operation. The public opinion about the emergency response operation to the Turkish Airlines crash was generally positive. The headline on the national newspaper 'NRC-Next' of February 27th, 2009 is illustrative of this opinion: *"No disaster after the disaster"*. Although the media applauded the professionalism and promptness of the emergency response operation, the public investigation reports of the Inspectorate of Justice and Safety (IoJS) and the Dutch Safety Board (DSB) also noted some hard to solve challenges. As it turned out, these challenges where not unique to this response operation, but were similar to the organizing challenges that were identified in emergency responses worldwide.

In the following paragraphs I will explore the organizing challenges that emerge during coordination processes in emergency response operations. A key characteristic of these challenges is that they are based upon opposing coordination approaches that exist simultaneously, but are in apparent contradiction with each other. I will explore these contradictions by using a paradox perspective. With a paradox perspective it becomes possible to explore how organizations can attend to competing demands simultaneously (Smith and Lewis 2011), which, as we will see, is a key characteristic of emergency management. Following Smith and Lewis (2011) I regard a paradox as: *"contradictory yet*

interrelated elements that exist simultaneously and persist over time; such elements seem logical when considered in isolation, but irrational and inconsistent when juxtaposed" (Smith and Lewis 2011, p. 387). A paradox is different from a dichotomy in the sense that: *"taken singly, each proposition is incontestable, but taken together they seem to be inconsistent incompatible"* (Poole and Van de Ven 1989, p. 563).

My analysis of the public investigation reports indicated that three paradoxes emerged during the response operation to the Turkish Airlines crash. Using these paradoxes will enable me to show the layeredness of the coordination challenges, that include the coordination of on-scene action, information sharing, expertise, and network relations. I will use the paradoxes to illustrate the main coordination challenges in this particular response operation, and subsequently link them with the central theoretical phenomena discussed in the upcoming chapters of this dissertation:

1. designed and emergent coordination;
2. administrative and expertise coordination;
3. centralized and networked coordination.

1.1 Designed and Emergent Coordination

The first challenge in the report of the Dutch Safety Board (2010) identified that the first fire engines responding from both Schiphol Airport and the regional fire stations had trouble locating the crash site. Crash tenders drove down the runway and did not see the aircraft, because it crashed behind a dike that obscured the view from the runway. Accidentally, around the same time, an ambulance passing by on the A9 highway from the adjacent safety region 'Noord-Holland-Noord' spotted the aircraft. The driver passed the information to his Emergency Response Center (ERC) in Alkmaar. However, the location of the crash site was not communicated to the ERC in Haarlem, which was responsible for the dispatch to the crash site. In the ERC in Haarlem several calls came in from citizens that had seen the crash site, but this information was not shared between the dispatchers in the ERC working in the same room, in the first chaotic moments of the response operation (often symbolically characterized as the 'fog of war'). Consequently, as the first official call came from the Schiphol tower that had lost the aircraft on the radar, the ERC dispatchers (incorrectly) activated the VOS6 procedure meant for a plane crash

on the Schiphol Airport grounds. However, the actual crash occurred in a ploughed field just outside the Schiphol airport perimeter. The consequence was that all incoming units were directed to UGS A (a designated staging area at Schiphol), as the VOS6 procedure prescribes, instead of directly to the crash site.

Figure 1. Location of the crash site in the path of runway 18R

The logic behind the VOS procedure is that emergency services cannot freely drive on the airport grounds, but must be marshaled by airport police to avoid collision with aircrafts and other airport traffic. The activation of the VOS6 procedure thus let first responders believe that they were responding to a crash on the airport grounds. When they could not locate the crash site on the airport grounds, a new search had to be initiated in the surrounding areas. Valuable time was lost due to this confusion. The Dutch Safety Board concluded that *"the consequence of activating a VOS6 was that the regional fire department reached the crash site only after approximately half an hour"* (DSB 2012, p. 6).

The trouble with locating the crash site and the discussion around activating the (in) correct procedures illustrates that emergency responders have to make quick decisions, often based on incomplete information. These decisions, in the first moments of the response operation, are often hard to revise once they have been made. As such, we have to question the effectiveness of coordinating based on predefined plans and procedures in fast paced environments. Still, the activation of the VOS6 procedure also had a positive side to it. When we interviewed the field commander several months after

the response operation, he explained that for him and other units it was a blessing that the VOS6 procedure had been activated. Once the crash site was located, it meant that the Schiphol military police units were positioned at strategic points on the airport to guide the emergency units from the UGS to the crash site. This allowed a faster guidance of units and resources, once the crash site was located.

Standard operating procedures, like the VOS procedure, are designed coordination mechanisms that function by structuring the response operation in advance, and allow professionals to fall back upon well thought out plans of action, known to everybody in the organization (Okhuysen and Bechky 2009). In this way, in stressful and dynamic environments less time is needed to structure the organizational response itself. This allows commanders to focus on other priorities in the first moments of the response operation. Like the actual use of the VOS6 procedure shows, contingencies in the response operation often turn out to be more complex than anticipated in the original procedures. Once emergency responders arrive at the disaster scene predetermined plans need to be adapted to the dynamically unfolding situation at hand. Therefore, to explain the actual coordination processes at the incident scene, the emphasis must not only lie on studying *designed coordination* mechanisms, but also on understanding the nature of *emergent coordination* (Bechky and Okhuysen 2011, Bigley and Roberts 2001). Recent studies have shown that in addition to standard operating procedures, mutual adaptation, improvisation, and ad-hoc networking are important elements of emergent coordination that enable first responders to adapt to changing circumstances at the disaster site (Kapucu 2006, Comfort 2007, Moynihan 2009). Therefore, it is important to consider in what way the tension between designed and emergent coordination manifests in the on-scene coordination processes.

Shifting the perspective towards organizational theories opens the door for more extensive theorizing on how the tension between designed and emergent coordination manifests. Traditionally, in the 'design school', coordination is explained from an information processing logic (March and Simon 1958, Lawrence et al. 1967, Van de Ven et al. 1976, Argote 1982). This logic supposes that each coordination mechanism has certain information processing capabilities that can be utilized in different kinds of environments. In stable environments, coordination can be achieved by using procedures that have a low information processing capability. That is, procedures prescribe a specific way of working, but do not provide a means to transfer additional information. In contrast, more dynamic environments require coordination mechanisms with higher information

processing capabilities. These are for instance group meetings that allow a more elaborate processing of information. Following this logic, optimum coordination takes place when a mechanism is selected that closely matches the dynamics of the situation.

However, one of the key features of coordinating in dynamic environments is that circumstances change more rapidly and unexpectedly than anticipated. Recent studies illustrate that ongoing adaptation is required as fast paced environments are often too unstable for aligning coordination mechanisms with predefined contingencies (Bigley and Roberts 2001, Faraj and Xiao 2006, Kellogg et al. 2008). This shows the limits of the information processing logic, as this logic supposes that contingencies can be assessed beforehand, and that predefined coordination mechanisms actually fit the situation at hand (Faraj and Xiao 2006). This is not possible in dynamic environments as the environment is prone to change and predefined interdependencies emerge differently in practice. Hence, classic coordination theories based on an information processing logic do not sufficiently incorporate the organizing dynamics we recognize in fast response organizations (Klein et al. 2006, Bigley and Roberts 2001). Therefore, the information processing logic does not offer a holistic approach for explaining how coordination processes actually occur in dynamic environments.

Studies that explore how coordination processes occur in dynamic environments show that on the one hand, unambiguous command is needed for the timely direction of the involved units, while on the other hand flexibility, and on-the-spot decision making is required to adapt to the continuously changing situation (Bigley and Roberts 2001, Moynihan 2009, Comfort 2007, Majchrzak et al. 2007). When professionals need to combine the best of these two worlds simultaneously, it results in paradoxical demands between following the designed coordination mechanisms or opting for an emergent solution (Poole and Van de Ven 1989, Smith and Lewis 2011, Bigley and Roberts 2001). This is the paradoxical relation between *designed* and *emergent* coordination that is present in emergency management. This paradox illustrates that coordination is not so straightforward as matching predesigned mechanisms with emerging contingencies. As the contingencies become more complex, local on-scene adaptations are necessary to continue the operation. While these adaptations create flexibility, they also increase ambiguity and diminish the predictability of the outcome of designed procedures that partly restricts coordination based on anticipation (Okhuysen and Bechky 2009). In other words, designed and emergent coordination cannot be seen separate from each other. To understand how their paradoxical relation develops in action, it is helpful to zoom in on

how crisis managers manage between following procedures and adapting on-scene. This requires zooming in (Nicolini 2009) on how crisis managers actually deal with adapting to a continuously changing, or emergent environment, while departing from a designed coordination structure.

Practice based studies offer a tradition that facilitates this by zooming in on what people actually do in organizing (Nicolini 2006, Schatzki et al. 2001). Like Orr (1998, p.439) describes: it focuses on *"what is actually done in the doing of work and how those doing it make sense of their practice"* (Orr 1998, p. 439). As practice based studies zoom in on the performance of ongoing work, organizing processes are central in this approach (Tsoukas and Chia 2002). Organizing processes are interlinked, on-going, and contextualized streams of activities that are enacted by individuals (Orlikowski 2000, Faraj and Xiao 2006). As such, people's work practices constitute the process of organizing by them. Bourdieu (1990, p. 12) defines practices as *"generative formulas reflecting the modus operandi"*, or simpler said, the manner of working. He characterizes practices as constantly in flux, because they are not based upon conscious, constant rules. Instead, practices are based upon practical schemes that are embodied by individuals, and vary according to the logic of the situation. Consequently, the manner in which individuals experience, or make sense of, the environment shapes what kind of activities they undertake (Brown and Duguid 2001). This corresponds with the idea that crisis managers have to constantly make sense of, and adapt to, a changing environment. Therefore, a practice view helps understand how the process of coordination is executed or neglected, and how crisis managers deal with and make sense of the paradoxes they are confronted with.

In this dissertation will I use a practice based perspective to study cross-boundary coordination in action. Practice based studies of coordination have focused mostly on practices occurring within a single organization (e.g. Orlikowski 2002, Bechky 2003, Carlile 2004, Faraj and Xiao 2006, Bechky and Okhuysen 2011, Hsiao et al. 2012). What has been underexposed in the practice debate is that not only do organizations face more and more volatile and specialized environments that require collaboration between professionals, the collaboration also increasingly takes places across the boundaries of different organizations (Brusoni and Prencipe 2001). That is why there is a necessity to study coordination across the boundaries of organizations. There is limited knowledge on what constitutes coordination through work practices that *cross* the boundaries of organizations operating in dynamic environments, and how actors deal with and make sense of these organizational boundaries. It's my objective to explain more precisely how

crisis managers practice *cross-boundary coordination*, while dealing with the paradoxical demand between operating based on *designed* coordination and incorporating the need for *emergent* coordination.

1.2 Administrative and Expertise Coordination

How challenging dealing with the paradoxical demand of designed and emergent coordination may seem, unfortunately this was not the only concern the emergency responders faced in their response to the Turkish Airlines crash. The second challenge described in the public investigation reports was that common understanding between different organizational actors was compromised at several moments during the response operation. During the response operation a deviating understanding existed about the number of victims that are transported to different hospitals (IoJS 2009a, p.13). *"At a certain point no-one knows who is doing what. That the victims are transported to hospitals rather quickly, is because of the professionals in the field who just transported the patients to a hospital, despite of a missing command structure"*. (IoJS 2009a, p.97). This is a rather bold statement in the incident report, but indeed tactical and strategic command units had trouble getting validated information from the field. Improvised action at the crash site by medics triggered new, and obstructed existing information flows in the network of collaborating actors. The following example shows clearly how this occurred.

At the moment the first ambulance arrives at the crash site 18 minutes after the crash at 10:44AM, its crew starts a triage of the amount and severity of wounded victims. The incident report describes that this is immediately problematic, as several victims have already left the crash site by themselves and are transported to a temporary shelter, a nearby barn, with help from bystanders, fire department, and police units (IoJS 2009a). Sometime later, two trauma doctors arrive at the temporary shelter, observe the situation, and decide to intervene. They believe it is necessary to perform a second triage. The trauma doctors assess that 19 victims are incorrectly identified as slightly wounded (Triage Category 3); 17 are seriously injured (Triage Category 2) and two of them are severely injured (Triage Category 1). In addition, the doctors judge that all of these victims need to be transported to the hospital to check for a 'high energetic trauma', due to the severity of the crash speed of 180 km/h (IoJS 2009a, p.91). As a result the 19 victims are transported to the hospital immediately, and all other passengers in a later stage.

The information about the second triage and the new triage status of the victims never reached the other crisis management teams (IoJS 2009a, p.66). Due to the different locations at which the triage has taken place, different numbers of victims with different triage statuses spread throughout the continuously evolving and expanding response network. For a long time it is unclear to the public authorities how many wounded there are and what their status is. In the end it took *four* days to validate the incomplete lists gathered from various on-site medical teams with lists in the 13 involved hospitals (IoJS 2009a, pp. 93-94). The final count shows that 57 victims were transported with ambulances from the crash site, 42 victims were transported from the mobile field hospital and 25 victims were transported with own means of transportation. These numbers illustrate the diffuse situation the crisis teams had to deal with.

Triage is a medical decision making process meant for prioritizing transport of injured to the hospital, and for assessing the medical capacity required for the transport (Koenig and Schultz 1994). Yet, the previous situation shows that triage information is also used for interpreting the number and severity of wounded by other (non-medical) response organizations. It is a well-known concern in emergency response operations that crisis managers with different backgrounds, specialized operational expertise, and different professional languages need to coordinate across their jurisdictional and organizational boundaries (Comfort and Kapucu 2006). This offers a multilayered coordination challenge, as the gathering of victim information requires the crossing of jurisdictional boundaries, which includes the regulation of authority, legitimization, and the application of expertise. This is especially the case for communicating information about the number and severity of wounded. Providing the correct number of victims is an important aspect for different response organizations in their (public) crisis communication. When multiple response organizations use and interpret triage information, misunderstandings about the status and number of victims will likely reverberate throughout the entire emergency response network, causing extensive coordination problems.

I will characterize this coordination problem in terms of *administrative* and *expertise coordination*. Administrative coordination is based on tangible resources, such as documents, checklists, and standard operating procedures, which are employed for routine tasks. For more complex, non-routine tasks, administrative coordination is insufficient. Managing complex tasks requires expertise coordination, the management of knowledge and skills. Expertise coordination is much harder to grasp because professional judgment and skills remain embodied in the craftsmanship and proficiency of professionals (Faraj

and Sproull 2000). As such, expertise coordination often occurs implicitly between groups that have a similar proficiency, through anticipation and dynamic adjustment (Rico et al. 2008). For instance, when firefighters estimate the hose length for frontline teammates, they do not explicitly discuss so, but will continuously adjust in course of the operation. In the aftermath of the Turkish Airlines crash expertise coordination is visible through the 'expert' on-scene reassessment for another triage by the trauma doctors. Paradoxically, this *expertise coordination* directly influenced the validity of the ongoing *administrative coordination* of triage numbers between the involved command centers. As a second triage was performed based on the expert assessment of the trauma doctors, it conflicted with the ongoing administration of triage classifications, as new triage statuses were given. The expert assessment that all passengers need to be checked for a high energetic trauma in a hospital poses a formidable logistical task for the medical agencies. Hence, similar to designed and emergent coordination, administrative and expertise coordination also have a paradoxical relation since expertise judgment often coincides with administrative procedures.

When expertise is coordinated across the boundaries of organizations it is likely that professionals have different backgrounds and knowledge. As a result common understanding is often limited, as each actor relies on his own training and expertise for assessing the situation. Once different actors interpret the situation from their own background, differences in judgement of interdependencies and subsequent coordination requirements appear. This is regarded as problematic in the coordination debate since common understanding is a key integrative condition for coordination (Okhuysen and Bechky 2009). Common understanding is required to oversee the whole, assess what interdependencies arise and how they should be managed. Therefore, in the coordination debate a considerable amount of attention has been paid to how boundaries can be bridged to develop common understanding (Carlile 2004).

The debate on cross-boundary coordination of knowledge centers around three boundary-spanning models: *trading*, *sharing* and *knowing* (Hsiao et al. 2012). These different boundary spanning models focus on different kinds of cross-boundary coordination processes. In the *'trading model'* coordination is achieved through negotiation of interests, while in the *'sharing model'* the exchange of knowledge is central, and in the *'knowing model'* the process of learning is emphasized. Each model identifies a different boundary spanning process that has a different logic and duration. The *'knowing model'* emphasizes long term learning processes by studying how members

of different communities can gradually acquire knowledge through participating in each other's craft (Hsiao et al. 2012, Brown and Duguid 2001, Lave and Wenger 1990). Learning how the other party operates, what language they use, and how they solve problems, helps to cross similar boundaries in the future (Hsiao et al. 2012). In the *'sharing model'* transferring, translating and transforming knowledge is put central (Carlile 2004, Bechky 2003). It's argued that experts need to communicate ambiguous meanings across the boundary of their organizations so simply transferring knowledge is often not enough. Instead, in the process of boundary spanning, knowledge needs to be 'translated' to establish common meaning, or 'transformed' to support the negotiation of contested meanings.

Yet, as the triage process in the aftermath of the Turkish Airlines crash shows, the problem that fast response organizations face, develops too fast for learning and entails more than merely translating knowledge. Experts need to coordinate in an environment that is unknown, difficult to oversee, and that is characterized by unexpected and continuous change. This dynamic environment makes it very difficult to develop and sustain common understanding. Moreover, action and expertise are often distributed and need to be employed immediately, to prevent the situation from escalating or deteriorating. Studies about organizations operating in fast paced environments stress the limitations of developing common understanding for coordination (Kellogg et al. 2008). This is reflected in the *'trading model'*, in which members of different communities coordinate their actions temporarily and locally, navigating their differences in norms and interests only as needed (Kellogg et al. 2008). During the trading process experts make information visible through representations of the situation, which function as a shared medium to support the coordination process (Okhuysen and Bechky 2009). I will conceptualize these representations as *boundary objects* (Star and Griesemer 1989). Boundary objects are representations that help to cross boundaries between two intersecting social worlds. They are generally treated as means of translation based on their interpretive flexibility, as different groups develop different interpretations of the same object (Star 2010, Pickering 2003). A boundary object facilitates the cross-boundary coordination process as actors with different backgrounds try to find enough common ground to understand their interdependencies, while retaining their differences.

In emergency management a boundary object often takes the shape of a 'Common Operational Picture' (COP). A Common Operational Picture represents a map of the disaster area that is used for coordination by pinpointing important objects, as well as

the progress of the response operation (Wolbers and Boersma 2013). Using the Common Operational Picture to represent the disaster site helps crisis managers to quickly display the state of affairs, while they can negotiate their different interpretations of the situation. Maps are general enough to provide quick overview, while different users can still interpret them in different ways. Therefore, it is commonly claimed that boundary objects have a capability of being malleable enough to adapt to different local needs and routines, while at the same time being robust enough to foster common understanding (Trompette and Vinck 2009, Star and Griesemer 1989, Star 2010). In the boundary objects literature a lot of attention has been paid to the different manifestations of the boundary object itself (Zeiss and Groenewegen 2009). Relatively little, however, is known about the process of how the boundary object is configured in-use. Especially in emergency management crisis managers from multiple disciplines have to continuously update the Common Operational Picture to match changing contingencies. Therefore, the boundary object is continuously changed in course of the response operation. To study this process of change I will zoom in on the coordination processes through which boundary objects are constructed and configured in use throughout the response operation. This perspective moves the attention away from the object itself, to the process of its construction and use. It helps to understand in more detail how boundary objects develop and change during the coordination process, which generates a more complete understanding of the processes that support or inhibit cross-boundary coordination.

In crisis management the Common Operational Picture is receiving progressively more attention, as it's recognized that representations of the disaster scene are an important coordination mechanism for supporting the development of situational awareness (Endsley 1995, Comfort 2004, Wolbers and Boersma 2013). Finding the appropriate technological infrastructure for the Common Operational Picture has been considered a key challenge. However, this technological solution is rooted in an 'information warehousing logic', which implies information can be collected, sorted and exchanged in an accessible and univocal form. Yet, the focus on the technological aspect of information management is decreasing the concern for social and organizational processes, as for instance, in practice professionals interpret similar information differently. Therefore, it is valuable to focus on how emergency responders try to develop common understanding by making sense of information (Weick et al. 2005, Maitlis and Sonenshein 2010). To capture these aspects of coordinating with help of a Common Operational Picture, I will use a sensemaking perspective to show how crisis managers attribute different meanings to information

that can help or distort information sharing. A sensemaking perspective is appropriate since it focuses on how actors interpret information, and how they try to develop a shared understanding of the same information. This provides a more holistic, embodied perspective on the process of information sharing during cross-boundary coordination.

1.3 Centralized and Networked Coordination

The third challenge described in the public investigation reports was the information management between different crisis management teams, operational in the GRIP3 emergency state. Several agencies and teams were active quite rapidly, but were deprived of information for several hours (IoJS 2009a, p.66). This led to coordination problems between the medical organizations in the now rapidly expanding emergency response network. Providing emergency care for 86 wounded overwhelmed the local medical response capacity, but fortunately the VOS6 protocol didn't only designate staging areas; it also activated the procedures to call 3 Mobile Medical Trauma teams (MMT) and 64 ambulances to the crash site (IoJS 2009a). Furthermore, it notified dispatchers that between 7 and 13 hospitals had to be warned to create emergency trauma room capacity. Emergency response centers throughout the Netherlands received the call and rerouted their ambulances to the crash site.

While the initial dispatch of 64 ambulances was fast, the quick capacity buildup created additional problems. In the heat of the moment dispatchers only warned 6 hospitals and failed to call in the MMTs in first instance (DSB 2012). As the focus was on building ambulance response capacity, limited attention was paid to the information needs of other partners in the medical response network. This led to several problems in the periphery of the network. As no calls came in several hospitals anticipated on a large amount of wounded at own initiative, kept trauma rooms at bay, and called in additional surgical capacity. This forced several hospitals to cancel their planned surgeries to keep trauma care available, but they were not notified when the number of severely wounded was far less than expected (IoJS 2009a).

It's a well-known phenomenon in emergency medical care that organizing a coherent triage, transportation, and registration during mass casualty situations leads to coordination issues (Tierney 1985, Koenig and Schultz 1994). Monitoring the status and location of casualties requires consistent communication between a wide

spectrum of medical actors: the medical officer, casualty transport coordinator, mobile field hospital commander, ambulances crews, emergency response centers, national ambulance dispatch center, and hospitals. To make matters more complicated, police and municipalities share responsibility for casualty registration and communicating information to victims' relatives.

The common solution for structuring communication and enabling fast decision-making is by employing a centralized command and control structure, in which communication lines and authority are formalized. Command and control structures are known for their hierarchical decision capacities and clear role structures, and are a powerful instrument for accomplishing tasks characterized by repetition and uniformity (Quarantelli and Dynes 1977). Its underlying premises is that when the organizations involved in the response operation match the existing command structures, centralized coordination forms a quick and effective solution. Yet, such a system is difficult to maintain in a dynamic environment in which a large number of organizations become involved and membership fluctuates over time. Like I have argued in the previous paragraphs, in these situations command and control structures insufficiently account for the decentralization and flexibility that is required during the response operation.

Similarly, the coordination process in the aftermath of the Turkish airlines crash shows that the dynamics occurring around medical logistics cannot be understood completely in terms of *centralized* coordination. The problems response organizations are confronted with outgrow the span of control of the existing command and control structure, as organizational and jurisdictional boundaries need to be crossed. This calls for a coordination structure that is able to account for the distributed nature of this coordination problem: *networked* coordination. Due to its enhanced capacity for adaptation to fluctuations in the environment, networked coordination is found to be more effective to deal with the distributed nature of information and decisional challenges under pressure (Moynihan 2008a, 2009). Therefore, centralized command structures are gradually extended with or transformed into inter-organizational networks to provide a structure through which distributed crisis response activities can be coordinated (Topper and Carley 1999, Moynihan 2008a).

An important coordination challenge of networked coordination is that as new organizations are included in the network, information sharing becomes increasingly complex, as information flows through the network from various positions at different times. This occurs because response organizations have operational field units at different

levels, different functional command structures, and separate back-offices for information and resource management (Comfort and Kapucu 2006). Therefore, a rapidly evolving network triggers an information flow that is in flux. The research challenge is that, as Topper and Carley (1999) argue, much remains unclear about how information flows through the network and what networked coordination looks like in terms of structural evolution. In other words, how does information sharing in response networks develop, and how does this affect cross-boundary coordination?

To depict these network dynamics I will focus on how to capture the time critical nature of the communication and coordination during a response operation. While a lot of network studies try to depict and conceptualize the characteristics of networked coordination, they fail to take into account its processual nature. Hence, it is important to explore the time critical processes that constitute the network, to develop a better idea of the dynamics underlying networked coordination.

1.4 Defining cross-boundary coordination

Where does the previous analysis of the coordination issues during the Turkish Airlines crash leave us? The set of three paradoxes -designed and emergent coordination, administrative and expertise coordination, and centralized and networked coordination- all have their own specific way of conceptualizing cross-boundary coordination. Still, if one important aspect of coordination stands out from the case of the Turkish airlines crash, it is that the processes are interrupted when the officers experience and create different sorts of boundaries, while they need to coordinate simultaneously with multiple sets of actors in a very limited time frame. The manifestation of boundaries makes it difficult for organizations to foresee the consequences of their actions in relation to the whole in a turbulent environment, where there is an immediate need to act.

This features in the incident reports when information that is required for coordination tends to be shared only in a specific functional or organizational setting, and it is likely to stay only in that 'silo' or 'stovepipe' (Roberts 2011). For example, the combination of a geographical and a jurisdictional boundary is encountered when the location of the crash site was known almost instantly by the ERC in Alkmaar, but this information was not communicated on time with the ERC in Haarlem. A different type of boundary is encountered during the triage of victims. What seems as a logical intervention for the

trauma doctors is not immediately recognized and communicated due to a knowledge boundary between the emergency management officials. Ultimately, what stands out from these examples is that different boundaries emerge, at different locations and at different times, that hamper coordination. To understand the different coordination issues during the Turkish Airlines crash it is necessary to unpack the concept of boundaries.

I consider a *boundary* as a demarcation that marks the limits of a common set of practices, which may include functional and hierarchical boundaries, as well as, knowledge, cultural, temporal, and spatial boundaries (Hsiao et al. 2012, Carlile 2002, Beckhy 2004, Levina and Vaast 2005, Orlikowski 2002). Boundaries are not fixed entities or obstructions waiting out there to impede coordination between different parties. Instead, boundaries as social objects are shaped by spatial locations, temporality, personal interpretations, patterns of interactions, and formal and perceived accountabilities (Barley and Kunda, 2001). As such, boundaries are created and perceived by individuals; they are socially constructed. Regarding boundaries as social constructions allows me to reflect upon whether boundaries themselves are problematic during coordination, or whether cross-boundary coordination actually depends more on how people socially reconstruct a boundary.

Treated in this way, boundaries form a discontinuity, and therefore require actors to negotiate the way in which the boundary shapes the collaboration beyond the discontinuity (Watson-Manheim et al. 2012). When a boundary is encountered during coordination it momentarily inhibits actors from grasping the nature of the interdependencies between them. Difficulties to grasp interdependencies can emerge due to knowledge differences, different expectations, or unexpected changes during the coordination process. To be able to coordinate based on a new situated understanding of how interdependencies can be managed, actors have put effort in crossing the perceived boundary between them. This activity is commonly addressed as *boundary spanning*, which occurs, for instance, through redefining roles (Okhuysen and Beckhy 2009), crafting boundary objects (Star and Griesemer 1989, Carlile 2002), negotiating interests (Vaughan 1999, Kellogg et al. 2006), sharing knowledge (Carlile 2004), engaging in epistemic contestation (Faraj and Xiao 2006), or creating shared understanding (Hsiao et al. 2012, Bechky 2004). My definition of cross-boundary coordination can be derived from this conceptualization of boundaries.

I define *cross-boundary coordination* as a temporally unfolding and contextualized process of managing interdependencies in response to the discontinuity of a boundary, in order to realize a collective performance (Malone and Crowston 1994, Faraj and Xiao 2006,

Okhuysen and Bechky 2009, Watson-Manheim et al. 2012). In this definition coordination is treated as a process (Jarzabkowski et al. 2012, Gkeredakis 2014) that temporarily unfolds on the basis of the perceived contextualization of the interdependencies by different actors. During this coordination process actors may encounter different sorts of boundaries that offer discontinuities, which need to be overcome in order to align their interests (Watson-Manheim et al. 2012). This definition leaves us to question how the process of managing interdependencies occurs in the challenging and dynamic environment of emergency response.

1.5 Research Methodology

Emergency management provides a dynamic empirical field to study cross-boundary coordination. As we have witnessed in the analysis of the Turkish Airlines crash, cross-boundary coordination is a multi-layered phenomenon, as it occurs at the level of task execution, regulation of authority, information sharing, and during the application of expertise. The locus of these different coordination processes can be traced back to the incident site when emergency officers from different organizations and their field commander need to understand each other and synchronize their interdependent actions in a very limited time frame. Giving attention to these actors helps to gain understanding of how cross-boundary coordination unfolds in these fast-paced environments.

Intriguing about the operations at the disaster site is that officers in command face paradoxical demands in their work practices, that entail working in predefined structural designs based on protocols and procedures, while the situation calls for rapid adaptations based on their expert judgment. As these adaptations take place in changing configurations, different types of boundaries are encountered that need to be bridged. This occurs in a 'pressure cooker' in which time pressure pushes the officers to make rapid decisions in a context that is very difficult for them to oversee. These fast-paced dynamics provide a major challenge for cross-boundary coordination and allow me, as an organizational scientist, to challenge existing and develop new conceptual and theoretical inferences about the nature of cross-boundary coordination practices in fast-paced environments.

To capture the complexity of how these multilayered coordination processes unfold, I will use a mixed methods research approach. This is necessary because the

interactions that constitute cross-boundary coordination occur at different levels, and boundaries emerge at different places. Consequently, different types of interactions and processes need to be studied at these different levels. In the different empirical studies I will move from the locus of practice at the field command level, towards information flows in the network of collaborating organizations. As the different chapters focus on different kinds of coordination processes, each empirical chapter employs its own appropriate methodological toolset, based on a different combination of methods which is justified accordingly. In the different chapters I will focus on four different coordination processes: cross-boundary coordination practices, the tailoring and configuration of boundary objects, processes of sensemaking and narratives, and sequences of information flows through the response network.

The qualitative data is collected from the winter of 2010 into the winter of 2014, and focuses on both field exercises and real-life incident response operations. To get access to the cross-boundary coordination processes in situ I observed and recorded 40 emergency management field exercises and in a later stage interviewed the involved officers in command, field commanders and other experts at the operational and tactical level. This resulted in total in 64 formal interviews, and numerous site visits to 19 different safety regions in the Netherlands. The interviews with the officers that participated in the exercises allowed me to reflect on their actions during the exercises and to explore if and how they experienced similar tensions during real-life emergency response operations. Later I interviewed another set of 13 officers at the operational and tactical level that were involved in the response to a large traffic accident on a Dutch highway on June 28th 2011. As this incident was similar to one of the training scenario's it allowed me to compare the analysis of the exercise with a real operational event. Finally, the network analysis is based on a document analysis and formalization of interactions described in the incident report about the response operation to the Schiphol Tunnel fire that occurred on July 2nd 2009. In addition to the analysis of the Schiphol Tunnel fire report, multiple other incident reports are analyzed to check for descriptions of cross-boundary coordination dynamics.

As the different studies all have their own methodological approach, they are supported by an overall coherent approach, in which ontological assumptions and methodological choices are aligned (Nicolini 2012). The common ontology behind my methodological approach is a *process ontology*. A process ontology is based on the premise that the world is in constant movement, and consists of flows, in which things are reifications of the continuous process that constitute it (Tsoukas and Chia 2002). As

the world is considered to be in constant movement, process studies focuses on evolving phenomena, how and why things emerge, develop and end over time (Langley et al. 2013). Therefore, it draws on theorizing that explicitly incorporates temporal progression of activities. By adopting a process approach I'm able to connect the different studies of cross-boundary coordination in the upcoming chapters.

To study the coordination practices I employed inductive, qualitative field studies during field exercises using the grounded theory approach outlined by Corbin and Strauss (2008). Studying a practice in general requires two basic movements: zooming in on the accomplishments of practice, and zooming out towards the relationships in space and time (Nicolini 2012). As practices are inherently contingent they cannot be understood without reference to a specific place and time. Therefore it is necessary to capture the full richness of the stream of activities and investigate how they are connected to the interdependencies in the environment (Barley and Kunda 2001, Langley 1999). Zooming in on the contingent actions of the officers in command makes the interactional order, temporal adaptations and artefacts they work with visible. This approach is characterized by an iterative process of continuously moving back and forth between the empircal phenomena and its theoretical reading (Alvesson and Kärreman 2007). In the end, I systematically abstracted this grounded data into more general patterns, and used these for theorizing that result in a process model (Gioia et al. 2012).

For the study on the use of boundary objects I required more insight into the sequential nature of these process dynamics. To capture cross-boundary patterns of action over time that center around boundary objects I performed a Markov chain analysis on the codes of the coordination modes from the transcriptions of the field exercises. Markov analysis gives an indication of whether there are regularities in local sequential structure whereby acts are predictable from immediately preceding acts (Poole et al. 2000). By identifying common recurrent sequences, Markov analysis points to features of interaction that can then be explored in further discourse analysis when returning to the transcripts themselves. To visualize this structure, I utilized a visual mapping strategy (Langley 1999) by creating a timeline that visualized the transitions between the coordination modes. This timeline depicts the sequence of coordination modes as it unfolds during the episodes and affords a more detailed understanding of the temporal sequencing of coordination.

To capture sensemaking processes and underlying narratives I analyzed the field exercise transcriptions by adopting an interactional narrative analysis (Riessman 2005). This type of narrative analysis zooms in on the dialogue between teller and listener to

analyze the dialogue as a process of co-construction, where teller and listener create meaning collaboratively (Riessman 2005). Analyzing narratives enabled me to zoom into the underlying cues, roles, scripts, and recurrent action that arise from the different institutional context of the emergency responders, as well as their organizational values (Gabriel 2000).

By using these previous methods I have zoomed in on the dilemmas of the officers in command on the disaster site. Yet, this does not provide the full picture of the distributed cross-boundary coordination challenges described earlier in the analysis of the Turkish Airlines crash. As the analysis of that response operation showed, it is necessary to zoom out because cross-boundary coordination is a multifaceted process that occurs at different places, and at different times. This networked coordination process is based on distributed information streams that evolve throughout the response network. I used social network analysis to study the temporal flows of information sharing processes. To be able to capture the temporal information sharing processes I used network analysis based on a process ontology that focuses on the flows of information inside the network. This approach does not regard the network structure of relationships as a fixed entity, but, instead is treated as being permanently in a state of becoming. While the network is continuously evolving as information is send and received by different actors at different times it creates an information sharing process that is in flux. By taking different snapshots of this network moments of temporal stability can be detected, in which the relations can be assessed as temporal social network structures.

1.6 Chapter overview: 'drawing the line' as the central metaphor

In the upcoming chapters of my dissertation I will be unpacking the processes of cross-boundary coordination along the lines previously articulated. I will explore, analyze, and theorize in what ways emergency response officials deal with the challenges they encounter during the coordination process. As a reader, you might recognize that the paradoxes between designed & emergent coordination, administrative & expertise coordination, and between centralized & networked coordination, offer a recurring perspective in all four chapters, either explicitly stated or implicitly implied. This also features in the title of this dissertation *'drawing the line'*, which serves as the central metaphor to connect the different theoretical perspectives and methodological approaches in each of the chapters.

Chapter 2. Picking up the Pieces: A fragmentation perspective on cross-boundary coordination

'Drawing the line' means to treat one thing different from another. In chapter two I will show that fragmentation is central to coordination in crisis management. Fragmentation emerges because ambiguous demands lead to a complexity of relationships and multiplicity of interpretations. In this chapter I will zoom in on how officers in command deal with such ambiguity by negotiating the relevance of their experienced boundaries. By showing how coordination is also about constructing boundaries, or metaphorically drawing different lines, I will illustrate that negotiation is a key aspect of cross-boundary coordination.

Chapter 3. Drawing the Line: Tailoring boundary objects for cross-boundary coordination

'Drawing the line' is also literally done by officers in command to develop situational awareness by using the Common Operational Picture. Maps and drawings of the disaster site function as boundary objects that are used to acquire overview on the response operation, and to negotiate the value of different perspectives. In this chapter I will analyze a case where a red line is drawn on the COP in a field command meeting to demarcate a hazardous no-go area. Moments after a red line is drawn on the map in the field command meeting, a medical officer wanders off into the toxic area. This situation is analyzed in-depth, compared with other cases, and used to show that it's important to study the configuration of boundary objects from a processual view. The inductive process analysis results in the distinction of four coordination modes, which show how boundary objects are tailored in action by moving between modes that stress integration or segmentation, and modes that stress an open or closed configuration. In this chapter a relational perspective on boundary objects-in use is developed by showing how boundary objects can support different coordination modes simultaneously. This generates a more complete understanding of the process by which the configuration of a boundary object is constituted in-use and why this supports or inhibits cross-boundary coordination.

Chapter 4. You Didn't Know This Was Relevant For Us? Excuse me!

'Drawing the line' also means to define when the limit has been reached. In this chapter I will illustrate how officers at the disaster site contest and negotiate their actions by using a Common Operational Picture. During the negotiation process it becomes clear that information is often expressed only in a particular way, benefiting the actions of

one response organization, but diminishing the importance of the actions of others. This offers a new 'trading zone' perspective in contrast to the dominant 'information warehouse' logic many information systems scholars use in crisis management studies. By using sensemaking theory I will show that the officers experience different cues and enact coordination differently, when dissimilar lines are drawn and limits are negotiated, which impedes cross-boundary coordination of the response operation.

Chapter 5. *Incorporating Time Dynamics in the Analysis of Social Networks in Emergency Management*

Finally, *'drawing the line'* resembles the emerging connections between actors in a network picture. In this final chapter I zoom out towards the network level to depict the tension between centralized and networked coordination. The analysis of the response to the Schiphol tunnel fire is used to introduce a process perspective to social network analysis. I argue that the role of temporality and timeliness is not properly dealt with in network studies of emergency response networks, thus limiting our knowledge of how these structures evolve, enable, or constrain different coordination possibilities over time.

1.7 Chapter background

The chapters in this dissertation are based on a number of international, peer-reviewed publications, conference proceedings, professional publications, and presentations. An overview of this output is presented below, organized by empirical chapter. As our research group has a tradition of cooperative research, the empirical chapters of my dissertation are co-authored. Therefore, in these chapters the we-form is used. As a first author on all these manuscripts I took the lead in both the research and writing process.

Chapter 2

Wolbers, J., F. K. Boersma, P. Groenewegen. 2014. 'Picking up the Pieces. Towards a Fragmentation Perspective of Cross-boundary Coordination'. Manuscript under review at *Organization Studies*

Accepted for: the 2015 Academy of Management Meeting: Opening Governance, August 7-11 2015, Vancouver, British Columbia, Canada.

Presented at: 30th EGOS Colloquium: Reimagining, Rethinking, Reshaping: Organizational Scholarship in Unsettled Times, July 3-5 2014, Rotterdam, Netherlands.

Presented at: 8th Annual Liverpool Symposium on Current Developments in Ethnographic Research in the Social and Management Sciences: The politics of meaning making and meaning breaking, August 28-30 2013, Amsterdam, Netherlands.

Presented at: Conference on Coordination within and among Organizations, Administrative Science Quarterly (ASQ), Academy of Management OMT Division, June 2011, HEC, Paris, France.

Chapter 3

Wolbers, J., F. K Boersma, P. Groenewegen, M. S. Poole. 2015. 'Drawing the Line. Tailoring boundary objects for cross-boundary coordination'. To be submitted.

Presented at: 30th EGOS Colloquium Pre-Colloquium Paper Development Workshop Understanding organization as process, July 2nd 2014, Rotterdam, Netherlands.

Presented at: 29th EGOS Colloquium: Bridging Continents, Cultures and Worldviews, July 4-6 2013, Montreal, Canada.

Presented at: 3rd International Process Symposium: How Matter Matters: Objects, Artifacts and Materiality in Organization Studies, 16-18 June 2011, Corfu, Greece.

Chapter 4

Wolbers, J., K. Boersma. 2013. The Common Operational Picture as Collective Sensemaking, *Journal of Contingencies and Crisis Management*, **21**(4): 186-199.

Presented as Keynote: 'The Common Operational Picture as Collective Sensemaking', Situational Awareness & Incident Management (SAIM) Symposium, 17-18 June 2014, *Joint Research Center*, *European Commission*, Ispra, Italy.

Presented in Expert Panel: 'Creating the Common Operational Picture with the Crowd': 11th International Conference on Information Systems for Crisis Response and

Management, (ISCRAM), 19-21 May 2014, University Park, State College, Pennsylvania, USA.

Wolbers, J., K. Boersma, J. de Heer. 2012. *Netcentrisch Werken in Ontwikkeling. Een cultuuronderzoek naar multidisciplinaire samenwerking en gezamenlijke operationele beelden in de Veiligheidsregio's*. De Swart, Den Haag.

Chapter 5

Wolbers, J., P. Groenewegen, J. Molle, J. Bim. 2013. Incorporating Time Dynamics in the analysis of Social Networks in Emergency Management, *Journal of Homeland Security and Emergency Management*, **10**(2): 1-31.

Passenier, D., J. Mollee, J. Wolbers, K. Boersma, P. Groenewegen. 2012. Formalization of crisis response coordination from a public inquiry report. In: L. Rothkrantz, J Ristvei & Z. Franco (Eds.), *Proceedings of the 9th International Conference on Information Systems for Crisis Response and Management ISCRAM 2012*. Vancouver, April 2012: 1-5

1.8 Drawing another line: beyond the focus of this dissertation

In my years as a PhD candidate I have also studied other phenomena in emergency management, in addition to the four empirical articles that are focused on cross-boundary coordination. This resulted in 10 additional publications that are not directly included in this dissertation. These studies articulate my earlier work as a bachelor and master student and functioned to sharpen and articulate my ideas. I will briefly list these to show the full spectrum of my work during my PhD trajectory.

The original study towards the implementation of Netcentric Work that led to the interview on the day of the Turkish Airlines crash is published in the *Journal of Homeland Security & Emergency Management*.

Boersma, F. K., F. P. Wagenaar, J. J. Wolbers. 2013. Negotiating the 'Trading Zone'. Creating a shared Information Infrastructure in the Dutch Public Safety Sector. *Journal of Homeland Security and Emergency Management*, **9**(2) 1-25.

An ethnographic study of multi-organizational collaboration an Emergency Response Center (112 calls) from my bachelor thesis –by which I set my first steps into the field of emergency management– is published in the IGI handbook of research on electronic collaboration.

Wolbers, J., P. Groenewegen, P. Wagenaar. 2009. 'ICT to Facilitate Emergency Response in the Netherlands' In: J. Salmons and L. Wilson, *Handbook of Research on Electronic Collaboration and Organizational Synergy,* Hershey: IGI Global: 626-636

A research report focused to give advice to improve the role of Netcentric Work for information management is published in a Dutch report: *'Netcentric Work in Development'*

Wolbers, J., K. Boersma, J. de Heer. 2012. *Netcentrisch Werken in Ontwikkeling. Een cultuuronderzoek naar multidisciplinaire samenwerking en gezamenlijke operationele beelden in de Veiligheidsregio's.* De Swart, Den Haag.

Together with Willem Treurniet, master thesis student Manne Messemaker and Kees Boersma, I published a comparison of crisis communication styles and command doctrines during the Moerdijk Chemical Fire and Alphen mall shooting.

Treurniet, W., M. Messemaker, J. Wolbers, K. Boersma. 2015. Shaping the societal impact of emergencies: striking a balance between Control and Cooperation, *International Journal of Emergency Services,* **4**(1).

During the PhD trajectory I regularly visited the 'International Conference on Information Systems for Crisis Response and Management' (ISCRAM) to present new ideas and findings in Work in Progress papers. This resulted in 5 publications in the ISCRAM conference proceedings.

Boersma K., J. Ferguson, P. Groenewegen, J. Wolbers. 2014. Beyond the Myth of Control: toward network switching in disaster management. In: S.R. Hiltz, M.S. Pfaff, L. Plotnick, and A.C. Robinson (Eds.), *Proceedings of the 11th International Conference on Information Systems for Crisis Response and Management ISCRAM 2014*. University Park, Pennsylvania, USA, May 2014: 125-129

Messemaker, M., J. Wolbers, W. Treurniet, K. Boersma. 2013. Shaping Societal Impact: between control and cooperation. In: T. Comes, F. Fiedrich, S. Fortier, J. Geldermann and T. Muller (Eds.), *Proceedings of the 10th International Conference on Information Systems for Crisis Response and Management ISCRAM 2013*. Baden-Baden, May 2013: 901-905

Passenier, D., J. Mollee, J. Wolbers, K. Boersma, P. Groenewegen. 2012. Formalization of crisis response coordination from a public inquiry report. In: L. Rothkrantz, J Ristvei & Z. Franco (Eds.), *Proceedings of the 9th International Conference on Information Systems for Crisis Response and Management ISCRAM 2012*. Vancouver, April 2012: 1-5

Treurniet, W., K. van Buul-Besseling, J. Wolbers. 2012. Collaboration Awareness. A necessity in crisis response coordination. In: L. Rothkrantz, J. Ristvej & Z. Franco (Eds.), *Proceedings of the 9th International ISCRAM Conference*. Vancouver, April 2012: 1-5

Boersma, F. K., F. P. Wagenaar, J. J. Wolbers. 2010. Organizing Emergent Safety Organizations. The travelling of the concept 'Netcentric Work' in the Dutch Safety Sector. In: S. French, B. Tomaszewski and C. Zobel (Eds.), *Proceedings of the 7th International Conference on Information Systems for Crisis Response and Management ISCRAM*. Seattle, April 2010: 1-6.

Finally, I have co-edited 4 articles and 3 essays on the challenge of Incident Command, as a guest editor in the Special Issue of the Journal of Contingencies and Crisis Management on: *'Incident Command Systems: A dynamic tension among goals and rules'*.

Boersma, F. K., L. K. Comfort, J. Groenendaal, J. Wolbers. 2014. Incident Command Systems, A dynamic tension among goals and rules. *Journal of Contingencies and Crisis Management*, **22**(1): 1-4

2. Picking up the Pieces [1]

Summary

Already for several decades empirical studies in disaster management show that fragmentation is a prevailing phenomenon. Still, coordination theories are primarily characterized by a focus on integration, aimed at achieving a coherent and unified set of actions. A tautology is concealed in this approach: coordination is simultaneously the diagnosis of the problem and the way forward to resolve it. We will show that dealing with fragmentation is not only inevitable; it is a key characteristic of coordinating across the boundaries of response organizations in turbulent environments. Fragmentation emerges because ambiguous demands lead to a complexity of relationships and a multiplicity of interpretations. We zoom in on how officers in command from fire department, medical services, and police coordinate through boundary work on the basis of negotiation. Our analysis indicates that cross-boundary coordination is not based on integration, but can be better interpreted through a fragmentation perspective to unveil the cross-boundary coordination dynamics of negotiation. By showing how fragmentation is not a deficiency of integration, but has features in itself that are necessary for coordination in fast-paced environments, our work generates a more complete understanding of the process of coordinating, in both the practice of crisis management, and for organizational theory in a broader sense.

1 This chapter under review at *Organization Studies* and is co-authored with Kees Boersma and Peter Groenewegen.

2.1 Picking up the Pieces

Emergencies offer a unique challenge for coordination between emergency response organizations. During an emergency situation circumstances change rapidly over time, which makes it difficult for emergency management organizations to oversee the full complexity of their interdependencies (Rimstad and Sollid 2015). Emergency response units need to coordinate across their organizational boundaries in these turbulent environments, often with partners they have not worked with before (Comfort 2007). This offers two challenges for coordination. First, a multitude of organizations engage in emergent collaborations to tackle unforeseen problems that no single organization can address singlehandedly, which leads to the emergence of ad-hoc interdependencies (Roberts 2011). Second, expertise is suddenly needed on emerging coordination issues responders are confronted with that exceed their own knowledge (Weick and Sutcliffe 2011). Combined, these issues challenge emergency responders to coordinate ad-hoc with experts from different response organizations who have different skills and professional jargons, in an environment that is characterized by continuous time pressure, as it is prone to escalate.

As emergency responses to disasters have shown, this often results in fragmentation: the separation of the organizational responses into segments, leading to disjunction. For example, Dearstyne (2007) describes the fragmentation in the mobilization of the response operation in New York on 9/11. Organizing a coordinated response after the attacks proved to be a daunting task, as: *"commanders in the towers had very little reliable information on what was happening outside the towers. They had no external information about the overall status of the incident area. This lack of information hindered their ability to evaluate the overall situation. Command posts were set up and then moved before they accomplished substantive work"* (Dearstyne 2007, p.40). Fragmentation is not exclusive to large-scale catastrophic events, it is also visible during much smaller incidents. In response to the collapse of the I-95 highway in Mississippi, for example, police and fire departments set up command posts in different locations and struggled with combining rescue and crime scene investigation (Cook 2009). Also, during a chemical spill in Helsingborg, Sweden commanders struggled to deal with the ad-hoc response operations that *"did not follow fixed plans or procedures"* (Uhr et al. 2008, p. 83). Fragmentation emerges during these response operations because emergency responders have to deal with unexpected turns of events, attend to a variety of demands

simultaneously, and manage opposing interests in situations that are difficult to oversee and are characterized by high time pressure.

These observations should give reason to pause. While in organization and management theory coordination is considered to be about *"the integration of organizational work under conditions of task interdependence and uncertainty"* (Okhuysen and Bechky 2009, p. 469), already for several decades empirical studies in emergency management showed that reaching integration is problematic (Dynes and Aguirre 1979, Drabek 1985). Instead, fragmentation is a prevailing phenomenon during smaller and larger incidents (Drabek 1985, Quarantelli 1997). At the same time, fragmentation has a negative connotation in the coordination debate and is often treated synonymously with a notion of uncontrollability, disorder and failure. This relation between integration and fragmentation points us to a tautology that is concealed in the coordination debate: a lack of integration is the diagnosis of the coordination problem and more or better integration is the way forward to resolve it (Kettle 2003). Likewise, Roberts (2011, p. 677) notes that *"despite constant calls for better coordination, the path to get us there keeps circling back on itself"*. We claim that the tautology originates in the treatment of integration and fragmentation as a dichotomy, in which integration leads to coordination and fragmentation should be avoided. The consequence of theorizing coordination only in terms of integration is that the significance of fragmentation has been overlooked.

However, we believe that fragmentation has something to offer for our understanding of coordination. To see the possibilities of fragmentation, the term requires amelioration: the transformation of a negative connotation to a positive one. Fragmentation is too often simply portrayed as a lack of coordination, while it might better characterize the reality of operating in fast-paced environments like emergency management, in which interdependencies arise under high time pressure, are difficult to oversee, and offer equivocal demands due to ambiguity and unexpected changes. Ambiguity and ad-hoc adaptations stand at contrast with an integration logic, since they prevent from managing based on a cohesive whole. Nevertheless, in the fast-paced dynamics of emergency situations integration is often the least viable option, or simply cannot be achieved. This leaves open research ground, because *how is cross-boundary coordination practiced in fast-paced environments like emergency management, when achieving integration is challenged?*

To explore how coordination is performed in situ, we will zoom in on the contextualized coordination practices of officers in command that are responsible for cross-boundary

coordination. Our insights are drawn from a 4 year multi-sited ethnographic study of 40 emergency management exercises in the Netherlands, combined with 56 retrospective interviews with emergency response officials about their coordination practices during both real life response operations and exercises. The contribution we make in this paper is to develop grounded theory on how coordination is accomplished in fast-paced environments that are characterized by fragmentation. To frame our contribution we will first explore the current literature on coordination and show how this body of knowledge has left the fragmentation perspective underexposed.

2.2 From integration, differentiation, and modularization towards fragmentation

The traditional idea of coordination is based on the relation between integration and differentiation (Lawrence et al. 1967), which consists of the decomposition of subtasks, and the need to bring these together into one cohesive whole (Heath and Staudenmayer 2000). As such, coordination is meant to achieve *"the integration or linking together of different parts of an organization to accomplish a collective set of tasks"* (Van de Ven et al. 1976, p.322), which is based on *"the interdependent nature of the activities that organization members perform"* (Argote 1982, p. 423). The notion of integration finds its roots in the designability of coordination mechanisms. For several decades coordination theories have focused on designability, in which scholars supposed that organizational systems could be articulated with enough precision to allow individuals to complete their work in a coordinated fashion (Malone and Crowston 1994, Okhuysen and Bechky 2009). Coordination studies have since then moved from the design of work processes (Taylor 1914), to the design of management systems (Fayol 1949), but as organizations turned from manufacturing systems towards service oriented forms the limitations of designability became evident. Coordination theorists realized that coordination in these organizations relied less on predefined hierarchy and more on interpersonal communication and feedback (Argote 1982, Van de Ven et al. 1976). This broadened our understanding of coordination, and led to the emergence of coordination dichotomies. Most well-known conceptualizations of coordination are based upon such dichotomies, such as formal versus informal coordination, programmed versus non-programmed (March and Simon 1958), and personal versus impersonal coordination (Van de Ven et al. 1976).

As in the following decades collaboration increasingly took place across the boundaries of organizations in different geographical locations (Srikanth and Puranam 2011) a new way of decomposing subtasks emerged next to differentiation: modularization. Modularization is based on the decomposition of a system of activities into modules, such that activities within a module are highly interdependent with one another, but there are few dependencies between activities that are part of different modules (Sanchez and Mahoney 1996). Modular coordination centers around the problem of the division of work and specification of the nature of responsibilities between organizational units from one or more firms that provide the components and modules of a work system (Sinha and Van de Ven 2005). Because coordination mechanisms are designed in advance, coordination based on modularization takes place in relatively stable environments.

What has kept the coordination debate from advancing in a new direction is that integration, differentiation, and modularization are still based upon the notion of designability, which has difficulty incorporating coordination in ambiguous and fast-paced settings (Faraj and Xiao 2006). As organizations face more and more volatile environments, time pressure hampers the achievement of designed coordination (Kellogg et al. 2006). This notion is picked up in a comprehensive review of the coordination literature by Okhuysen and Bechky (2009), who identified that coordination is a combination of design and emergence, based upon three different *integrative* conditions: accountability, predictability and common understanding. First, accountability is conditional for coordination because it aligns responsibilities. This occurs through either designed coordination that is based on the enactment of formal authority and organizational standards, or through emergent coordination in which other parties become accountable for their own contribution, when others make their responsibilities visible (Reagans et al. 2005, Bechky 2003, Bechky and Okhuysen 2011). Second, predictability enables actors to anticipate subsequent task related activity based on familiarity with the elements and timing of task execution (Espinosa et al. 2004, Rico et al. 2008). Predictability based on designed coordination occurs through scheduling of formal workflows that are depicted in protocols and procedures (Reagans et al. 2005). Predictability during emergent coordination functions though anticipation that is based on perceived fit with each other's roles during task execution (Rico et al. 2008, Okhuysen and Elsbach 2005). Third, common understanding is considered necessary for coordination because a shared perspective on the objectives of actions is required to perform a task (Bechky 2003). Common understanding can be based on designed coordination when it is embodied in plans and schedules that are

created in advance (Okhuysen and Bechky 2009). In addition, common understanding can also develop in an emergent fashion during the iterative process of discussing how interdependencies can be managed while an operation unfolds (Bechky and Okhuysen 2009). It's important to notice that by showing how these three integrative conditions contribute to coordination Okhuysen and Bechky (2009) voiced a new dichotomy in the coordination debate between *designed* and *emergent* coordination.

Contemporary studies of coordination can be positioned in this dichotomy, as these explore the performance of emergent coordination. In these studies coordination is treated as an emergent process, which is always 'in the making' (Bechky 2003, Bechky 2006, Faraj and Xiao 2006, Kellogg et al. 2006, Majchrzak et al. 2007, Majchrzak et al. 2012). Consequently, coordination in these studies is generally defined as a: *"temporally unfolding and contextualized process of input regulation and interaction articulation to realize a collective performance"* (Faraj and Xiao 2006, p. 1157). As coordination is performed through a dynamic and adaptive activity in which local trajectories of interdependent action are synchronized (Jarzabkowski et al. 2012, Gkeredakis 2014), interdependencies among activities continuously shift and are negotiated and reframed in the context of work (Kellogg et al. 2006). While recent attention for emergent coordination is opening the window for theorizing more dynamic coordination processes, in general, these studies are still based upon the notion of *integration*. Like Okhuysen and Bechky's (2009) review also coalesces into three *integrative* conditions of coordination. This shows that the underlying rationale is that local trajectories of interdependent action are considered to be coordinated when they result in a set of integrated actions.

However, as novelty arises in turbulent environments it becomes increasingly difficult to reach cohesive action, because it increases uncertainty of how interdependencies influence collective action (Carlile 2004). The challenge of coordination in turbulent environments that prevents integration is that organizing processes tend to be distributed, because expertise is dispersed among team members, and answers or solutions are not predefined but are generated through interactions (Faraj and Sproull 2000). The result is that during emergent coordination processes incongruent perspectives are likely to emerge (Bechky 2003, Bechky 2006). For instance, in a study of trauma teams, Faraj and Xiao (2006) show that coordination practices are based upon dialogue in which epistemic contestation occurs. Experts challenge each other's assumptions to develop sufficient shared understanding to solve the complex problems at hand. Other studies of emergent coordination also show signs of divergence, such as misunderstandings due to different

interpretations (Bechky 2003), and the emergence of knowledge boundaries (Carlile 2004, Levina and Vaast 2005). Current studies of coordination treat divergent perspectives as something to be solved, as it does not contribute to common understanding, which is considered to be essential for coordination (Okhuysen and Bechky 2009). The conversion of disorder to order is seen as fundamental to the process of coordinating, since organizational structures are primarily directed to processing information and removing its equivocality (Weick 1993). However, in fast-paced environments divergence and disconnections are key characteristic of cross-boundary coordination that cannot be converted to an integrated order (Kellogg et al. 2008). Therefore, it's essential to look for a different perspective on coordination that incorporates ambiguity and unpredictability.

In her work on organizational culture, Martin (1992) describes such a perspective in addition to integration and differentiation: fragmentation. This fragmentation perspective is helpful to explain how incongruent perspectives contribute to coordination, since it is rooted in the appreciation of ambiguity, rather than excluding it or channeling it into a realm of order and clarity (Martin 1992). Ambiguity is paramount in turbulent environments and is perceived when *"a lack of clarity, high complexity, or a paradox makes multiple, rather than single or dichotomous explanations plausible"* (Martin 1992, p. 134). A fragmentation approach focuses on *multiplicity* of interpretations, which emerges when, due to ambiguity, meanings are hard to decipher and necessarily open to multiple explanations. As possible interpretations multiply a *flux* emerges, in which temporary issue specific coalitions form around certain interpretations. Thus coordination is not based upon a single solution that results in coordinated action, but consists of a changing configuration, a contested order, that needs to be negotiated and augmented time and again.

A fragmentation perspective takes ambiguity that is also consistently described in crisis management (Dynes and Aguirre 1979, Bigley and Roberts 2001, Suparamaniam and Dekker 2003) as an inescapable reality rather than complications to be resolved, or reduced into a cohesive whole. This has several consequences for studying coordination. While from an integration perspective an ambiguous, environment in flux might be regarded as unwanted or required to be resolved, from a fragmentation perspective ambiguity is an inescapable reality. Our understanding of coordination in fast-paced environments might be expanded in a direction that values ambiguity, rather than a stance that is aimed at producing clarity. This leaves us to explore how coordination is performed if the environment is in constant flux and multiple perspectives prevail.

2.3 Methodology

Data collection

In this study we set out to learn how emergency management officers practice cross-boundary coordination in a fast-paced environment. Based on our interest to elaborate theory on cross-boundary coordination processes in fast-paced environments, we conducted an inductive, qualitative field study using grounded theory approaches (Corbin and Strauss 2008). This approach is valuable for developing theories about dynamic processes, because it captures the full richness of the stream of activities that is intimately connected to the interdependencies in the environment (Barley and Kunda 2001, Langley 1999). This grounded data is then systematically abstracted into more general patterns that can be used for theorizing (Gioia et al. 2012). This approach is characterized by an iterative process of continuously moving back and forth between the empircal phenomena and its theoretical reading (Alvesson and Kärreman 2007).

The qualitative data presented in this article is collected from the winter of 2010 into the winter of 2014, and focuses on cross-boundary coordination processes in both emergency response field exercises and real-life incident response operations. In this period 40 exercises are observed, and 56 interviews were held with emergency officials in which they reflected on their coordination experiences during these exercises and actual operations. The data collection is divided into three phases: a pilot phase, main data collection phase and a validation phase. This allowed us to develop a gradual understanding of the core puzzle of cross-boundary coordination processes, to later zoom in on these processes in detail, and finally to zoom out again to validate our now detailed understanding of cross-boundary coordination processes during response operations (Nicolini 2009).

	Observations	Interviews
Pilot Phase	3 Command Exercises	12 experts interviews
Main Data Collection	16 Field Exercises in disaster area 21 Command and table-top exercises	10 interviews with officers that participated in exercises
Validation Phase		10 interviews exercise participants 13 officers on highway accident case 11 experts interviews
Total	*40 exercises*	*56 interviews*

Table 1. Data Collection

In the pilot phase we advanced our intuition about the research question on how coordination is practiced in fast-paced environments. We conducted exploratory interviews to better understand how coordination is accomplished and institutionally organized in emergency response. We interviewed 12 experts in the field and observed 3 exercises. We learned that during the response operation officers in command and the field commander should be the key actors in our research, since they are responsible for managing the coordination on scene. Their role is to oversee the response operation, coordinate the employment of resources, and protect the emergency responders from taking unnecessary risks. In addition, we learned about the difficulties of observing the work practices of officers in command during emergency response operations. Therefore, we explored the possibility to study field exercises that allowed us to engage freely with the officers and to study their behavior and interactions, without the risk of jeopardizing the safety and quality of an actual response operation. Exercises are good analytical tools to study coordination, because the emergency management organization is similar to real events, and actors are obliged to act and forced to make decisions (Latiers and Jacques 2009). Despite these benefits exercises may lack the same emotional aspects, decision impact and in some cases recruitment delay (Latiers and Jacques 2009).

The main data collection focuses on observations of a set of 16 field exercises staged in a disaster area on an old air force base in the winter of 2010. We selected these exercises for our main analysis, because the respondents described that the staging of these exercises gave a more tense dynamic that represented more closely the realism and feel for the situation they had experienced during actual emergency operations. Furthermore, we had the possibility to walk around freely during the exercises and record conversations between the officers in detail. The exercise scenarios included: a fire in a youth hostel, fire in an adult club, collision on a highway, hostage situation, carbon monoxide poisoning in an elderly home, fire in a tire factory, explosion after a failed SWAT raid, and a Cessna plane crash on a gas station. The staging of the exercises in different locations on the training grounds enhanced the realism and feel for the situation, as for example an exercise that involved a highway traffic accident was located at a fully reconstructed highway with crashed vehicles and trucks on the training grounds. In addition to the observations, respondents who participated in the exercises were interviewed during 1 or 2 hours in the spring of 2011 to induce their view on coordination challenges during the response exercises.

In the validation phase we wanted to compare our analysis of the exercises with the real life experience of the officers. First we felt that we needed a member check (Schwartz-Shea and Yanow 2009) to see whether our ideas were in line with the operational experiences of the officers that participated in the exercises. We conducted these interviews in the summers of 2011 and 2012, two years after the initial observations. In this stage, our acquaintance with the officers allowed us to reflect on their actions during the exercises in comparison with their real-life operational experience in the two-year period. This enabled us to confront and build on one of the challenges in our material, the fact that the observations are based on exercises instead of real incident response operations. By taking this final step and checking the analysis and results with the officers, we feel much more confident that the results represent the actual practices of emergency response operations. In addition, we also wanted to broaden our validation of the analysis in the exercises with the analysis of a single case from an actual response operation. To do so we interviewed a set of 13 officers that responded to a large highway traffic accident. As this incident was similar to one of the scenarios of the field exercises, we were able to compare the responses. Finally, we interviewed 11 experts to validate coordination issues in situations with hazardous materials as these became central in our analysis.

Data analysis

By combining the wide array of materials, the analysis was characterized by an iterative process that gradually deepened and interconnected our insights, which developed alongside the three phases of our data collection. In the first phase we identified the main themes in cross-boundary coordination, while reading through our field notes and discussing our preliminary ideas from the field. Consequently, the notion of boundaries and ambiguity emerged. In the second phase we analyzed the transcribed recordings of the set of 16 exercises and the transcribed interviews with its participants in detail. This was a significant step in unraveling the nature of coordination practices, since *"most work practices are so contextualized that people often cannot articulate how they do what they do unless they are in the process of doing it"* (Barley and Kunda 2001, p. 85). The analysis was based on theoretical sampling (Corbin and Strauss 2008) during which codes were assigned, with the help of the analysis tool MaxQDA, to what we considered to be important events, aspects, and interactions during the coordination process. We started with open coding to break down the data to understand the underlying dynamics, and continued with axial coding to reveal the thematic relationships and contrasts between the

codes (Strauss and Corbin 1990). This allowed us to develop an in-depth understanding of the pace and sequence of events, through which we were able to unravel how the interplay between integration and fragmentation occurred, which became central to our understanding of coordination. In the third phase our analysis gradually arrived at three practices *distancing from the incident*, *demarcating expertise* and *switching tactics* with an underlying data structure (Gioia et al. 2012). This final phase allowed us to zoom in and out on the data to critically assess, compare and broaden our understanding of the dynamic phenomena we observed in the training exercises (Nicolini 2009). Based on the data structure we were able to develop the dynamic relationships among the emergent concepts. Next to the analysis of the interview data we consulted materials stemming from other sources, such as evaluation reports, after-action reviews, and video excerpts from other exercises to validate our model. We used this material to strengthen our analysis by comparing the results of our analysis to a broader set of video's and documents.

2.4 Findings

Our analysis of cross-boundary coordination processes during emergency response operations revealed that officers-in-command coordinated their actions across the boundaries of their organizations by using a set of three interrelated practices: *distancing from the incident*, *demarcating expertise* and *switching tactics*. By employing these practices the officers strived at keeping sufficient overview on the operation, recognize and assess potential dangerous situations, and retain flexibility to adapt to unexpected events. In the following sections, we discuss each practice in turn and describe how the boundary work that is part of these practices shows the relevance of a fragmentation perspective.

2.4.1 The practice of 'distancing from the incident'

One of the first actions the officers engaged in when they arrived on scene during the exercises was trying to find out what is going on, as the response operation itself was already underway. The situation the officers found themselves in was prone to escalate, and events quickly followed up under increasing time pressure. The officers experienced that it's difficult to oversee this fast-paced environment, which is necessary for developing an emergent task distribution. First they had to catch up with the situation on scene, assess priorities, identify interdependencies to other response organizations, and get an

overview of the overall progress of the response operation. Like one of our respondents mentioned, to be able to coordinate in such an environment, one needs to acquire room to maneuver as soon as possible.

> Police Officer: *"the sooner you are free, the more overview you get, because if you lack overview, you're in trouble. Situational awareness is important when you arrive at the incident scene and you need to retain it. That's the feeling, right? The feeling that you are in control. To get there you have to let go. If you don't delegate, it starts to grow over your head. You will lose situational awareness pretty quickly. If you think this will be taken care of, that will be taken care of, you start to relax and acquire overview. That is the art I think, putting your hands in your pockets halfway through, and thinking, well, what's next? That is when you've got it".*

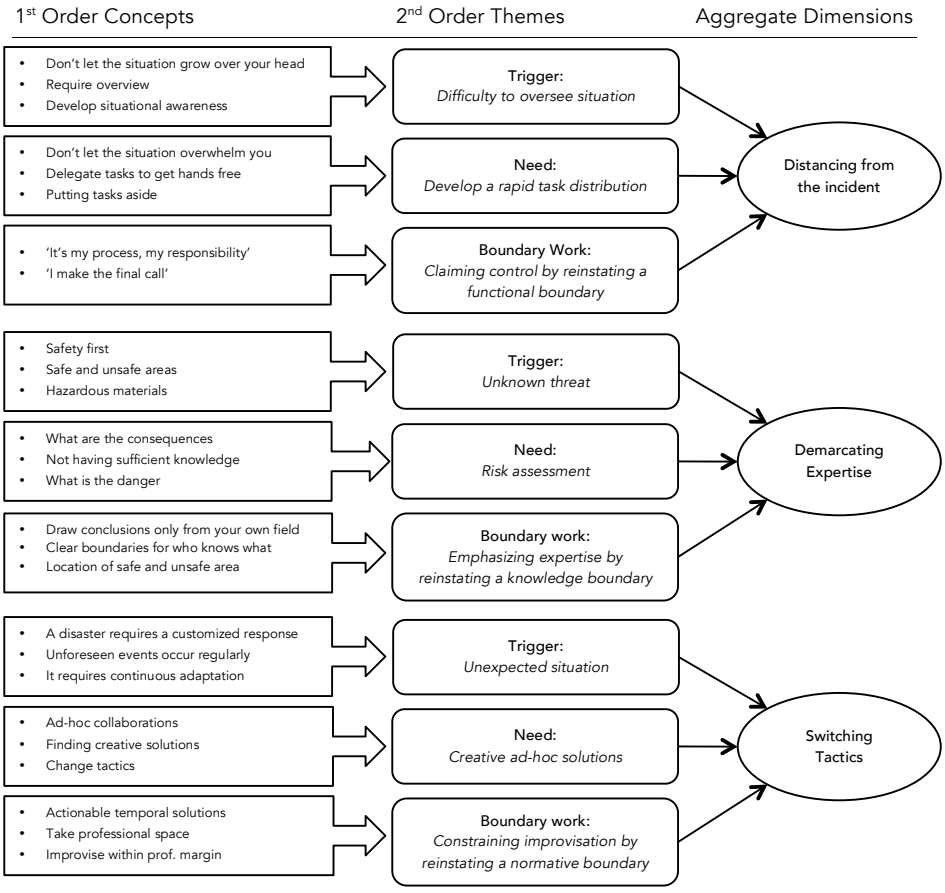


Figure 2. Data Structure

Like this Police Officer mentions, for the officers 'letting go' is a prerequisite to assess the situation and acquire situational awareness. To prevent the situation from overwhelming them, the officers explained that their first actions are aimed at putting tasks aside immediately. We will refer to this coordination practice as *'distancing from the incident'*. Distancing is aimed at detaching one from the task complexities of the incident to acquire overview. The officers delegate tasks to their subordinates to organize enough time for them to reflect and assess the situation before coordinating with others. While the officers regard distancing as way to get overview on the unfolding response operation, it also challenges them to partially give up control. Through distancing themselves from the operation, they lose sight on the distributed actions of their subordinates that take place at different locations and at different times. Our conversations with the officers indicated that coordination on the incident site is not about coordinating by integrating all actions to achieve a coherent response. In the turbulent environment of emergencies this option is just not feasible as it takes too much time and the interdependencies keep changing as new tasks emerge.

> Interviewer: *"you mention putting task aside, but how do you keep overview? You seem to imply that you consciously lose sight?"* Fire Officer: *"that is the nice part of my function. As Fire Officer I only deal with a specific part and if you put something aside, somebody else will deal with it. But you're right at the moment I put tasks aside to be able to deal with other problems I lose grip on everything else that is going on".*

Vignette 1. The consequence of distancing: distributed action leads to a multiplicity of interpretations

In order to show how the practice of distancing unfolds in action, we will analyze the response to a fire in a hostel from one of the field exercises. The situation is as follows: fire crews are responding to an automatic fire alarm in a hostel. As the first units arrive on scene it becomes clear that a large, yet unknown, number of persons are trapped inside the hostel, but it's unclear how many persons exactly. When the officers arrive on scene they distribute their crews to perform rescue operations and try to develop a correct estimation of the amount of persons trapped inside the building. Soon discussions about the correct amount of victims emerge at different times and locations during the response operation.

First units arrive on scene and assemble in front of the building.

Fire Engine Commander	is unknown, there was a group of 50 persons with 10 staff.
Police agent	inclusive?
Fire Engine Commander	50 and 10 staff.
Police agent	50 plus 10 staff?

After about 10 minutes on the right side of the building.

Hostel manager	there are still persons trapped inside!
Fire Officer	do you know how many?
Hostel manager	yes 50 and 10…
Fire Officer	[interrupts owner] and the children, what age are they?
Hostel manager	yes, between 15 and 20, but they are mentally disabled, so you have to take that into consideration.

After about 20 minutes in the first Field Command Meeting.

Field Commander	All right, is everybody present? Ten minutes max for this meeting so you can return to your units quickly. What is the situation?
Fire Officer	Situation is fire in a youth hostel. There is a group of 40 disabled children with a nursing staff of 10 persons.
Medical Officer	I have called in 26 ambulances in total and a Medical Combination because the women outside talked about 50 disabled children with 10 staff, that is 60 in total. She has not included herself, so I activated plenty of resources.

In this vignette from the emergency response operation we witness the emergence of a multiplicity of interpretations. The units operating in different areas develop their own interpretations based on their view on the incident. This is not something that can be prevented, but is a direct consequence of the fast-paced action required to rescue victims from a blazing fire. The fire engine crews are busy with evacuating the building and have little time to discuss the correct number of persons inside.

We witnessed similar problems with verifying the number of victims in nearly all exercises. Therefore, we wanted to find out whether this coordination issue also occurred during real operations. We interviewed 13 officers that responded to a large traffic accident on the Dutch highway A2 on 28th June 2011, where several cars collided with a military truck. A field commander noted similar issues with assessing the amount of victims:

> *"It's very difficult to assess how many victims were involved. Are there 14 people including a fatality, or are there 15? How many of those are soldiers, and where are*

> *they coming from? The information I received from the emergency response center indicated 7 injured of which 3 are military personnel, 3 cars involved, and 1 person deceased. The Fire Officer told me that these amounts were incorrect, as according to him there are 5 cars involved, 3 persons trapped instead of 2 and 1 was already rescued. The Medical Officer later told me that 2 persons were deceased instead of 1. There is always a tension in those numbers. At the same time the medical services are responsible for the victim counts, so every time there is a discrepancy I will tell the medical services to go back and check. If the Fire Officer says there are 14 and the Medical Officer says there are 16, then it's 16".*

In both exercises and real operations, the consequence of the practice of distancing is that, while action gets distributed, multiple units develop different contextualized interpretations. As every officer focuses on a specific part of the response operation these different interpretations increase equivocality, as different numbers start to emerge. Therefore, the practice of distancing doesn't provide the officers with a complete situational awareness, but a partial view on the operation, that is continuously updated with different perspectives from different locations. This leads a situation in flux in which shared accountability between the officers becomes contested.

We found that the common response of the officers when encountering multiple, conflicting interpretations was seeking for control by reinstating the functional boundaries between them. As the boundary is reinstated during an emergent task distribution it results in separate pockets of control. The Medical Officer involved in the response to the hostel fire explained:

> *"I make the final call on the number of victims. It has to go through me. At a certain moment you as an officer must have the guts to claim this is my responsibility, we're not all going to say something about this. Of course I need input from my own colleagues and from the police and fire department, but in the end I decide on what we are dealing with in medical terms. If everybody starts to articulate the number of victims, well, I'm sure we'll end up with the wrong number. I really try to take on that role, also because I can judge which victims are transported in ambulances".*

In sum, the practice of distancing is triggered by the difficulty to oversee the situation and the need to develop an emergent task distribution. As the officers gradually develop overview on different aspects of the response operations and reassign task to their units, new interdependencies between the officers emerge. To retain control on their own tasks the officers reinstate their functional boundaries, which results in separate pockets of control instead of shared accountability. Paradoxically, the practice of distancing from the incident thus also contributes to the very fragmentation the officers try to resolve.

2.4.2 The practice of 'demarcating expertise'

One of the most complicated situations the officers can encounter that literally brings the response operation to a halt, is when they are confronted with a threat to safety. This involves, for example the spill of an unknown hazardous material, a hostage situation, or explosion danger. In these situations safety is one of the primary concerns for the officers. Their adagio is: safety first. As a Field Commander explains: *"safety is priority one for me. It means that you need to be informed adequately about what is going on, combined with the risk assessment from each response organization"*. Also a Medical Officer explains: *"my philosophy is if I have to safe someone in just one minute, it would already be too late. Safety is everything for me. Yes, we have to provide aid, but safety first"*. In the following excerpt a Fire Officer reflects on explosion danger after a large gas leakage in a residential area he experienced during an actual response operation.

> *"A great example is the gas leakage two weeks ago. Multiple locations were evacuated in a hurry. The problem was that a gas cloud is not visible, so we need to measure it. Now, what's my estimation, what capacity should you call in? The only thing we knew was that the diameter of the pipe, which implicated a pressure of 8 bar. Our hazardous materials advisor calculated afterwards that a no-go area of 250m was on the safe side. So we were operating in a safe area with evacuating two elderly homes on the edge of that circle. But still, if he concluded that the safe area was 500m we would have done too little".*

Yet, paradoxically, the assessment of what is safe and unsafe is subject to diverse interpretations, because officers have different understandings about the threats to safety. When a dangerous situation is encountered the common response is to halt the response operation and designate the location of the unsafe area, so that the emergency responders can work safely in the surrounding area. This is a difficult assessment as the nature and degree of the threat can change, and often limited information is available. A Fire Officer explains what he experiences when he encounters such a situation:

> *"Yes, safe and unsafe, you've heard that hundreds of times probably. The Police and Medical Officers are explicitly trained on that point. You have to know where you can work safely. It's the first thing they ask, sometimes it drives you crazy! You have to explain time and again that smoke is never healthy, but they won't immediately pass out if they're standing in thin smoke. I don't want to be busy with that. Just be clear, this is safe and this is unsafe. Good luck".*

The Fire Officer suggests he has no time to explain every detail, because the emergency situation requires quick action, so he just designates a safe and unsafe area. Putting effort

in developing common understanding seems not to be the most viable option in these fast-response circumstances. Creating common understanding requires effort and takes time, two resources that are often at stake during response operations. We observed that in contrast to building common understanding, the way to coordinate action during unknown situations in this fast-paced environment was to engage in the *practice of demarcating expertise*. As the officer with sufficient expertise claims responsibility over handling the dangerous situation, the other officers stand down and rely on the knowledgeability of the officer with expertise. Like a Police Officer explains:

> *"When you are talking about a fire the discussion soon starts to move in the direction of hazardous materials, smoke clouds, etc. My actions and communication depend on the information I receive from the fire department. Those are topics in which I have to trust the fire officer for the full 100%. a) I don't have sufficient knowledge about that. b) I don't feel any need to check that person. There is a lot of pressure to act on me at that time".*

When ambiguity is high the officers primarily ask for the location and nature of the threat so they can keep their distance and let the officer with sufficient expertise handle the threat. Therefore, the officers in general do not strive for common understanding as this takes too much time, but instead rely on the expertise of others for dealing with the situation. A Field Commander stresses the logic behind this way of operating:

> *"Now you're getting at my point of view, you don't have to know much about it, because if you do you will draw conclusions from another field of expertise. It might work out, but you can also get it all wrong. For example, when talking about a 'large fire' protocol it's better to observe that there are a lot of engines on their way, rather than thinking: 'oh, a large fire, that means the fire is getting out of control'. That is no definition for us [the fire department]. If someone else thinks it is, you can suddenly get a totally different situational awareness".*

Vignette 2. Demarcating expertise in response to explosion danger

The situation is as follows: a small Cessna plane has a mechanical failure in flight and tries to perform an emergency landing on a highway. The landing attempt fails and the plane crashes near a petrol station, where a fuel truck is just unloading its petrol. The debris of the plane hits one of the gas pumps and its catches fire. Emergency services respond and soon try to extinguish the fire and rescue the pilots, truck driver, and the people in the petrol station. During the rescue operation the Medical Officer feels her units are at risk due to the explosion threat posed by the petrol truck. She consults with the Fire

Officer about the safety of her units. However, the Fire Officer is under a lot of pressure to act. Consequently, he demarcates his expertise and starts an argument with the Medical officer.

1st Fire Officer	An important question for you to ask is: how much fluid is left inside?
Medical Officer	Yes, well then you must find the driver.
1st Fire Officer	No, we can see that with our heath camera… and it shows it's half empty.
Medical Officer	I don't know that, so you must share that information with me!
1st Fire Officer	I'm telling you an important question for you is to ask how much is in there!
Medical Officer	How should I know you can see that, you also don't know what needles I use? You've got your profession and I've got mine. You can also explain unasked things to us!
2nd Fire Officer	I don't see why it's relevant for you to know what is inside. Unless those victims are lying in the fluids.
Medical Officer	No, but still. My colleagues are walking around here and if it explodes my medical hazardous materials expert knows what it's about. I want to move ahead of the facts, not behind.
2nd Fire Officer	Yes, but do you know what the problem is? I'll share my consideration. The thing is that if I keep telling those issues, it might get interpreted wrong. Someone else might say, oh then we need to do this and that. The fluid, the fire, that's Fire Department!

The contestation between the Medical and the Fire Officers shows that during the response operation knowledge boundaries are reinstated. Expertise becomes an instrument to segment the operation. During the discussion the Fire Officer uses his expertise to retain control over dealing with the explosion risk. The consequence for coordination is that knowledge boundaries are not bridged, but actively reinstated. This shows the importance of demarcating expertise to coordinate unknown threats in the fast-paced environment of emergency response. On the one hand, shared understanding is important for the officers to retain a safe operating environment, but on the other hand the officers demarcate their expert authority to be able to take quick actions. During our interviews the officers noted the importance of respecting the expertise of other emergency response officers.

> Medical Officer: *"In one situation a Field Commander was thinking what I should be doing. When the meeting ended and we went outside I asked him, do you have a minute? I said: I am a blonde, but it's not my natural color! I am perfectly able to decide what I can and cannot do. You don't have to think for me!"*

In sum, the practice of demarcating expertise enables the officers to quickly contain potential dangerous situations by reinstating the knowledge boundary and putting the other response operations on hold. This diminishes the importance of common understanding as other officers are kept away from the hazardous area and the officer with the expertise manages the threat on his own. When other officers are kept out of the action, it becomes very difficult for them to keep track of what is going on. By not directly involving others this practice triggers equivocality, as multiple interpretations of the situation develop. Like we have seen in the vignette, this leads to ongoing negotiations between the officers. Therefore, the practice of demarcating expertise is a way to coordinate unknown situations in a fast-paced environment, but by reinstating the knowledge boundary it also contributes to fragmentation.

2.4.3 The practice of 'switching tactics'

Another important aspect of coordinating emergency response operations is *switching tactics* to respond to unexpected events. The officers are trained to recognize deviant situations and anticipate on them. Procedures that entail a specific sequence of action are often adjusted during this process. These adaptations cannot be predicted in advance, but occur 'on the run'. A Police Officer describes such a situation from an actual response operation:

> *"There was a fire in an elderly home, and we decided to evacuate the residents. Unfortunately, it was freezing outside. So where do you leave those people? There was a shelter location in town, but we knew the key holder was very difficult to reach. So, a spark of creativity triggered, an ad-hoc collaboration between fire department and police on scene. I happened to be at the station and I could listen in on their conversations. I said guys listen up. We've got a gym here. I have got it operational within 30 minutes. All right, go for it. Another colleague stops a bus and lets it drive to the gym. The registration process is a bit fuzzy then, but at least we've got everybody warm inside".*

This example illustrates the officers on scene develop ad-hoc collaborations to address emerging problems. In general, the officers have to coordinate different aspects of the response operation that take place at different locations. In this case, there are existing procedures for arranging a temporary shelter and bus transportation by the municipality. However, the Police Officer knows it often takes a long time before the municipality is operational. Therefore, the Police Officer takes matters in his own hands and arranges transportation before the elderly are affected by the cold weather, which could potentially

worsen the situation. This situation shows that switching tactics enables the officers to coordinate in response to unexpected events, but has the downside of compromising predictability. When standard operating procedures are used in a different fashion, different interpretations of what is about to happen can emerge, resulting in deviating expectations and anticipations.

Vignette 3. Switching tactics on-scene for a carbon-monoxide threat

In the following case of a carbon monoxide threat in a nursing home we see how a Fire Officer switches tactics to get more units on the scene to assist for an evacuation, which goes against the logic of the up-scaling procedures. The situation is as follows: ambulance crews arrive at a nursing home, where several residents have become nauseous. When the paramedics enter the elderly home their bootstrapped carbon-monoxide (CO) alarm triggers. There seems to be a high-level of CO concentration in the nursing home. The paramedics decide to back up and call in the fire crews for taking measurements. The first fire engine on scene contacts the Emergency Response Center (ERC): *"ERC, we are taking measurements that confirm the presence of carbon-monoxide. We'll start evacuating, but I don't have enough crews on scene. I would like more people here, over"*. The ERC relays this message to the Fire Officer, who is still on route, and he requests to initiate the procedure that alarms 4 engines: '*very large fire'*. The Fire Officer explains: *"it's the responsibility of the Fire Department to take care of the evacuation. I issued 'very large fire' to get more people on the scene quickly"*. However, mentioning a 'very large fire' on the radio triggers a widespread misunderstanding amongst the other officers.

Response Center	Medical Officer, the Fire Officer makes it a very large fire, over.
Medical Officer	Oh, it's a very large fire? Do you know if there is fire inside the building?
Fire engine commander	Euhm, no, I don't smell anything.
	…
Response Center	Police Officer, there is a very large fire, over.
Police Officer	I heard that there is a very large fire on the radio too. [radio's] Response Center, do we know where the fire is located in the building?

The misunderstanding reverberates for some 40 minutes in the distributed response operation. In the meantime, by altering the response tactic, the Fire Officer succeeds in activating a large fire response capacity to evacuate the nursing home. As the Fire Officer explains in an interview, this procedure is normally issued when there is an actual fire that

requires four engines and additional water transport capacity. So, by issuing the very large fire procedure the Fire Officer adjusts the use of the procedure for this particular situation. The confusion eventually ends up back at the Fire Officer. At that time the Medical Officer begins to grasp the origin of the misunderstanding.

Fire Officer	I heard there is a fire. Is there a fire? Have you located a fire?
Police Officer	I have heard from the ERC that there was a fire.
Medical Officer	No, dispatch has told us that there was a very large fire. I now presume that you have done that to get more units on the scene faster?
Fire Officer	yes.
Medical Officer	right, but that has caused the confusion.

Like this vignette illustrates switching tactics on the one hand allows the officers to adjust to unexpected situations, but on the other hand, it increases equivocality during the response operation. Different interpretations develop because predictability from the regular procedures is compromised. The Fire Officer raises a normative boundary based on how he thinks the protocol can be altered for this situation. This is at odds with the expectations of the other officers. A 'very large fire' procedure in its regular use means that four fire engines and fire extinguishing water supply units are called to the scene. To arrange a large water transportation capacity on scene roads are generally blocked, due to large diameter fire hoses lying across them. For the Police Officer it means that he needs to consider that certain roads are cut, which calls for an alternative traffic circulation plan. For the Medical Officer it means that dealing with an unknown amount of persons trapped inside calls for her to increase the on-scene treatment capacities and to notify the hospitals specialized in burn traumas. These anticipations by the other officers during the response operation is not what the Fire Officer considered when he decided to switch tactics to get more units on the scene to perform a quick evacuation.

In sum, the practice of switching tactics enables the officers to adapt in response to unexpected events, but it also compromises predictability. This in turn increases equivocality as the predictability from regular tactics is compromised and divergent ad-hoc anticipations are performed. Like we see in the vignette boundary work is required to negotiate the deviating understanding that arises from the different anticipated sequences of action. In response to the equivocality that arises from unexpected adaptations the officers reinforce the normative boundary based in the regular procedures to retain operational control.

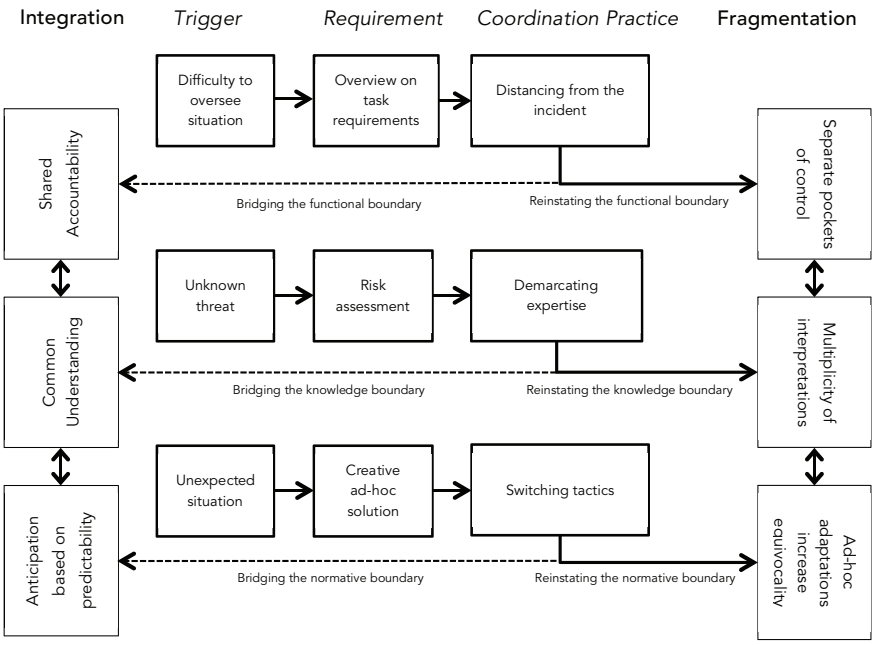


Figure 3. A process model of cross-boundary coordination during Emergency Response Operations

Our analysis can be integrated into a process model that theorizes cross-boundary coordination in fast-paced environments. The analysis indicated that three characteristics during response operations trigger a process that leads to fragmentation: a turbulent environment that is difficult to oversee, the emergence of unknown threats to safety, and dealing with unexpected situations. In accordance, we found three coordination practices to be central in the way officers in command responded to these characteristics of a fast-paced environment: *distancing*, *demarcating expertise*, and *switching tactics*. The model shows how these coordination practices lead to boundary work in which the officers reinstate functional, knowledge, and normative boundaries to be able to cope with the fast-paced changes in the emergency situation. Paradoxically, on the one hand their actions of reinstating boundaries result in the very fragmentation they are trying to overcome. On the other hand, these coordination practices also allowed the officers in command to initiate fast-paced action by temporarily reinstating boundaries that served to momentarily hold off interdependencies with other officers. As boundaries are reinforced to retain control and speed, fragmentation emerges that is constituted by *separate pockets of control*, *a multiplicity of interpretations*, and *ad-hoc adaptations*.

2.5 Discussion

Our model of cross-boundary coordination extends theorizing on coordination by suggesting a different perspective on the accomplishment of coordination in situations when achieving integration is challenged. By considering the coordination practices of emergency officers in command over the course of exercises and real life operations we have described a process model of cross-boundary coordination that shows the emergence of fragmentation. This extends theorizing on coordination in three different domains: coordination, boundary spanning, and high reliability organizations.

First, our analysis shows that coordination in fast-paced environments results in a dynamic that cannot be explained in terms of integration, as the integrative conditions of accountability, predictability and common understanding become contested in action (Okhuysen and Bechky 2009). Instead, our analysis shows a dynamic in which functional, normative and knowledge boundaries are reinstated to put interdependencies at bay. This results in a flux of issue specific coalitions that create a multiplicity of interpretations. Consequently, coordination takes the character of a contingent, and emergent outcome that cannot be planned or prescribed, but is highly dependent on the situated activities of the various actors. This fragmented nature of coordination has important virtues for operating in fast-paced environments because it allows speed, distributed action, and creative contextualized solutions to emerging problems, at the expense of multiplicity and issue specific coalitions. Segmenting the response operation by reinstating boundaries keeps interdependencies at bay, which enables swiftness that is required in fast-paced environments. It's important to put interdependencies on hold in complex environments, because *"it reduces the system liability to deadlock by reducing the number of actors that have to reach agreement"* (Genschel 1997, p. 617).

While contemporary coordination studies explore processes of emergent coordination, they are often based upon an integration logic. Studies of emergent coordination tend to neglect that interpretive flexibility creates contradictions and uncertainties that make disputes endemic to the coordination process, resulting in incongruent perspectives and equivocality (Bechky 2003, Martin 1992). From an integration perspective such ambiguity is seen as problematic, because common understanding is necessary to develop a shared perspective on the actions to be coordinated (Okhuysen and Bechky 2009). Yet, from a fragmentation perspective it has value when multiple perspectives prevail, precisely because it allows professionals to find non-conventional solutions and

stimulate creativity and improvisation to adapt in unknown situations (Weick and Roberts 1993, Harrison and Rouse 2014). Different interpretations stimulate doubt, discovery, and on-the-spot decision-making, which stimulate sensitivity to operations (Weick and Sutcliffe 2011). Also Harrison and Rouse (2014) who studied emergent coordination practices in dance groups, note that predictability and common understanding are compromised when looking at coordination processes in creative environments. Instead, they argue for the importance of *de-integration*. De-integration enables 'mis-fitting' that increases creativity and pushes the group to discover new problem domains. As such, de-integration disrupts a sense of predictability and common understanding, but it allows to accommodate the quest for new ideas. It shows that ambiguity and incongruent perspectives are not necessarily negative for coordination. Instead, it indicates that a different mode of coordination is required to explain the coordination processes in environments characterized by ambiguity. Our results indicate that coordination based on boundary work features *negotiation* as coordination mode to deal with a multiplicity of interpretations. This is in line with several studies that show negotiation is helpful in dynamic environments, as it allows members of different issue specific coalitions to coordinate their actions temporarily and locally, navigating their differences in norms, meanings, and interests only as needed (Kellogg et al. 2006, Vaughan 1999). When negotiation functions as coordination mode, coordination *"doesn't have to depend on shared idea's, interest, or norms, which are difficult to accomplish when time is short, meanings are divergent, and conditions are ambiguous"* (Kellogg et al. 2006, p. 39).

Second, our model extends theorizing on boundary spanning in organizational literature. We contribute to the debate on boundary spanning, in which one of the central ideas is that boundaries need to be bridged in order to enable collaboration (Levina and Vaast 2005). In contrast, our study shows the importance of keeping boundaries in place by reinstating them to put interdependencies on hold. In a fragmented environment in flux also boundaries become *"permeable and fluctuating in response to changing positions"* (Martin 1992, p. 132). Fluctuating boundaries keep actors from anticipating and building a shared understanding, because differences in roles, work processes, and knowledge arise that compromise predictability and common understanding. As boundaries are blurred this results in confusion and misunderstanding. Like Bechky (2003) and Dougherty (1992) already observed that when different occupational groups come from different worlds of thought and practice, it pushes them to continuously negotiate group boundaries. Still, our analysis shows that it's important to reinstate boundaries

to be able to claim accountability and expertise to initiate fast responses. Boundaries form a distinction (Zietsema 2010, Lamont and Molnar 2002) that enables actors to keep interdependencies at bay. Boundary reinforcement is also noted by Faraj and Yan (2009), who describe ways in which a team internally sets and reclaims its boundaries by increasing member awareness of boundaries and sharpening of team identity. Therefore, in addition to bridging boundaries, renewed attention is required for how actors reinstate boundaries to execute cross-boundary coordination.

Third, our results extend theorizing on high reliability organizations (HRO). Emergency management organizations, like the Fire Department, are frequently characterized as a HRO (Bigley and Roberts 2001, Weick and Sutcliffe 2011, Weick 1993). In HRO's increasing sensitivity to operations and deference to expertise are key features for managing the unexpected in a reliable manner (Weick et al. 1999). A hallmark of HRO's is that they are *"pressured by ambiguity to demonstrate more use of specialized professionals skills, continual redefinition of individual tasks, and development of more ad-hoc centers of authority located closer to the source of a problem"* (Weick 1985, in: Martin 1992, p. 158). Studies of HRO's indicated that to deal with unexpected events and retain sensitivity to operations, expert authority and decisions are mitigated down to the front line based on deference to expertise. Our findings indicate that this process actually results in separate pockets of control, ambiguity, and a multiplicity of interpretations (Vaughan 1999, Martin 1992). We contribute to the HRO debate by showing that if coordination among multiple HROs occurs across their boundaries, it triggers negotiations between issue specific coalitions at the front line.

2.6 Conclusion

We conclude that cross-boundary coordination practices in the fast-paced environment of emergency management triggers fragmentation, instead of integration. A key difference to previous studies about coordination is that in our work fragmentation is not treated as a deficiency of integration, but we recognize that fragmentation has important virtues that are necessary for coordination in fast-paced environments. A crisis is likely to force multiple organizations to coordinate in ambiguous situations, where ad-hoc adjustments and issue specific coalitions make dealing with multiplicity and emergence inevitable. Our analysis shows that a lack of integration doesn't mean crisis management spirals

into chaos. On the contrary, daring to let go of the aim of integration, and preparing for a coordination mode that is based on negotiation actually supports the very flexibility, sensitivity to operations, and improvisation that are claimed to be hallmarks of swift and effective crisis management.

3. Drawing the Line [2]

Summary

Boundary objects are commonly described as supporting cross-boundary interaction by virtue of interpretive flexibility; being malleable to adapt to local needs while being sufficiently robust to foster common understanding. Relatively little, however, is known about the processes by which the configuration of boundary objects is constituted in-use to support cross-boundary coordination. In this paper we explore the process by which boundary objects are continuously tailored through different coordination modes. We explore this in a multiple case study of emergency response management teams engaged in exercises in which officers from multiple disciplines need to continuously update the boundary object. We find that officers employ four different coordination modes –selecting tasks, phasing action, standardizing information and transforming understanding– as they engage with the boundary object. We use a mixed methods approach that combines qualitative analysis with process modeling to study the temporal sequential adaptation of the boundary object. By showing how boundary objects can support different coordination modes simultaneously, our work develops a relational perspective on boundary objects-in use. This generates a more complete understanding of the process by which the configuration of a boundary object is constituted in-use and why this supports or inhibits cross-boundary coordination.

2 This chapter is co-authored with Kees Boersma, Peter Groenewegen and Scott Poole.

3.1 Introduction: tailoring boundary objects for cross-boundary coordination

> Numerous vehicles, including a petrol truck, crash on the highway. In the chaos that follows leaked fuel catches fire and a large smoke column spreads across the highway surrounding the entire area in thick black smoke. Near the front of the accident, several blue barrels fall off another truck and start to leak a toxic substance. This exercise scenario poses a real challenge to four emergency response officers and their Field Commander. To harmonize their points of view in a command meeting the officers draw a map of the situation, number the cars, and locate the hazard posed by the barrels. The Fire Officer explains: *'They cannot approach that area without protective gear and clothes. Not behind the area that is cordoned off. We have created a line there.'* Field Commander: *'Right, let's determine that from here on* [draws a red line on the flip chart] *this is a no-go area.'* Immediately after the meeting the officers return to the accident site to instruct their units. At that moment the Medical Officer does something unexpected: *'Yes* [walks through the incident to talk to the Fire Officer]. *We can go until behind the water-screen. It's here right?'* Fire engine commander: *'No, it's at the other end, way back.'* Medical Officer: *'Oh my god, where?'* Fire engine commander: *'The water-screen is between…'* Fire Officer (shouting): *'Medical Officer!! YOU ARE WALKING IN A CONTAMINATED AREA!!!'*

What has just happened here? How can the Medical Officer wander off into a highly toxic area, around which the Field Commander has just drawn a red line, symbolizing a "no-go area"? Our field study of emergency response coordination, suggested that the map the officers' draw to harmonize their points of view in order to coordinate their actions provided a starting point to answer these questions. In this study we initially focused on cross-boundary coordination in emergency response and noticed that the central medium by which emergency officers coordinated was by developing a representation of the disaster scene to set out the action to be taken. They refer to this representation as a Common Operational Picture (COP). The COP is both a representation of the situation of the disaster, as well as an object that structures the multi-organizational response to the disaster (Wolbers and Boersma 2013). It characterizes, for instance, the terrain of the disaster area, location of hazards, available resources, and the number of dead and wounded. Additionally, it provides for a means of depicting the progress of the response operation and can help to identify coordination issues between the different emergency response organizations, each of which is staffed by members of different disciplines or professions (Comfort 2007). As our study progressed we noticed that the COP exhibited clear characteristics of a boundary object.

Scholars have devoted much attention to boundary objects as an important means to support cross-boundary interaction between different communities or professionals (Bechky 2003, Kellogg et al. 2006, Levina and Vaast 2005, Meyer et al. 2013, Orlikowski 2002, Sapsed and Salter 2004, Yakura 2002, Zeiss and Groenewegen 2009). Boundary objects are able to reside between intersecting social worlds by forming a temporary 'anchor or bridge' (Star and Griesemer 1989). As a temporary anchor their effectiveness is often attributed to the capability of being sufficiently common enough to ensure a minimum of shared consensus, whilst being sufficiently flexible to adapt to the specific needs and constraints of each of its users (Star and Griesemer 1989). Based on this prospect boundary objects are generally treated as means of translation based on their interpretive flexibility, as different groups develop different interpretations of the same object (Star 2010, Pickering 2003).

Hence, as the emphasis is put on the objects' interpretive flexibility, most of the seminal literature implicitly distinguishes between the boundary object itself, and the interpretations that are developed around it. This distinction, however, guides attention away from the process of configuring the object itself. As our opening case shows, the configuration of the boundary object directly influences its users' understandings of the situation, which in this case impedes cross-boundary coordination. In order to gain insight into the configuration process, we pose the following research question: *how do different users tailor the boundary object, and how does this process support or impede cross-boundary coordination?*

We advance an analysis that argues that the boundary object, its construction, and the interpretive uses to which it is put are inseparable; they are part of the same process. Our analysis builds on recent studies that regard coordination as a temporally unfolding and contextualized *process* of managing interdependencies to realize a collective performance (Faraj and Xiao 2006, Okhuysen and Bechky 2009, Jarzabkowski et al. 2012). We will show how the boundary object itself is employed in various ways through the course of interaction, when it is tailored based on its users different coordination modes to bridge different kinds of boundaries. We therefore problematize the idea that boundary objects exist out there waiting to be used.

Our study is based on an in-depth processual analysis of 10 emergency response exercises and corresponding interviews with the participating officers. The dynamic nature of these emergency management situations provides a unique opportunity to gain insight into the coordination process in which the configuration of boundary objects is

developed and refined in the course of action. We adopted a mixed methods approach to investigate the temporal and relational processes through which the configuration of the boundary object in-use is tailored to fit its users' needs. This extends our initial inductive analysis with a process analysis that is used to map the changing configuration of the boundary object. By analyzing the relation between the sequences of tailoring we are able to show how and when the changing configuration of the boundary object supports or impedes coordination. This explanation offers new insights into the coordination functions of boundary objects, and gives a specific example of how inductive grounded theory can be extended by using a process analysis.

3.2 The coordination function of boundary objects

In contrast to our focus on coordination, the seminal literature on boundary objects is primarily focused on knowledge creation activities, where the majority of the studies are conducted in the context of product or software development environments. These studies have shown how different functional groups involved in design and development activities interact and share knowledge around a range of boundary objects, such as assembly drawings, technical specifications, and computer-aided design tools and prototypes (Henderson 1991, Carlile 2002, Bechky 2003, Subramanian et al. 2003). In these production environments studies focus on how different groups negotiate, share knowledge and learn (Carlile 2004, Hsiao et al. 2012), while the boundary object offers a shared medium for co-orientation between different groups (Star 2010).

In our study not knowledge sharing, but acts of coordination are central in the use of the boundary object. The focus on coordination extends the functionality of boundary objects beyond the scope of interpretive flexibility towards their utilization for action. Boundary objects can support coordination in different ways, either to develop accountability, predictability or common understanding (Okhuysen and Bechky 2009). Boundary objects can provide a scaffolding structure to develop accountability that functions by representing elements of the tasks individuals are working on (Kellogg et al. 2006). The interaction around a boundary object also enhances predictability because it enables actors to acknowledge the progression on a particular task (Bechky 2003, Carlile 2002). To develop common understanding the boundary object may facilitate the development of a shared understanding of activities, for instance about patient

progression in emergency trauma centers (Faraj and Xiao 2006). Like these studies show, boundary objects feature in different settings where different modes of coordination are required to tackle different kinds of coordination issues.

It is important to note that these coordination issues involve different kinds of boundaries. A boundary is a demarcation that marks the limits of a common set of practices, and may be defined by function, hierarchy, expertise, cultural, discipline and temporal/spatial differentiation among other things (Hsiao et al. 2012, Carlile 2002, Bechky 2003, Levina and Vaast 2005, Orlikowski 2002). Boundaries are shaped by personal interpretations, patterns of interactions, and formal and perceived accountabilities (Barley and Kunda 2001). Encountering a boundary requires actors to coordinate the way in which the boundary shapes the perceived collaboration beyond a common set of practices.

What functionality of the boundary object is used to support boundary spanning depends on what information needs its users have and what type of boundaries they experience (Star 2010). We will approach the problem of how boundary objects figure in coordination from the perspective of the functionality of boundary objects. In their original work, Star and Griesemer (1989) describe different forms boundary objects can take based on particular types of action and cooperation (Star 2010): repository, standardized form, coincident boundaries, and ideal type. We argue that a boundary object can be configured based on the coordination function inhibited in these typologies, which offers different properties for bridging different kinds of boundaries during cross-boundary coordination.

The first type of boundary object is a repository, whose functionality is based on providing a modular configuration, as it consists of many different elements that are indexed in a standardized fashion and can be taken out by its users. Libraries and museum collections are typically described as examples of repositories. Not only in the original study of Star and Griesemer (1989), but also in more recent studies (Martens 2011, Poehls 2010). The modular nature of the repository allows its users to select and extract parts of the boundary object without compromising the overall structure of the repository. Therefore, people from different worlds can use or borrow from the repository for their own purpose without having to directly negotiate with other users (Star and Griesemer 1989).

In terms of coordination, the repository can be understood through the type of interdependence it fosters (Malone and Crowston 1994). It corresponds to what Thompson (1967) termed pooled interdependence, in which each individual or group draws on a

common resource, but are otherwise independent. This coordination approach is based on the idea that people can work separately in parallel, by assessing what modules are necessary for them to use, and the performance of the whole is more or less of an aggregate of individual performance. Along the same lines, Galbraith (1973) discusses departmentalization, in which a single unit takes care of a task. In this form of coordination the collective responsibility for a task is broken down into individual responsibilities, and the functional boundary between groups is sustained.

In more recent coordination approaches, the coordination function of repositories is related to the process of self-synchronization, which is based on the functionality of the modular nature of repositories. This is a form of designed coordination in which actors can select the information from the repository that is appropriate for them to perform their tasks, whereby *"information useful to processes is stored … in an easy and accessible form"* (Davenport 1993, p. 89). Likewise, Henderson (1991) describes an example in which the modular nature of boundary objects is used to separate tasks. Assemblers and inventory control staff in product development teams view the same industrial drawings either as installation guidelines or as indices of part numbers, which allowed them to work separately on separate elements of the tasks. In this situation interdependence is pooled, as the functional boundary between different professionals is (re)defined on the boundary object (Faraj and Yan 2009).

The second type of boundary object, the standardized form is described in situations where the boundary object is used as a device that is intolerant of local tinkering, but enables integration of collective work across social worlds by holding certain elements constant (Fujimura 1992). The standardized form is referred to as 'immutable mobiles' (Star and Griesemer 1989): objects that can be transported over a long distance that convey unchanging information. It is most commonly described in clinical contexts, by referring to the use of standardized protocols, prescriptions and information systems (Bjorn et al. 2009, Cooper 2011, Mackintosh and Sandall 2010, Gittell 2002, Faraj and Xiao 2006). Also in other settings, like construction work, standards are established beforehand through CAD tools to allow the integration of work on different sites without local tinkering (D'Adderio 2001). In the context of education, Nolen et al. (2011) show how assessment forms function as immutable mobiles, when course grades are regarded as standardized information about what has been learned of levels of student achievement. These grades keep viable across different contexts, while stripping away the local details about what has been actually learned in the classrooms.

These studies show that the standardized type supports coordination by providing standards that reduce the need for interaction among participants, and is therefore a relatively low-cost way to coordinate work (Galbraith 1973). Standardization is categorized as a form of programming, which examines the extent to which activities can be specified in advance (Argote 1982, March and Simon 1958). Specifying standards in advance stimulates predictability and offers a form of co-orientation, which is an important condition for coordination that enables interdependent parties to anticipate subsequent task related activity by knowing what the elements of the task are and when they happen (Okhuysen and Bechky 2009). The standards themselves are described as a specific form of administrative coordination, in which tangible resources, such as documents, checklists and standard operating procedures are used to assign routine tasks (Faraj and Sproull 2000). Standards are useful for supporting cross-boundary coordination because they provide a prescribed work order that is transferable across different contexts. By providing an equal norm across different contexts this type of boundary object bridges a normative boundary, because different perspectives of how work should be completed are already described in advance.

The third type, coincident boundaries, *"have the same boundaries, but different internal contents"* (Star and Griesemer 1989, p.410). For coordination, a particularly important instance of coincident boundary is the timeline, which defines a series of steps or time units, each of which can be assigned to different people or units and populated by different activities and outcomes. This makes time concrete through defining sequences of activities or events. It has been analyzed most commonly in the literature on project management (Lindkvist et al. 1998, Yakura 2002) and information systems development (Barrett and Oborn 2010). These studies describe how the boundary object is passed on to different groups that take control over specific elements of the tasks sequentially. For example, Yakura's (2002) analysis of project timelines as boundary objects shows how Gantt charts are used to delegate tasks to different users in different geographical locations. The chart functions as a 'temporal' boundary object that provides closure to the collaboration by making time concrete and negotiable for its various users. Different time periods are distinguished within the boundary object, each of which corresponds to a specific type of activity. By using the boundary object to separate tasks, the focus is often put on perceived interdependence and the negotiation of priorities (Sapsed and Salter 2004). For example, Lindkvist et al. (1998) describe how timelines become instruments of authority and control by triggering a negotiation process between collaborating parties.
The coordination function of the coincided boundary form is based on arranging

sequential interdependence (Thompson 1967). In this type of coordination actors are dependent on the performance of actions by others for arranging their own work. As work in projects often occurs at different locations in parallel, it requires collaborators to stay informed about what work is being done (Kellogg et al. 2006). In order to do this, work is made visible by arranging the order of activities. This is a form of temporal coordination that is based on making time and space concrete. Temporal coordination bridges a spatiotemporal boundary through specifying sequences of action.

Fourth, the 'ideal type' boundary object features in situations where shared understanding is developed through interaction with the object (Barley et al. 2012). The ideal type boundary object is abstracted from all domains, but is adaptable to local sites, because it's potentially multivocal. The object is treated as a symbol that becomes a 'good enough' roadmap for all parties (Star and Griesemer 1989), since both groups contextualize the boundary object in their own way (Doolin and McLeod 2012). This process is mainly discussed in studies of knowledge sharing (Carlile 2004) and learning (Akkerman and Bakker 2011, Wenger 2000). Likewise, Broberg et al. (2011) regard boundary objects as flexible and malleable objects that offer a temporal learning space. Groups resolve conflicts by transforming ideas and building trust by using boundary objects (Black and Andersen 2012).

This functionality of the ideal type boundary object is recognized in a wide array of fields as a way of integrating understanding among different groups. An example is the use of prototypes in design and manufacturing (Subrahmanian et al. 2003, Leonardi 2011). Prototypes (drawings, 3D models, and other graphical representations) become permanent means of negotiation in the product development process between developers and engineers. The boundary object is not functioning as static means of translation, but arises over time, through which opposing interests and interpretations are negotiated and transformed. Bechky (2003) describes this process in negotiations about a pump between assemblers and engineers that took on meanings that reflected both the manufacturing concerns and the engineering needs. Actors learned about their differences and dependencies, then jointly transformed current knowledge into a new contextualized understanding.

Like these studies show, the ideal type boundary object features in organizational settings characterized by reciprocal interdependence (Thompson 1967). Challenging coordination problems require actors to interact frequently to develop a common perspective to coordinate their actions. Frequent contact offers the advantage of

adaptability by supporting mutual adjustment, which feeds into the development of common understanding (Okhuysen and Bechky 2009). Faraj and Sproull (2000) describe coordination based on sharing expertise to build common understanding as expertise coordination. Expertise coordination is defined as the management of knowledge and skill dependencies (Faraj and Sproull 2000, Faraj and Xiao 2006). In contrast to administrative coordination that focuses on protocols and routines, expertise coordination is based on professional judgment. This forms the basis for the translation or transformation of knowledge between actors to bridge a knowledge boundary (Carlile 2004).

In sum, we can discern the following overview of the coordination function of boundary objects.

Boundary object type	Boundary	Coordination type(s)	Coordination function
Repository	Functional	Designed coordination	Modularity supports self-synchronization
Standardized form	Normative	Administrative coordination	Conveying similar norms across different contexts
Coincided boundaries	Spatiotemporal	Temporal coordination	Sequencing task related activity by defining a time and location allows multi-tasking
Ideal type	Knowledge	Expertise coordination	Developing shared understanding based on abstraction leads to collective sensemaking

Table 2. The coordination function of different types of boundary objects

3.3 Towards a process perspective on tailoring boundary objects

The overview in Table 2 of the coordination function of boundary objects shows that boundary objects have certain characteristics that suit the management of a particular type of boundary. While this overview might indicate rather static distinctions between different types of boundary objects and their coordination function, there is reason to believe that the distinctions between them are not so fixed. As coordination is a temporally unfolding process of managing interdependencies, also coordination mechanisms change in the process of adapting to conditions of uncertainty, and novelty, when existing ways

of organizing activities are disrupted and must be accomplished in new ways (Crowston 1997, Jarzabowski et al. 2012). Boundary objects are part of this dynamic as they are categorized as a coordination mechanism of representation that supports coordination by providing a common referent (Okhuysen and Bechky 2009).

This corresponds to recent insights in boundary object literature, which indicate that the use of a boundary object is dependent on the way it is put into practice (Levina and Vaast 2005). Accordingly, boundary objects can facilitate interaction in different ways (Trompette and Vinck 2009). As the boundary object itself is (re)configured to accommodate changing information and work requirements (Doolin and McLeod 2012), different users employ boundary objects in different ways as it is embedded in their situated practices (Bechky 2003, Carlile 2002). As such, boundary objects require a fair amount of updating and tailoring to continue to satisfy the changing needs of the collaborating parties (Lee 2007).

We build on and connect these ideas by investigating how the boundary object is tailored in different ways when people make a bid to configure the object for a specific coordination function (DeSanctis and Poole 1994). This builds on earlier work that shows how actors may employ different strategies to shape the form and use of the boundary object, while engaging in cross-boundary interaction (Barley et al. 2012). Understanding the way in which its users tailor the configuration of a boundary object, and how the individual tailoring influences the efficacy of cross-boundary coordination, would require that we begin to pay attention not to the object itself, but to the cross-boundary coordination processes underlying its constitution.

3.4 Methods

3.4.1 Research Setting and Data Collection

In order to obtain access to the short-cycle coordination processes through which the officers tailor the boundary object, we conducted a qualitative field study of emergency management exercises. This allowed us to study how boundary objects were configured in the interaction between Police, Fire Department, Medical and Municipal officers during a response operation. The data presented in this article was collected in the winter of 2010, in which 10 field exercises were observed, recorded, and transcribed in detail. In addition, 20 in-depth interviews were conducted with all the officers that participated in these exercises.

We chose to focus in depth on the collaboration processes in these exercises, favoring accuracy over generality in the first stages of our research (Brinberg and McGrath 1985, Langley 1999). This enabled us to capture the process of creating the COP as a boundary object, which is grounded in the ongoing interpersonal interaction between the officers. Our data collection focused on how officers interpreted the information shared concerning this boundary object and how it influenced their consequent actions. For us it was very important to understand how these actions were embedded in context of response operations, to be able to capture the richness of the coordination process without abstracting it away from the interdependencies in the environment (Barley and Kunda 2001).

Emergency response field exercises offer a unique opportunity to study the use of boundary objects *in situ*. They are scenario-based exercise sessions in which emergencies are simulated, that start with a predefined script, but continue in any possible direction as the events unfold. As such, the exercises resemble the reality of emergency response, since actions of the officers have direct influence on subsequent events and outcomes. Exercises differ from training sessions in that events are not interrupted for moments of reflection, but the response operation is left to unfold. As such, exercises are a good focus for analysis because the emergency management organization is similar to events in the field, and actors are obliged to act and forced to make decisions that influence the way in which the exercise unfolds. Still, it is also necessary to acknowledge the limitations of exercises: because scenarios are removed from reality they may lack the same emotional aspects, decision impact and in some cases delay in the recruitment of units (Latiers and Jacques 2009).

The exercises themselves were staged in different locations on training grounds specially designed for emergency response exercises. These training grounds were located at a former military airbase, on which abandoned buildings like an energy plant and a small village were transformed into a disaster area with caved-in buildings, a gas station, train yard, a section of highway, etc. These enhanced the realism and feel for the situation, as for example an exercise that involved a highway traffic accident was located at the realistically reconstructed highway with crashed vehicles and trucks. The exercise scenarios included: a fire in a youth hostel; fire in an adult club; a highway collision; a hostage situation; carbon monoxide diffusion in an elder home; a fire in a tire factory; an explosion after a failed SWAT raid; and a Cessna plane crash on a gas station. The average length of the exercises was 1h26m, ranging from 1h2m to 1h54m. Each exercise consisted of two or three command meetings, with approximately 15 to 30 minutes of

time in between to carry out the tasks set out in the meeting. This corresponds to the phase of group activity that Marks, Mathieu and Zacarro (2001) call transition. Following the exercise, an after action review was held.

In the exercises the COP is created on a white board or flip chart in a mobile field command center. A command meeting was held approximately every half hour to create or update the COP on a common display, and to discuss the progress and challenges of the response operation. In many countries including the Netherlands, the COP is a common part of response operation training and contains two elements: a geographical representation of the situation (drawing) and a checklist of the actions (both completed and "to-do") (Wolbers and Boersma 2013).

The sequences of activities during the exercise were observed and audio recorded by the first author by shadowing lead officers. The first author also took field notes on the interactions between officers from different organizations, in order to analyze and reconstruct the way in which the COP was used to guide actions and decision making. Observations are important tools to capture this process since people often cannot articulate how they do what they do unless they are in the process of doing it (Barley and Kunda 2001). In addition, informal conversations were held before and after the exercises to allow participants to reflect on their actions. After the exercises, participants were interviewed in the spring of 2011 to ascertain their view on the response exercises in order to find out how they understood the COP and the actions of other emergency services in specific exercises. Discussions in the interviews suggested that the interviewees still recalled the exercises in quite some detail and felt confident commenting on them. The analysis of the exercise transcripts and field notes provided the input for the interviews. We asked the officers how they constructed the COP, both mentally and on paper, how they perceived the information and collaboration with other officers, and how this influenced their decisions for specific actions. As such, moving back and forth between analysis of the transcripts and the interpretations of the officers in the interviews allowed us to explore and explicate the dynamic of tailoring the boundary object.

The prolonged period of data collection allowed us to zoom in and out on the data (Nicolini 2009), and enabled us to critically assess, compare and broaden our understanding of the phenomena we observed in the field exercises and heard described in the interviews. The research process developed iteratively as we analyzed transcripts of the recordings, interviewed the participants of the exercises based on the previous analysis and combined this with analysis of documents on the use of the COP. During this

process we realized that the officers tailored the COP in unique ways, each of which had its own temporal trajectory. This guided our focus towards the sequential order in which the tailoring occurred, requiring a mixed methods design to investigate this.

3.4.2 Analytical Process

We have divided our analytical approach into five stages based on a conversion mixed design (Teddlie and Tashakkori 2009), to integrate our qualitative and quantitative analysis. A general overview of this mixed methods design is visualized in Figure 4.

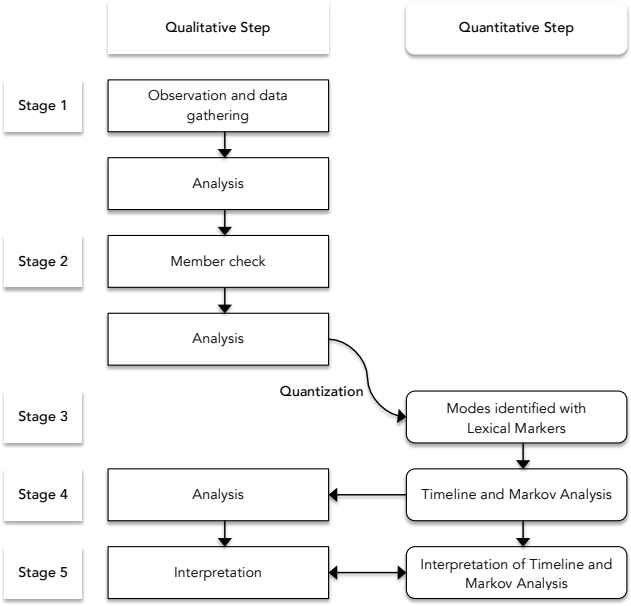


Figure 4. Design of the study, using notation described in Teddlie and Tashakkori (2009)

In the first stage of our analysis we started with inductive theory building (Corbin and Strauss 2008) to develop the theoretical concepts and connections among them from our process data (Langley 1999). The transcripts from the interviews and exercises were combined with the help of the data analysis tool MaxQDA (Corbin and Strauss 2008) to inform our analysis. The fully transcribed exercises allowed us to reconstruct the interactions of the officers with each other and the COP chronologically. We coded the elements of this process, which provided insight into the different ways of tailoring the boundary object.

In the second stage of the analysis we conducted a member check (Schwartz-Shea and Yanow 2009) to see whether our ideas applied to the operational experiences of the officers. We conducted these interviews in the summer of 2012, two years after the initial observations. Our acquaintance with the officers allowed us in this stage to reflect on their experiences during the exercises in comparison with the actual operational responses in the two-year period, and ask them about the relative importance of the COP in these response operations. In these interviews we asked the officers to describe their work and experiences during operational responses of the last two years. This enabled us to confront and build on one of the challenges in our material, the fact that the observations were based on exercises instead of real incident response operations. By taking this step and checking the analysis and results with the officers, we felt more confident that the results reflected the actual practices of emergency response operations.

In the third stage of our data analysis we focused on possible temporal patterns in the development of the boundary object during the exercise. If the officers tailored the boundary object to suit their coordination needs, did they do this in specific ways and were there discernible patterns in the process of development over time? In combination with a progressively deepening literature review we gradually arrived at four coordination modes used to tailor the boundary object: selecting tasks, phasing action, standardizing information and transforming understanding. We recognized that these could be connected to the original forms of the boundary object in the work of Star and Griesemer (1989), and reframed them to capture processual moves. As such, our inductive theoretical reasoning was an iterative process of moving back and forth between empirical impressions and theoretical inferences (Alvesson and Kärreman 2007).

In this stage we continued moving back and forth between these theoretical insights and our empirical data. We analyzed the transcripts of the exercises to discover if specific patterns of discourse were present that resembled each coordination mode. A human/machine augmented analysis with help of a lexical search in the program MaxQDA (Corbin and Strauss 2008), aided us in providing a word frequency analysis that suggested that each coordination mode had specific terms associated with it that were not associated with other patterns. We used these as markers of the mode, if we believed it represented the mode accurately enough. After this semi-automatic coding, we rechecked whether the codes actually reflected our original definition of the coordination mode and deleted those codes that did not reflect this original definition. A more elaborate description of the logic we used to code the discourse based on the four coordination modes can be

found in appendix 1. The average number of coded segments per exercise is 143, and ranges from 132 to 171. This resulted in the following list of key terms that signaled which of the coordination modes the officers were in during a specific unit of analysis:

Selecting tasks	Phasing action	Standardizing information	Transforming understanding
Message	Later	Procedure	Because
Meanwhile	Take care	Regulate	Certain
Happened	In a while	Plan	Means
Task	First	Distance	Convenient
Created	Arrange	Alarming	Think
Self	Each other	Deploy	Sensible
Done	Time	Scaling up	Why
Last	Adjust	Protocol	Reason
Control	Feedback	GRIP	Danger
Mono	Consult		Estimate
	Bilateral		Accounting
	At this moment		Safe
	Pass on		Understand
	Priority		
	Busy		
	Ongoing		

Table 3. Terms associated with each coordination mode

The third stage of analysis produced temporal sequences (timelines) of codings of coordination modes for the ten exercises. To facilitate identification of common sequential patterns across the exercises, we utilized formal modeling techniques in the fourth stage of our analysis. To detect patterns of action over time we performed a Markov chain analysis, which gives an indication of whether there are regularities in local sequential structure whereby acts are predictable from immediately preceding acts (Poole et al. 2000). The output of a Markov model is visualized in a transition matrix that presents the probability of the occurrence of sequences of coordination modes, relative to other sequences. This gives an overall 'picture' of the sequential structure in the data that

enabled us to determine statistically whether there were common recurrent structures. By identifying common recurrent sequences, Markov analysis points to features of interaction that can then be explored in further discourse analysis. The coded discussions among the emergency responders (coded into categories selecting tasks, phasing action, standardizing information, and transforming understanding) generated a sequence of activity types that are the input for the Markov analysis.

The validity of a Markov chain is assessed through testing the assumptions of order and stationarity based upon a log-linear analysis outlined in Poole et al. (2000), to which we refer the reader for a more detailed description of the statistical analysis. The first assumption of whether the process depicted by a Markov chain has a definite order is assessed by comparing the fit of models of successive order. We compared the fit of 'higher' order models (2nd order) with 'lower' order models (1st order), and a baseline model that indicates no local order in the interaction (0th order). In a first-order Markov chain, each successive action is reliably predictable from the preceding action, which implies an act-response format. In a second-order Markov chain, each successive action can be predicted based on the previous two actions, which implies an act-response-response format. All second order Markov chains can also be re-expressed as first order chains, which aids in interpretation of sequences. The second assumption is whether the same transition matrix exhibits stationarity, so the sequential probabilities hold for the entire sequence. This is tested by dividing the entire sequence into shorter segments, calculating their transition matrices and comparing these.

Our tests indicated that first and second order Markov chains represented the sequential dependencies. First order models fit five of the episodes: Exercises 1, 3, 4, 5, and 6. Second order models fit three of the episodes: Exercises 2, 7, and 10. Only two episodes, exercises 8 and 9, showed no significant sequential structure (0th order). The transition matrices are presented in appendix 2.

Markov analysis is useful because it tests whether there is structure in the overall episodes. To provide better resolution of this structure, we then utilized a visual mapping strategy (Langley 1999) by creating a timeline that visualized the transitions between the coordination modes based on the sequences of codings. This timeline depicts the sequence of coordination modes as it unfolds during the episodes and affords a more detailed understanding of the temporal sequencing. We moved back and forth between the Markov transition matrix and the line charts to look for and develop inferences about common sequences and the progressions of events (Langley and Truax 1994).

In the fifth stage we went back to our qualitative data of both the discourse strings from the exercises and interviews with the officers, to develop an interpretation of the critical transitions we identified in the previous analytical stage. The process analysis from stage four is suited to identify regularities in short sequences, while the discourse approach is able to lend meaning to the regularities, but also to make sense of significant, irregular patterns and longer strings of discourse. By analyzing and reflecting on the discourse in these critical patterns, we were able to develop theoretical inferences about how the boundary object is tailored to support or impede cross-boundary coordination.

3.5 Findings: Tailoring the boundary object for cross-boundary coordination

Now we will return to our example from the introduction to develop a more satisfactory answer concerning why the Medical Officer wandered into the contaminated area. Before doing this, however, we must first explain the relation between the four coordination modes used to tailor the boundary object: *selecting tasks, phasing action, standardizing information, and transforming understanding*. The coordination modes are processes based upon the functionality inhibited in the four forms of boundary objects—repository, standardized form, coincident boundaries, and ideal type (Star and Griesemer, 1989)—that describe the different ways in which cross-boundary coordination can be supported. We regard each coordination mode as the property of an act that one of the professionals engages in that (1) makes a bid to define the boundary object in a certain way (as a repository, a coincident boundary, etc.) and (2) may operate on the boundary object to support a particular form of coordination.

The coordination modes are illustrated in Figure 5, which differentiates between the structuring of the boundary object and the way in which it supports coordination. The columns differentiate coordination modes that tailor the boundary object as an open or a closed configuration. Closed use of boundary objects is based upon employing (temporary) established standards or arrangements, while open use of a boundary emphasizes processes that are in development: phasing action or transforming understanding. The rows differentiate the coordination modes that function to either segment or integrate work to enable coordination. Coordination modes of segmentation divide work into separate actions or phases, while modes of integration primarily attempt to bring together interdependent actions or understanding.

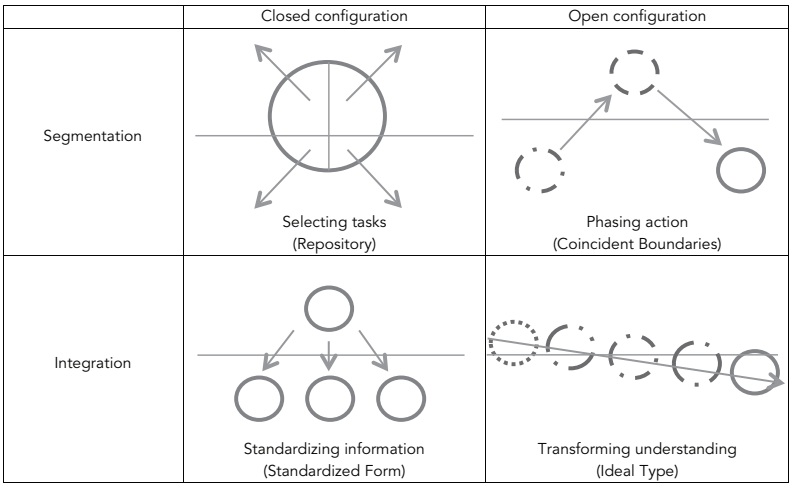


Figure 5. Coordination modes used to tailor boundary objects

Based on this analytical framework we will now go back to the case of the introduction to analyze how the boundary object was tailored during the response to the traffic accident, when the Medical officer crossed the line.

3.5.1 Tailoring the boundary object during the response to a traffic accident

Once emergency responders arrive at the scene of the accident on the highway, their first actions are aimed at getting an overview of the scene and identifying potentially dangerous situations. There is great danger for escalation in this scenario, because multiple vehicles are involved posing different kinds of hazards. At the front of the accident a truck carrying barrels, which are later identified as toxic XTC chemicals, has collided into the crash barrier causing the barrels to roll onto the highway. Multiple cars driving behind the truck failed to avoid the barrels and have collided. A small van behind the XTC truck leaks fuel that catches fire, which is threatening to ignite a nearby petrol truck. Black smoke clouds from the fire block the view of the accident and obstruct the traffic flow in the opposite lane. After the Police, Fire Department, and Medical Officer arrive on scene, they conduct an initial reconnaissance of the situation. The officers construct an individual picture of the situation, based on their professional interpretations and values regarding priorities.

In this first phase of the exercise the officers approach the incident by separating tasks, and order their own subordinates to complete the assigned tasks independently. This is possible because the dynamic of the incident is still limited and the officers are

able to, as they say, *"chop the incident into compartments"*. After 25 minutes the first field command meeting is held in the mobile command center on scene. The following discussion takes place between the Field Commander (a high ranking Fire Department commander) and the officers, while constructing the first common operational picture.

Actor	Conversation	Coordination modes
Field Commander	All right, welcome everybody, are we all here? Let's shut down the radios for now so we can have a quiet meeting. I would like to spend 10 minutes on constructing the operational picture and any bottlenecks that we can identify. I think it's good to draw the situation, and I would like to ask the Fire Officer to do that for us.	Transforming understanding
Fire Officer	*[starts drawing on the whiteboard]* Here is a money truck, a petrol tanker and a car. At the front there is a small fire and a truck with an unknown cargo that consists of several barrels.	
Field Commander	Okay, just to be clear, let's number the vehicles. 1,2,3,4,5,6, with your permission. Is that right? Does the picture correspond to the scenario outside? Okay, let's move on to what is happening right now. Fire Officer?	
Fire Officer	Let's start at number 1. Here are some barrels that fell off the truck, but seem to be intact. There is no leakage at this time, so there is no priority for me yet.	Phasing action Phasing action
Field Commander	Okay, truck number 2.	
Fire Officer	Is on fire, but we have it under control.	Selecting tasks
Field Commander	Fire under control. Right, 3?	Selecting tasks
Fire Officer	The truck is leaking at the shutoff valve, but we have it under control at this moment.	Selecting tasks Phasing action
Field Commander	Truck 3 is leaking at the shutoff valve, under control.	Selecting tasks
Fire Officer	Yes, they [Fire Engine 2] are working on it as we speak.	
Field Commander	Bottleneck seems to be sealing the valve. Right, 4?	
Fire Officer	Ambulance, with one T1 victim inside. *[triangulation classification used by the medical services to identify the urgency of victims' transport to hospital, T1 means within 1 hour].*	

Actor	Conversation	Coordination modes
Field Commander	T1 as patient?	
Fire Officer	The driver and the nurse are inside, both injured, but approachable at this time.	Phasing action
Field Commander	They are still in the ambulance?	
Fire Officer	They are, but they need to be rescued.	

Table 4. Exercise 3 First Field Command Meeting

In the first field command meeting the Fire Officer explains the drawing on the map. His conversational style shows that he is using the boundary object for segmentation through combining modes of selecting and phasing, by explaining that the fire department has managed to *control* specific elements of the incident, *at this moment*. The other emergency services are still keeping a distance, because of the danger posed by the fire near the petrol truck. At this moment their primary means of interpreting the situation is through the boundary object, which is constituted by the Fire Officer's drawing. Since the Fire Officer is using modes of segmentation, he asserts that the Fire Department has the situation under control, but this does not give the other officers a clear idea on how they can contribute. As the other officers are not privy to the understandings of the Fire Officer, they are prevented from building a contextualized understanding of the situation.

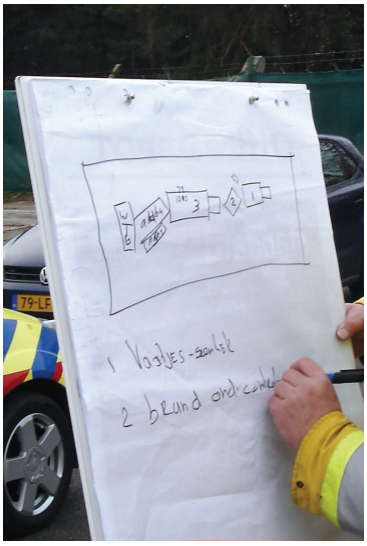


Figure 6. Drawing of the accident site

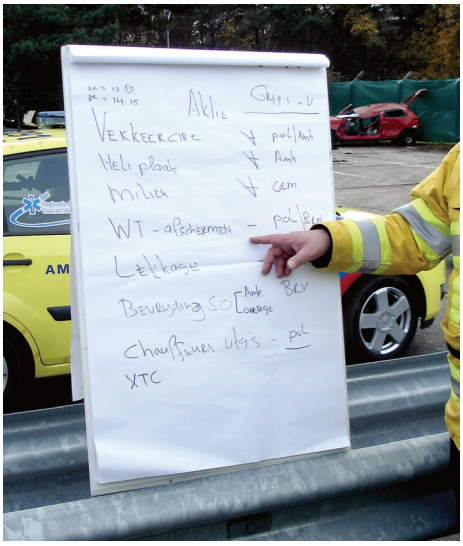


Figure 7. Checklist of actions

The second field command meeting is held 46 min into the incident, in which the following conversation takes place:

Actor	Conversation	Coordination modes
Field Commander	All right, let's get the picture clear. Developments: what has changed?	
Fire Officer	Developments: car 1 has a leakage at the barrels on top. One barrel is leaking an acetone like fluid *[highly flammable]*. I ordered the guys to put some foam on that. In addition, I'll arrange a water-screen to be placed between car 2 and 3, so the other emergency services are not affected by it.	Phasing action
Field Commander	Okay, so the story is not 'thickener', but acetone?	
Fire Officer	Right, and I have created a small OGS *[procedure for dealing with toxic materials]* in car 1.	Selecting tasks
Field Commander	Yes a small OGS. What does that mean for the other emergency services?	Transforming understanding
Fire Officer	They cannot approach that area without protective gear and clothes. Not behind the area that is cordoned off. We have created a line there.	Selecting tasks
Field Commander	Right, let's determine that from here on *[draws a line on the whiteboard]* this is a no-go area.	
Fire Officer	We have put additional traffic cones there.	
Field Commander	So the area is unsafe there, and safe on the site we are positioned now. From now on nobody can walk unprotected behind that line. Is that for the entire incident or for specific part?	Transforming understanding
Fire Officer	Until car 3. I placed a water screen between 2 and 3 and behind that it's safe.	Transforming understanding
Field Commander	From here on it's safe?	Transforming understanding
Medical Officer	Yes.	
Fire Officer	No, from there on…	
Field Commander	So this is the unsafe area, if everybody moves around that area we can apparently work safely, is that correct?	Transforming understanding

Table 5. Exercise 3 Second Field Command Meeting

In this meeting it becomes clear that the XTC barrels that fell of the first truck have started to leak and release toxic fumes that can pose a lethal threat to the emergency personnel near that area. To protect the emergency personnel from this chemical threat, a 'no-go area' is created around the truck at the front end of the collision. The COP is used to demarcate and validate this 'no go area' in the form of red lines on the diagram.

In this discussion about the representation of the situation based on the COP (as shown in Figure 6), the officers tailor the boundary object in different ways to cross the multiple types of boundaries they experience. The Field Commander perceives a knowledge boundary and engages the COP with an integration-based mode of transforming to develop shared understanding, while the Fire Officer is using modes of segmentation (selecting and phasing) to coordinate selecting and sequencing of tasks. This can clearly be seen through the Fire Officer's attempt to take care of the situation alone. We interpret that, based upon his actions, he experiences a functional boundary (who is responsible for what) and a spatiotemporal boundary (in what sequence is action to be taken). Accordingly, his actions are aimed at solving these two cross-boundary coordination issues. He later commented in an interview that only the Fire Department has the expertise and tools to operate in hazardous environments, thus for him shared understanding is not a relevant cross-boundary coordination issue at that time.

In the conversation that follows, the Field Commander tries to involve the other officers in his reasoning, and inquires about the meaning of the 'OGS' (Dutch abbreviation for: accident with toxic substance) procedure. The Field Commander is primarily adopting a mode of transforming, when he tries to pinpoint the location of the safe area, to encourage the officers to develop a shared understanding of the situation. He pulls other officers towards this mode, as the Fire Officer is encouraged to explain the location of the unsafe area. Yet, in the final moments of the meeting there is still a discussion between the officers about the exact location of the unsafe area. This is represented by the Medical Officer confirming the location of the area, while the Fire Officer is correcting her by stating *"No, from there on…"*. The boundary object appears to be openly configured to the Field Commander and the Medical Officer who try to develop shared understanding about the location of the red line, but the Fire Officer treats the boundary object as a closed configuration to support his primary goal of task segmentation.

In general, these instances in which parties disagree or misunderstand but believe that they are in agreement or have understanding—what Scheff (1967) called 'false consensus'—tend to cause coordination problems for the officers. While interpretive

flexibility is central in the functioning of boundary objects, it also enables a multiplicity of bids for coordination modes as the boundary object is constructed. As the boundary object is used to support different coordination functions simultaneously, 'false consensus' manifests, which impedes cross-boundary coordination. A Field Commander stresses this point in his own words:

> *"I tend to use the term on what pyramid are you sitting. They [the officers] tend to sit on their own pyramid and are under the impression that they are talking about the same sun, but in the meantime each one is looking in another direction. I think that's a problem. That tends to happen during incidents when we think we have the same operational picture, but in the end it turns out that the Fire Department thinks there are 10 victims and that the Medical Services explain: no, there are 10 persons, of which 3 are transported to the hospital and 7 are just fine. Now we are just talking about the term victim. The Fire Department tends to call everybody that is walking around the incident scene a victim, but the Medical Services specify this into 10 persons of which 3 are transported and 7 are taken care of and are no victims. I think that is the main task for a Field Commander to get that picture clear".*

The uncertainties about safe and unsafe areas that were superficially agreed on in the second field command meeting also appear not to be resolved by the officers, as the Medical Officer wanders into the toxic area affected by XTC chemicals moments after the meeting ends.

Actor	Conversation	Coordination Mode
Medical Officer	Yes *[walks through the incident to talk to the Fire Officer]*. We can go until behind the water-screen. It's here right?	
Fire engine commander	No, it's at the other end, way back.	
Medical Officer	Oh my god, where?	
Fire engine commander	The water-screen is between…	
Fire Officer	*[shouting]* Medical Officer!! YOU ARE WALKING IN A CONTAMINATED AREA!!!	
Medical Officer	Oh, I have just walked straight through that area.	
Fire Officer	You have just inhaled very toxic fumes.	
Medical Office	How stupid of me.	

Actor	Conversation	Coordination Mode
Fire engine commander	There's a line here for the unsafe area.	Transforming understanding
Fire Officer	They are not trespassing right? Now we have to decontaminate them.	

Table 6. Exercise 3 Walking in a Contaminated Area

We can now return to the question raised in the introduction: *How can the Medical Officer wander into an unsafe area, when this has been discussed just a moment before in the field command meeting?* We argue that the most likely answer lies in the types of boundaries the officers experience, and the fit between the coordination modes the officers consequently use to tailor the configuration of the boundary object to bridge these boundaries. If we take a closer look at the entire set of exercises, we can identify various sequences in which different types of coordination modes dominate the tailoring of the boundary object, and compare them.

3.5.2 Phase Analysis: comparing sequential patterns of tailoring the boundary object across exercises

In several sequences similar transitions between coordination modes are present, which influence the subsequent coordination efforts. Interviews with officers and Field Commanders hinted at both the difficulty and importance of one particular type of transition: experiencing knowledge boundaries and the subsequent process of developing shared understanding. One Field Commander describes one of these situations:

> *"Demarcating safe and unsafe areas does tend to cause problems. It's similar for medical personnel, who ask the question: where is it safe for me to work, is it already safe? Yes, No? How is it possible when he says it's unsafe and I see a bunch of fire fighters working in that area? We haven't lost those tensions in constructing a common operational picture. I think that's a, I am trying to translate that to my role, what I try to do is to let the officer who is providing the operational picture be more precise. What are we talking about and what does that mean, how long is that going to take? By asking those questions I try to help the others by taking that into account".*

We noticed that similar issues related to shared understanding arose during specific periods in the exercises. We analyzed these phases with help of the timeline charts to identify the transitions during the critical moments at which issues with shared understanding seemed

to occur. To introduce this part of the analysis, we will refer once more to the situation from exercise 3. The specific sequence illustrated in Table 5 shows the lack of fit between the closed use of the boundary object (selecting) by the Fire Officer, and the open use (transforming) by the Field Commander. This is visualized in Figure 8 between codes 17 – 26 on the horizontal axis (indicated by the dotted lines). The timeline indicates that sensemaking is accomplished in a pattern that oscillates between the coordination modes of selecting (1) and transforming (4), and leads into a longer period of transforming (codes 21 to 27), where actors try to make sense of the situation with help of the boundary object.

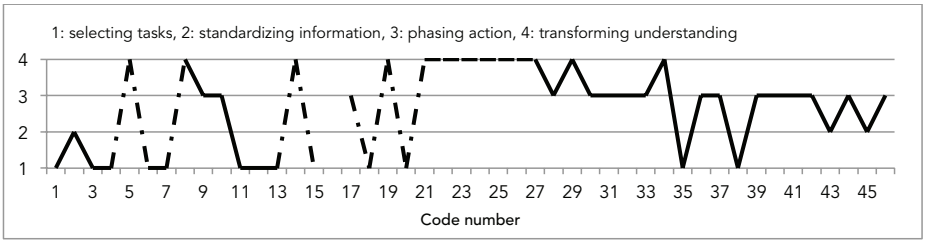


Figure 8. Timeline of coordination modes in Exercise 3: Traffic accident on highway

When analyzing the timelines of the other exercises, we realized that similar 1 – 4 (selecting - transforming) transitions also occurred during sensemaking sessions concerned with safety issues during the response operation. This specific combination tells us that safety issues trigger two kinds of parallel dynamics: a mode that is aimed at taking responsibility to deal with the safety situation corresponding to the predefined task division of a designated emergency response organization, and simultaneously the search for shared understanding of the situation. This shows a conflicting oscillation between the closed configuration of the boundary object aimed at task segmentation, and an open configuration aimed to develop a shared understanding of the situation.

In addition to the 1 – 4 transitions, we also analyzed the transitions between the four dimensions from Figure 5: closed use through selecting and standardizing (1 – 2), open use through phasing and transforming (3 – 4), integration through standardizing and transforming (2 – 4), and segmentation through selecting and phasing (1 – 3). By analyzing these transitions we were able to discern similarities and differences in tailoring the configuration of the boundary object during similar safety incidents in other exercises. In exercise 5 in which emergency services need to coordinate the evacuation of an elderly-care home in response to carbon monoxide poisoning, we observed several of these

phase transitions. This exercise starts with a period of closed use (1 – 2), and is followed by a period of sensemaking about safety (1 – 4), a period of open use (3 – 4), and a bit later by a period of segmentation (1 – 3). We will zoom into some of these critical phases, which are indicated by the dashed lines in Figure 9.

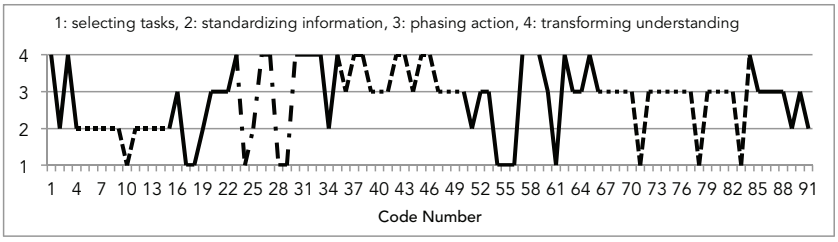


Figure 9. Timeline of coordination modes in Exercise 5: CO Threat in elderly-care home

In the first phase of the exercise (codes 4 – 15) the boundary object is tailored as a closed configuration falling back on designed coordination. The officers use the boundary object to write down and activate standard procedures to commence the response operation and select the tasks that need to be completed. The officers engage in cross-boundary coordination modes of selecting and standardizing to bridge both a normative boundary (what response capacity is generally required in these situations), and a functional boundary (who needs to perform specific actions).

Actor	Conversation	Coordination Mode
Medical Officer	There are only 4 nurses in the house, and I only have one ambulance on scene, so that is not much. I'm not sure if the police are helping with the evacuation? I'll ask those questions: how much teams are there, and is it safe inside?	Transforming understanding
Fire Officer	No, no, they cannot go in. The Fire Department brings them outside to the safe area. It would be convenient if they can be transferred there.	Transforming understanding
Medical Officer	Yes, that is happening now.	Selecting tasks
Fire Officer	Well, for now, what I know from the engine commander is that it's unsafe inside. If there are any safe area's inside is still the question. We will take care of that; in the meanwhile I have scaled up.	Transforming understanding Selecting tasks

Actor	Conversation	Coordination Mode
Medical Officer	The windows and doors are open, I assume fresh air is getting in?	
Fire Officer	Yes, but there is a danger because the CO is coming from somewhere.	Transforming understanding
Medical Officer	What is the safe area for us? Can we get the people out from there and take over?	Transforming understanding
Fire Officer	The CO alarm is not triggered outside. When they are really outside in the fresh air it's safe for you. All right?	Transforming understanding

Table 7. Sequence from code 28 to 32 in Exercise 5: Carbon-monoxide threat in elderly-care home

As the operation continues, there is a similar sensemaking problem occurring as in exercise 3, this time about the location of unsafe areas from the carbon-monoxide contamination. This safety question brings a new boundary into play, a knowledge boundary. The previous division of labor agreed to in the period of closed use of the boundary object puts the fire department in charge of the evacuation inside the elderly-care home, based on their access to respiration gear. This task division puts the Fire Officer in a position to assess the danger inside the elderly-care home, which is visible through the focus on selecting, combined with transforming in the next critical sequence (codes 23 – 33). As the 1 – 4 transition shows, a sensemaking problem is occurring. Yet, unlike the same 1 – 4 sequence in the highway exercise 3, in this exercise the officers engage collectively in the modes of selecting and transforming, synchronizing their configuration of the boundary object. A segment of the discourse in this sequence is presented in Table 7.

To resolve the safety issue, in this case the officers are not tailoring the boundary object from different coordination modes. Instead, they collectively tailor the boundary object as an open configuration, oscillating between modes of phasing and transforming, to combine the need to build common understanding with arranging the order of activities. The officers do not encounter coordination issues, because they are simultaneously using a similar configuration of the boundary object, hence using the object to bridge the same spatiotemporal and knowledge boundaries. This is visible in their discourse, where the medical, police, and fire officers are collectively engaging in modes of phasing and transforming.

Actor	Conversation	Coordination Mode
Medical Officer	I would like you to guide those people towards the shelter. My people are busy providing medical aid in the shelter and might transport elderly to the hospital if necessary.	Phasing action
Police Officer	Yes.	
Fire Officer	We as Fire Department will take care of evacuating the people from building, yes? So we have had a quick adjustment?	Phasing action
Head of elderly-care home	But there are people who are confused, because they live here for quite some time in a protected environment. At the moment we pull them out I think some of them might counter react. You have they keys to the rooms right?	Transforming understanding
Medical Officer	Yes we have, but the Geriatric department is a closed department I assume?	
Head of elderly-care home	Yes, it's a closed department. Keys are also on there. You can enter with them.	
Medical Officer	It might be convenient to do a CO measurement there, because if the CO is not too high they can stay where they are?	Transforming understanding
Field Commander	Are there persons in acute danger who need to be evacuated at this moment?	Transforming understanding
Fire Officer	Yes, we have measured CO all over the building. The Fire Department is busy with evacuating them.	Phasing action

Table 8. Sequence from code 41 to 45 in Exercise 5: Carbon-monoxide threat in elderly-care home

In another situation in exercise 7, officers are also trying to make sense of a safety issue. In this exercise a terrorist detonates an explosive device during a SWAT raid in a residential area. As the explosion tears the house apart and sets fire to surrounding houses, the regular emergency services are called to respond. In the first phase of the response operation the officers use the boundary object to develop situational awareness to be able to assess the possibility of another explosion. In this phase the boundary object is used as a tool to support integration through standardizing and transforming. The officers fall back on safety standards to assess in which areas access needs to be restricted due to the explosion danger. This is one of the few extended periods of integration we witness across all the exercises. These periods are represented by the dashed lines in Figure 10.

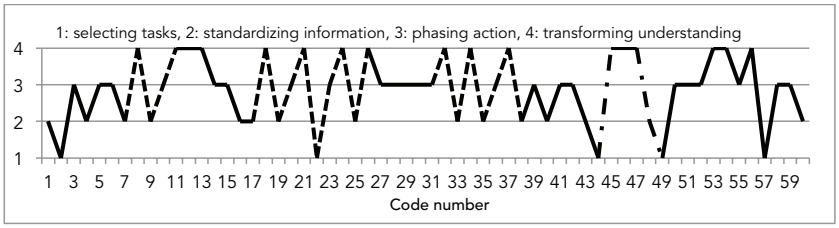


Figure 10. Timeline of coordination modes in Exercise 7: Failed SWAT raid

Zooming in on one of these integration sequences (codes 16-19), we find a situation where the officers are discussing the applicability of safety standards. It appears that the Police and Fire department have different standards for explosion danger. Experiencing different normative boundaries for dealing with safety triggers a discussion between the officers, where they collectively engage in modes of standardizing and transforming. In this first part of the exercise the officers are successful in crossing the normative boundary they are experiencing by constructing a similar configuration of the boundary object.

Actor	Conversation	Coordination Mode
Police Officer	Yes, but the point is, safe distance. 250 meters. Is that still applicable?	Standardizing information
Emergency Center	Yes, safe distance 250 meters, correct, over.	
Police Officer	All right, we will maintain 250 meters distance.	Standardizing information
Fire Officer	Two casualties are lying on the ground near that vehicle. The front of the building has collapsed, but it's not clear to me what is exactly going on. There are two casualties, of which one is a police officer. A SWAT officer told me they are deceased.	
Medical Officer	All right, I just heard from the ERC that there are explosives inside the building. My question is if 250 meters is enough distance. That is a concrete safety question to you.	Standardizing information
Fire Officer	For explosives is that enough?	
Police Officer	Yes that is safe.	Transforming understanding
Field Commander	We normally keep a different distance, 500 meters with cover and 1000 meter without cover.	Standardizing information

Table 9. Sequence from code 16 to 19 in Exercise 7: Failed SWAT Raid

Yet, in the second field command meeting the officers encounter an additional threat to safety: the possibility of an asbestos contamination that has spread in the area during the explosion. The Medical and Municipal officer bring this to the attention of the Field Commander in the second field command meeting.

Actor	Conversation	Coordination Mode
Field Commander	Other issues?	
Municipal Officer	Asbestos and safety.	
Field Commander	Yes, that is inferior to the explosion risk at this moment.	Phasing action
Medical Officer	Yes, well I do think this an important public health issue. Are we standing in a safe location in relation to the wind direction?	
Field Commander	I presume that we are standing at a sufficient distance.	
Medical Officer	We should investigate that.	
Field Commander	Asbestos risk.	
Medical Officer	Yes, I want to know that.	
Field Commander	Will be taken care of, I'll have that analyzed. Fire Officer, any other bottlenecks?	
SWAT Commander	There is no reason to assume that there are explosions in the surrounding houses.	Transforming understanding
Field Commander	The decision at this moment is safe to move in? All right?	Phasing action
Police Officer	All right, let's go.	
Field Commander	Go, decision is to investigate the asbestos risks. GRIP2. Do we need to change that?	Standardizing information

Table 10. Sequence from code 79 to 83 in Exercise 7: Failed SWAT Raid

In this discourse we recognize that the officers are not engaging in similar coordination modes. The Field Commander acknowledges that asbestos is involved, but does not give sufficient attention to the contamination, because he is still preoccupied by the explosives threat. He deals with the asbestos risk in the mode of phasing, as something to be sorted out later. At the same time, the Medical and Municipal officer regard asbestos as a serious safety threat, which they are unable to assess without the help of the Fire officer. As we

can see in the discourse, the Medical officer is likely experiencing a knowledge boundary by stating *"I want to know that"*. A few minutes after this discussion the decision to deploy is taken by the Field Commander and the fire units and ambulance crews enter the former no-go area. Moments later the Fire Officer notices that the area is contaminated with asbestos. This leads to a serious coordination problem as in the meantime the Medical officer has deployed her units in the contaminated area. These units need to be fully decontaminated before they can enter service again.

In sum, the timeline analysis shows that the boundary object is tailored differently to bridge different sorts of boundaries the officers' experience. The activity with the boundary object actually defines the boundary, or at least highlights which boundary the officers are paying attention to at any given moment. The officers run into coordination issues when tailoring the configuration of the boundary object from different modes, and as a result fail to bridge the different kinds of boundaries they experience. Tailoring the boundary object in similar coordination modes supports the coordination process, because in these situations the configuration of the boundary object matches the boundaries that are experienced by the officers, which can now be bridged.

3.5.3 Markov Analysis: general patterns of tailoring the boundary object

In the previous examples we witnessed that in two exercises the boundary object is configured as open and used for segmentation, while in the last exercise we see a prolonged period of integration. In this final part of our analysis we zoom out to compare what kinds of coordination sequences commonly occur and re-occur in all exercises. Figure 11 visualizes the results of the Markov analysis, showing which sequential patterns have the highest probability of occurring. It shows that by far the most common coordination mode in all exercises is *phasing action*. All the dominant sequences lead to *phasing action*, suggesting this is what Markov theory calls an absorbing state (Matthews 1970). This means that, in general, the boundary object is tailored towards an open configuration to segment action, supported by either a sequence in which standardizing information, transforming understanding or selecting task based responsibilities was central. In addition, phasing action, standardizing information and transforming understanding are processes that have a tendency to occur in repeated chains, suggesting longer periods of stable use of these coordination modes.

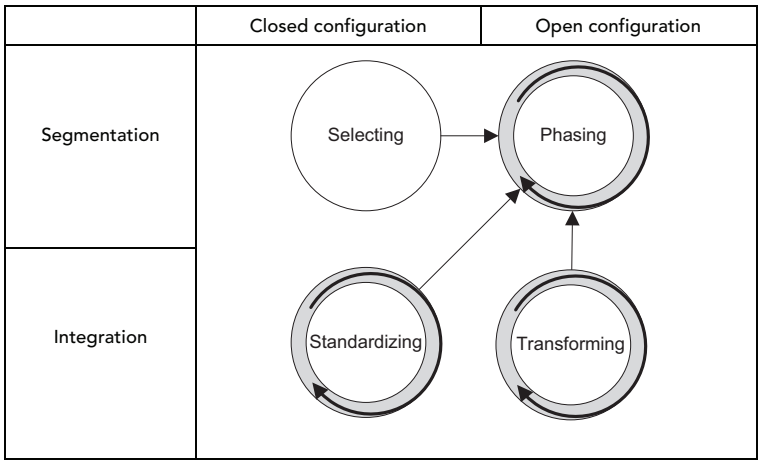


Figure 11. Sequential patterns with high probability, with the arrows indicating the direction of the sequence

This corresponds to findings in other studies indicating that once emergency responders arrive at the disaster scene, predetermined plans often need to be adapted to the dynamically unfolding situation at hand (Kapucu 2006, Moynihan 2009). Rather than predefined command structures, mutual adaptation enables first responders to adjust to changing circumstances at the disaster site (Bigley and Roberts 2001, Comfort and Kapucu 2006). Likewise, our findings suggest that if the officers tailor the boundary objects into a modular configuration to work on the task autonomously by selecting tasks, this represents an unstable state, and they ultimately adopt a different coordination mode.

3.6 Conclusion and Discussion

In this paper we have sought to answer the question: *how do different users tailor the boundary object, and how does this process support or impede cross-boundary coordination?* We were intrigued by the case of the Medical Officer wandering off into a toxic area, after being in a command meeting where a line was drawn to demarcate a no-go area. How could she do this, when she just has affirmed her understanding of the location of the danger zone? Our analysis pointed to the sequential tailoring of the boundary object. We identified four coordination modes used to tailor the configuration of the boundary object:

selecting tasks, phasing action, standardizing information and transforming understanding. Short cycle coordination patterns in sequences of these modes suggest the possibilities of constructing an open or closed configuration, which can support coordination through either integration or segmentation. In this particular instance, the Fire Officer introducing the no-go area was constructing a boundary object with a closed configuration, favoring his unit's autonomy, while tailoring the boundary object as a more open configuration would have been more helpful to foster shared understanding.

The mixed use of coordination modes was not unique to this single exercise, as the subsequent process and Markov analysis showed. During the response operation the officers' employ a variety of modes, because they are experiencing different types of boundaries. They make a bid to define the boundary object in using a particular coordination mode that corresponds with the experienced boundary. Our analysis shows that the boundary object represents not a single function (e.g. repository, coincident boundaries, standardized form, or ideal type), but is tailored by each of the users to fit the boundary they experience, thus producing individualized, yet to some degree intersecting boundary object configurations.

This finding has implications for the boundary objects literature, because our paper pulls through distinctions made early on by Star and Griesemer (1989) that have not been the subject of much inquiry. Our results yield a different conceptualization of boundary objects that stresses their relational nature. They suggest that the boundary object, its construction, and the interpretive uses to which it is put are inseparable. To go back to our case material, it is not about the red line itself, but about the relation between coordination modes in the process of *'drawing the line'* that determines whether coordination is supported or impeded. Based on this reconceptualization, we see three dimensions that have implications for the debate on boundary objects and cross-boundary coordination: relationality, temporality and intention.

First, relationality is an important dimension in our study as boundary objects are constructed through a relational process of tailoring. The majority of empirical research on boundary objects focuses primarily on their benefits (Bechky 2003, Henderson 1999), and less on how and why they function the way they do (Carlile 2004). Since this critique, one of the advances in the debate is the notion that different boundary objects are required to cross more complex boundaries: *"depending on the type of boundary faced, boundary objects with different capacities are required"* (Carlile 2004, p.565). What our findings suggest, however, is that successful cross-boundary coordination does not depend on

the capacities of the boundary object per se, but on the relationality between the modes used to actively tailor the configuration of the boundary object. The boundary object is able to support cross-boundary coordination through a relational process, where the fit between the perceived boundaries and subsequent coordination mode determines whether coordination is supported or impeded. So structuring the boundary object to support cross-boundary coordination is not about the capacities of the object itself, but about how the object is tailored to fit its users' needs.

Second, temporality becomes an important dimension, as we witnessed the construction of a boundary object over time. As most studies of boundary objects are performed in production and knowledge environments, the emphasis is often put on how boundary objects support knowledge sharing and learning. Hence, in these studies the boundary object becomes better structured over time, and coordination works by gradually integrating diverging perspectives when experts learn contingently, to develop a shared inferential logic (Hsiao et al. 2012). While the emphasis on learning explains cross-boundary coordination processes over the long term and in more stable environments, our findings indicate that one object can exhibit multiple coordination functions at the same time, and thus can be used for different purposes and cross different kind of boundaries simultaneously. As Doolin and McLoyd (2012) argue, boundary objects evolve and change, so they may not be able to span all boundaries equally effectively and may perform different roles in different settings over time. Alignments can be partial, shared understanding between groups can be spotty, which extends to the use of the object itself (Lee 2007). We add to this notion by showing that when actors engage with the boundary object together they might reach a temporary consensus, either true or false (as one of our respondents mentioned: *"talking about the same sun"*), but when they split up again this shared consensus might quickly dissolve and their understandings diverge. It shows that boundary objects are not always structured more completely through the process of use, but may be broken down and problematized as well. This has two implications: (1) when actors achieve a false consensus, they leave the meeting thinking they have a common object, but actually having different, conflicting or inconsistent understandings of it; and (2) when they reencounter the real situation and have to act in it, the boundary object that they remember gets reinterpreted in their local situation and so their understanding of it changes and diverges. The boundary object does not provide a stable, long-term cross-boundary coordination mechanism, but functions to support short-term coordination cycles, in which experts gradually reconstruct the boundary object.

The idea of false consensus leads into the third dimension of boundary objects in-use: intention. In the core definition of boundary objects, as a 'good enough' roadmap for both parties (Star and Griesemer 1989) lies the premise that actors develop a common orientation. The boundary object gains meaning through group interaction, or as Levina and Vaast (2005) claim, boundary objects are only adopted, or put 'in-use', when they are meaningfully and usefully incorporated into the local practices of each user. At the same time, boundary objects allow different groups to work together in the absence of consensus (Star 2010). As Huvila (2011) argues, boundary objects cannot be viewed as necessarily consensual, because the creation of boundary objects is always to some degree an expression of hegemony. Building on this idea, Barley et al. (2012) argue that actors employ different strategies to construct a boundary object to suit their needs. Also, Kimble et al. (2010), who criticize boundary objects as being too mechanical and ignoring the effect of intergroup politics and local conditions, argue that boundary objects need to be seen in context of the motivations of the people that choose the object as well as their communicative role. Our findings yield this similar tension: the boundary object is constructed to support cross-boundary coordination, while it is also constructed with a specific intent that might also impede coordination. When users make a bid to define the boundary object in a certain way, based on employing different coordination modes, these modes do not necessarily match with each other. Our study shows how the intention of its users actively shapes the configuration of a boundary object.

Some limitations of our study suggest opportunities for further research. First, our results are based upon an in-depth analysis of ten emergency response exercises. Although this was a conscious choice in the design of the study so that it would yield comparable cases, it still favors accuracy over generality (McGrath et al. 1982, Langley 1999). Our data yielded valuable insights, but also limited the scope of our findings. An interesting question is whether our findings also hold for other contexts, especially in related settings like high reliability organizations and project work that are less urgent and reactive than emergency response. How are boundary objects configured in these environments, and what sequences in coordination modes are visible?

Second, we have focused solely on the Common Operational Picture as a boundary object with a strong visual constituent. This left us to question how likely these results will generalize to other types of boundary objects? The visual dimension of organizing has recently been related to sensemaking and situated cognition (Meyer et al. 2013). Sensemaking involves comprehending and constructing plausible images (Weick et al.

2005), but the visual has been underrepresented in sensemaking theories. We gratefully relate to the call of Meyer et al. (2013) to encourage colleagues to explore how visual artifacts provide contextual cues for constructing cognitive schemas, and thus support or constrain decision-making. In combination with rising visual and technological development in our society, it becomes increasingly important to see if visual artifacts support, or inhibit specific methods of coordinating.

In the end, explaining the role of objects in how people are able to practice coordination across the boundaries of their organizations must not be about explaining the object itself, but about how the object shapes the collaboration. The boundary object is not what explains, but something to be explained; it is not the explanans, but the explanandum.

3.7 Appendices

3.7.1 Appendix 1. Coding Logic

Selecting tasks: An utterance was coded as selecting tasks when the boundary object is used to identify and perform specific tasks, which are completed autonomously by different disciplinary units (e.g., police, fire department etc.). In this coordination mode the boundary object is used to present an overview of the incident and each user selects his/her own tasks that are performed independently of others. One of the marker terms in the discourse of the officers that signals selecting is 'created'. The officers regularly indicated that a task was completed autonomously by referring to the task as a previous performance (in the case of our example, creating something). An exhibit from our data illustrates how we coded this in the discourse after a Police Officer completed a task by himself without communicating this to others: *"We took account of that and anticipated on the visible smoke. We have created a very spacious barrier and there are no people standing in the wind"* (exercise 2).

Phasing action: An utterance was coded as phasing action when there is discourse about the sequence of actions that must be completed in a specific order. In this coordination mode the boundary object is used to discuss how actions relate to each other. Two of the marker terms that signal phasing action are 'arrange' and 'bilateral'. The officers used the term 'arrange' when they talked about arranging sequences of action in the nearby future. Likewise, 'bilateral' was used when the officers needed to consult about sequences of actions with other officers. Phasing action bilaterally occurs through dialogue, and it is different from selection as a coordination mode, which is performed autonomously. An exhibit from our data illustrates how we coded this in the discourse when a Medical Officer addresses the need for traffic circulation: *"Traffic. We need a traffic circulation plan for the transport of victims. We will arrange that with the police bilaterally. Also, care for the people that are wandering around the incident, I will arrange that bilaterally with the municipality"* (exercise 3).

Standardizing information: An utterance was coded as standardizing information when the boundary object is used to designate a specific procedure or standard to foster coordination. Standardizing allows persons to formalize information on the boundary object by referring to a specific procedure, which provides a prearranged working order that can be effectuated without direct interaction. These can be both single- or multi-organizational procedures, but we only coded them as standardizing information when

the procedure affected cross-boundary coordination. One of the marker terms that signals standardizing information is 'distance'. An exhibit from our data illustrates how we coded this in the discourse, when the Police Officer radios the standard for safe distance issued by the Fire Officer: *"we were consulting the fire department, safe distance is 15 meters. If you are standing in front of the building facing the main entrance, there are a few persons stuck in the left side of the building, over"* (exercise 1).

Transforming understanding: An utterance was coded as transforming understanding when the boundary object is used to foster a contextualized shared understanding between the officers. The meaning and content of tasks needs to be understood by all officers in order to work collaboratively and understand each other's needs. This requires the officers to transform their own local interpretations into contextualized understanding to support the collaboration. Two of the marker terms that signal a transforming of understanding are 'reason' and 'because'. Both terms indicate that an explanation is about to follow that might lead to a transformation of understanding. An exhibit from our data illustrates how we coded this in the discourse, when a Fire Officer explains the reason behind a decision to a Medical Officer: *"the reason why it's large fire, is because the carbon monoxide is coming from somewhere, most likely because of a fire"* (exercise 5).

3.7.2 Appendix 2. Markov transition matrices

		T2				
		Selecting (1)	Standardizing (2)	Phasing (3)	Transforming (4)	Row Count
T1	Selecting (1)	.50	.13	.33	.04	24
	Standardizing (2)	.16	.42	.33	.09	43
	Phasing (3)	.07	.29	.50	.15	59
	Transforming (4)	.06	.24	.53	.18	17

Exercise 1: First Order Markov Chain

		T2				
		Selecting (1)	Standardizing (2)	Phasing (3)	Transforming (4)	Row Count
T1	Selecting (1)	.24	.20	.44	.12	25
	Standardizing (2)	.22	.33	.26	.19	27
	Phasing (3)	.16	.12	.41	.31	50
	Transforming (4)	.14	.19	.31	.36	36

Exercise 2: Second Order Markov Chain: re-expressed as First Order Matrix

		T2				
		Selecting (1)	Standardizing (2)	Phasing (3)	Transforming (4)	Row Count
T1	Selecting (1)	.27	.14	.35	.24	37
	Standardizing (2)	.50	.07	.43	.00	14
	Phasing (3)	.21	.11	.47	.21	53
	Transforming (4)	.29	.03	.32	.36	31

Exercise 3: First order Markov Chain Model Fit

		T2				
		Selecting (1)	Standardizing (2)	Phasing (3)	Transforming (4)	Row Count
T1	Selecting (1)	.39	.23	.32	.07	31
	Standardizing (2)	.25	.31	.28	.16	32
	Phasing (3)	.09	.10	.12	.28	40
	Transforming (4)	.17	.28	.17	.38	29

Exercise 4: First Order Markov Matrix

		T2				
		Selecting (1)	Standardizing (2)	Phasing (3)	Transforming (4)	Row Count
T1	Selecting (1)	.31	.23	.35	.12	26
	Standardizing (2)	.23	.42	.23	.13	31
	Phasing (3)	.11	.07	.60	.23	75
	Transforming (4)	.08	.18	.39	.36	39

Exercise 5: First Order Markov Chain

		T2				
		Selecting (1)	Standardizing (2)	Phasing (3)	Transforming (4)	Row Count
T1	Selecting (1)	.26	.21	.32	.21	19
	Standardizing (2)	.14	.31	.48	.07	29
	Phasing (3)	.13	.14	.61	.12	69
	Transforming (4)	.00	.30	.40	.30	20

Exercise 6: First Order Markov Chain Matrix

		T2				
		Selecting (1)	Standardizing (2)	Phasing (3)	Transforming (4)	Row Count
T1	Selecting (1)	.19	.13	.63	.06	16
	Standardizing (2)	.13	.29	.39	.19	31
	Phasing (3)	.11	.18	.49	.22	65
	Transforming (4)	.06	.25	.34	.34	32

Exercise 7: Second Order Markov Chain Matrix, re-expressed as First Order Matrix

(Exercise 8: 0^{th} order)

(Exercise 9: 0^{th} order)

		T2				
		Selecting (1)	Standardizing (2)	Phasing (3)	Transforming (4)	Row Count
T1	Selecting (1)	.30	.11	.33	.26	27
	Standardizing (2)	.28	.33	.28	.11	18
	Phasing (3)	.11	.10	.52	.27	63
	Transforming (4)	.21	.09	.48	.21	33

Exercise 10: Second Order Markov Chain Matrix, re-expressed as First Order Matrix

3.7.3 Appendix 3. Timeline charts of all exercises

Vertical axis: 1. selecting tasks, 2. standardizing information, 3. phasing action and 4. transforming understanding.

Horizontal axis: code number.

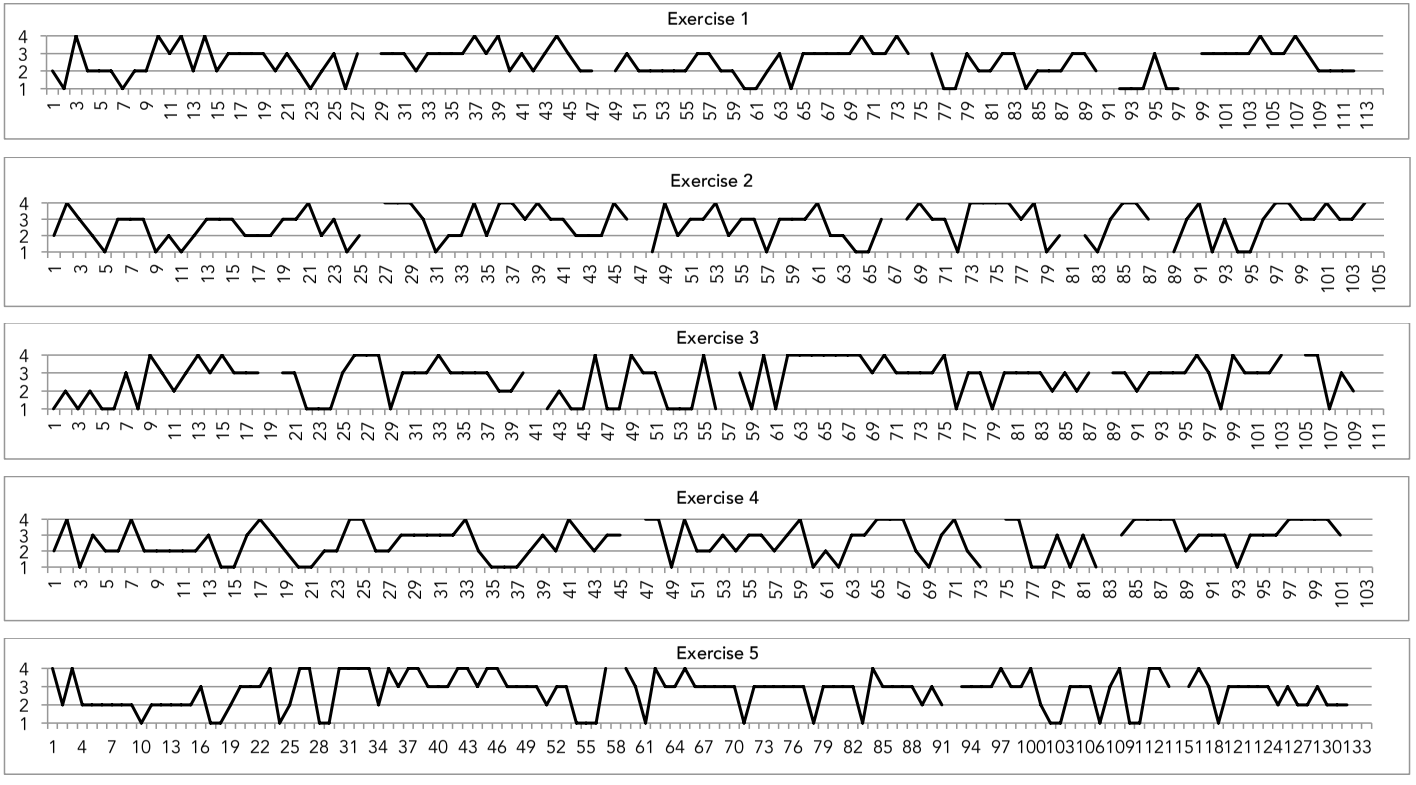


Figure 12. Timeline chart of exercises 1-5

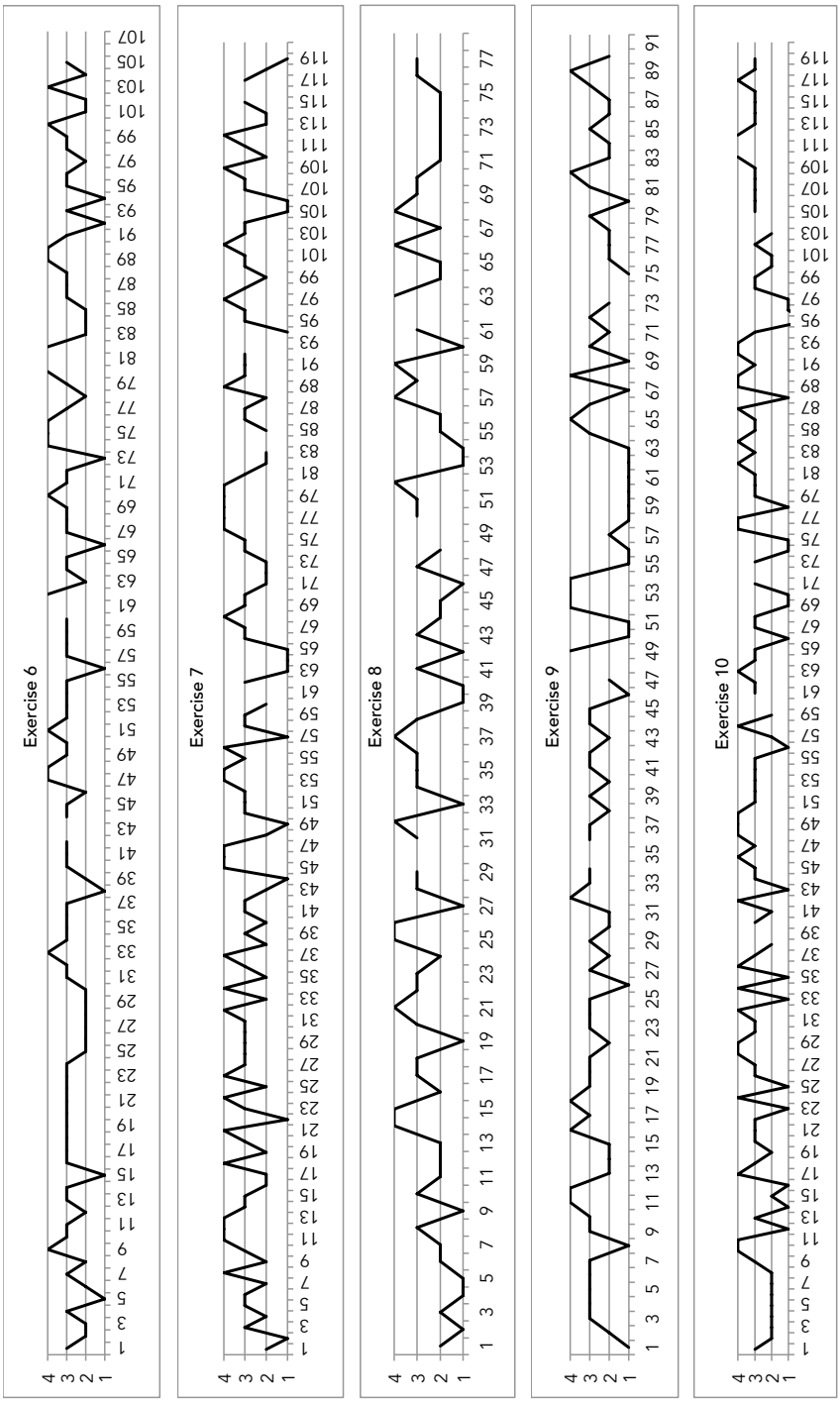


Figure 13. Timeline chart of exercises 6-10

4. You Didn't Know This Was Relevant for Us? Excuse me![3]

Summary

The common operational picture is used to overcome coordination and information management problems during emergency response. Increasingly, this approach is incorporated in more advanced information systems. This is rooted in an 'information warehouse' perspective, which implies information can be collected, sorted, and exchanged in an accessible and univocal form. In practice, however, professionals interpret similar information differently. Therefore, in this chapter the focus is on how emergency responders develop collective sensemaking from information. We employ a 'trading zone' perspective, in which information is negotiated, to study information management in an ethnographic study of disaster exercises in the Netherlands. The analysis shows how professionals attribute different meanings to information that distorts the coordination process. We end by stressing the importance of actionable knowledge and reflexivity.

3 This chapter is published as: Wolbers, J., K. Boersma. 2013. The Common Operational Picture as Collective Sensemaking, *Journal of Contingencies and Crisis Management*, **21**(4): 186-199.

4.1 The Common Operational Picture as collective sensemaking

> *'Once asbestos is part of the incident a whole new procedure has to be started up. What I need is our hazardous materials expert on the spot as soon as possible. I know about some of the asbestos procedures, and what should happen, but I think it is very important for us to ask for expert knowledge. I had the feeling the fire officer made the decisions very quickly by himself. He has taken measurements because of the asbestos: he took care of the decontamination on the street. It was like: "I do this" and "I do that" ... I had the feeling that the fire fighters were not collaborating with others. If I knew about that asbestos earlier I would have responded differently but they didn't tell us. "You didn't know this was relevant for us? Excuse me!"'*

This quote is from an officer who represents the municipal authorities. He made this remark as a reaction to a fire officer's action during a training session. It indicates that emergency response organizations rely upon each other's information to align work processes. At the same time, the quote reveals that the representatives of the different professions often 'forget' to share information because they tend to operate within their own professional 'silos'.

It is well documented that emergency response organizations struggle with information sharing, communication and coordination (Bharosa et al. 2010, Comfort 2007, Netten and van Someren 2011, Quarantelli 1997). During emergency response operations, organizations with different backgrounds, specialized operational expertise and different professional languages need to coordinate their actions across jurisdictional and organizational boundaries (Comfort and Kapucu 2006). This coordination problem is even more challenging because each response organization has operational field units at different levels, different functional command structures and separate back offices for information and resource management (Kapucu 2006, Moynihan 2009).

Adequate information management is regarded as crucial to overcome problems with coordination and information sharing between different organizational domains (Donahue and Tuohy 2006, Manzi et al. 2002) and is an important part of the response organizations' information sharing culture (Marincioni 2007, Schooley and Horan 2007). Encouraging the willingness to share information is believed to support collaboration and could foster organizational learning and facilitate adaptation and improvisation (Waugh and Streib 2006). However, failing communication and inadequate coordination between organizations, across levels and between back offices are also often blamed for problems with information management, such as information overload (Bharosa et

al. 2010), difficulties with information technology in-use (Quarantelli 1997), insufficient evaluation/validation of the information (Rake and Nja 2009) and insufficient attention for sharing data with others (Dearstyne 2007).

Paradoxically, information management is seen as both the problem and the solution for reaching sufficient situational awareness to support coordination. Emergency management agencies try to solve the information management problem by advocating more advanced and better-equipped information systems. The promise is that these systems should support its users to reach shared situational awareness by creating a *common operational picture* (COP) (Comfort 2007, Endsley 1995). Examples are time critical information systems (Schooley and Horan 2007) and systems from the logic of Netcentric Enabled Capabilities (Boersma et al. 2012). To solve the information management problem, the focus is put on building system architectures, in which the need is stressed for integration and linkage of information, fast access, timeliness, updating of information and standardization of information (Meissner et al. 2002).

Yet, the focus on building system architectures overlooks the social aspect of sharing and interpreting information. The different expertise of the emergency responders requires them to first develop common ground from which they can interact with each other (Clark and Brennan 1991). For example, Morris et al. (2007) described that the reason behind the success of the coast guard forces in accomplishing one of the few effective initial responses to hurricane Katrina was the attention to cooperation, adaptation, and flexibility in the work of the coast guard that *"embraced the many languages of other stakeholder organizations"* (Morris et al. 2007, p. 101). Learning how to bring together each other's complementary skills, learning from the experience of others and closely examining information (Moynihan 2008) is regarded as highly consequential for successful information sharing. Therefore, in order to understand how first responders interpret each other's needs and requirements for coordination, a *sensemaking perspective* on information sharing is necessary to capture the ambiguity of information, the presence of multiple perspectives and the role of representations in the common operational picture (Houghton et al. 2002, Weick et al. 1999).

In this chapter, we are interested in the question how the different emergency response organizations share information about their actions and the ongoing crisis, how they give meaning to the information, and how the information, is articulated in their narratives. The main question is: *How do emergency responders make sense of exchanged information and how does this affect their shared situated understanding of*

the emergency situation and response? The data collection for this article took place in the Netherlands during exercises for commanding officers in a field command center aimed at creating a common operational picture. As the coordination problems between Dutch emergency response organizations are not unique (i.e., they also exist elsewhere), we think this article has more general lessons to offer.

The chapter is organized as follows. We will first present a theoretical discussion to uncover the different perspectives of information sharing in the emergency management literature. Next, we will explain our methodology and continue with the description of the findings. Here we will present three cases that illustrate how sensemaking plays a crucial role in the information sharing practices of emergency responders. We end our argument by presenting a discussion about the importance and implications of taking a sensemaking perspective on information sharing in emergency management research.

4.2 From an 'information warehouse' towards a 'trading zone'

The COP is considered as one of the most promising solutions in emergency management to improve the quality of information sharing and to support the development of situational awareness (Comfort 2007). The COP is often manifested as a geographical representation combined with a checklist that describes the characteristics of the response operation. Despite its common use in emergency management, a univocal definition of the COP lacks both in the field and in the literature. There are disagreements as to whether the COP is a product, process or operating environment (Copeland 2008). Roughly two types of definitions can be distinguished: one that focuses on capabilities of information dissemination and another that stresses the need for reaching a sufficient level of shared understanding.

An example of the first type of definition is the way in which the COP is described in the US National Incident Management System: *"a common operational picture is established and maintained by the gathering, collating, synthesizing, and disseminating of incident information to all appropriate parties involved in an incident. Achieving a common operating picture allows on-scene and off-scene personnel to have the same information about the incident, including the availability and location of resources, personnel, and the status of requests for assistance"* (FEMA 2009, p. 4.5). In this definition, the COP is treated as a means to capture information and putting it in a place

where it can easily be accessed. The COP is treated as a solution to the problem of incomplete information, whereby making information better and more widely accessible solves the issue at hand. As a result, the current generation of COP is treated as an 'information warehouse' where its users can select the information that is appropriate for them to perform their tasks (Leedom 2003). In the information warehouse, *"information useful to processes is stored … in an easy and accessible form"* (Davenport 1993, p. 89), whereby the modular nature of the warehouse supports self-synchronization. Yet, the warehouse metaphor overlooks that different actors give different meanings to information at different points in time.

The second type of definition stresses the need for shared understanding and treats the COP as a way to *"achieve a sufficient level of shared information among the different organizations and jurisdictions participating in disaster operations at different locations, so all actors readily understand the constraints on each and the possible combinations of collaboration and support among them under a given set of conditions"* (Comfort 2007, p. 191). But also more generally, the *"common operational picture was specified as individuals knew who was doing what, who knew what; i.e., individuals had an accurate transactive memory"* (Carley 2002, p. 3). These definitions do stress the importance of shared understanding. The COP is not just an 'information warehouse' that supports self-synchronization but also a tool that supports its users to understand each other's needs and constraints during their collaboration. It recognizes that there are likely to be differences in mutual knowledge, belief, customs, and assumptions between different communities (Bechky 2003) that cause conflicting interpretations of information that need to be made workable in order to organize a coherent response operation (Artman and Wærn 1999).

Although the second type of definition subscribes to the importance of developing a level of shared understanding, they still overlook the *way* in which shared understanding is reached by using the COP. To get a deeper understanding of the problem of information management, we need to open the black box to see how information sharing supports shared situational awareness. Building a sufficient level of shared understanding to us is a sensemaking process in which organizational members (de/re)construct information influenced by their institutional background to find out what is going on in times of uncertainty (Weick et al. 2005). This sensemaking process is based upon the knowledge responders have gained through (1) education, including training/exercises; (2) (war) storytelling; and (3) past experiences (Endsley 1995, Taber et al. 2008). Emergency

responders have to constantly make sense of the situation because of the rapidly changing environment. During crisis management, not just individual sensemaking processes are important, but even more important is collective sensemaking, that is, how members from different communities try to generate shared understanding for coordinated action (Maitlis and Sonenshein 2010). Collective sensemaking in emergency management is about combining different cues, roles, scripts, and actions that arise from the actors' different institutional backgrounds (Weber and Glynn 2006) into a collaborative time critical response (Faraj and Xiao 2006).

Weak collective sensemaking is a major problem during crisis situations. For instance, Weick's (1993) analysis of the Mann Gulch fire shows that the lack of group level sensemaking processes resulted in poor decision-making and eventually in the loss of the lives of 13 fire fighters. Weick (1990) also made a similar analysis of poor sensemaking between the pilot crew of a KLM 747 moments before they crash into a Pan-Am 747 on the Los Rodeos airport in Tenerife. The co-pilot of the KLM flight stated 'we are now at take-off', while the tower and the Pan-Am crew interpreted this as being in the take-off position, the KLM crew had actually faulty initiated the take-off run.

While these sensemaking problems arose among actors with a similar institutional background, Dearstyne (2007) claims that sensemaking issues between actors with different institutional backgrounds lead to inter-organizational coordination problems. He shows that fire departments and police had trouble collaborating and sharing information during the World Trade Center attacks. Especially striking is his note that fire commanders on the ground experienced a lack of information about the burning towers, while police helicopter crews were filming them from above. These kinds of coordination problems between actors with different institutional backgrounds are central to large-scale emergency response operations.

Coordinating between actors with different institutional backgrounds is described by Faraj and Xiao (2006) as a process of dialogic coordination. By engaging in dialogue, professionals are able to confront their different professional languages (jargon) through epistemic contestation and achieve joint sensemaking. During the process of collective sensemaking, emergency responders need to coordinate their actions temporarily and locally across their organizational boundaries, in which they must navigate their differences in norms, meanings, and interests with members from other organizations to achieve a shared goal (Kellogg et al. 2006). This is especially challenging because in fast-paced environments, goals can be translated as such only in a limited amount

of time as the emergency situation changes, and the goal becomes outdated. As a consequence, actors often 'forget' to share information because in their view information is no longer significant or is outdated. In this way, the perceived relevance of information is compromised at different points in time, resulting in a dynamic information sharing situation that is constantly in flux.

The actors' different institutional backgrounds and the time criticality show that information sharing cannot be reduced to gathering information from a *warehouse*. We propose a different perspective on the COP in which information sharing is about sensemaking that is better characterized by using the metaphor of a *trading zone*. In the literature, the trading zone is used as metaphor to describe the process of negotiation between actors from different communities in which they work out 'exchanges' 'in exquisite local detail, without global agreement' (Galison 1997, p. 46). During the exchanges, actors must make sense and reach consensus about procedures of exchange in a mutually comprehensible language. In emergency management, trading is not just a metaphor because it sometimes literally means that actors have to reach an agreement on for instance the size of an evacuation zone. During this process, actors have to share their expertise to convince the other about the value of the alternatives. In this way, actors exchange ideas, learn from one another and make sense of each other's position and institutional background. Working out exchanges in this way is useful in conditions of uncertainty and change because the collaboration *"doesn't depend on shared ideas, interests, or norms, which are difficult to accomplish when time is short, meanings are divergent, and conditions are ambiguous"* (Kellogg et al. 2006, p. 39, Vaughan 1999).

In the literature, exchanges or trades often occur through the use of a boundary object (Hsiao et al. 2012, Kellogg et al. 2006). Boundary objects are coordination mechanisms of representation, in which coordination is reached by disseminating information and providing a common referent as basis for aligning work between organizations (Okhuysen and Bechky 2009, Henderson 1991). The COP can be regarded as a boundary object because constructing a COP is about sharing and constructing information about the response operation in such a way that it enables its users to continually redefine and mutually adjust their relationships. The COP provides a platform that allows experts to coordinate and negotiate their plurality of points of view through general procedures of exchange, without making their perspectives uniform or completely transparent to each other (Trompette and Vinck 2009, Hsiao et al. 2012). In turn, the trading zone perspective provides a way of analyzing how this exchange process influences the actors' sensemaking efforts.

In summary, for us, the COP resembles not an 'information warehouse' but a form of materiality that facilitates the ongoing negotiation process that takes place in a 'trading zone', in which actors share and give meaning to information to synchronize their actions. How we analyzed the data by applying the trading zone perspective to the sensemaking processes of the officers-in-command will be explained in the next section.

4.3 Methodology and cases: a narrative analysis of the 'trading zone'

Analyzing the collective sensemaking processes (Weick 1995) in the trading zone (Galison 1997) requires a perspective in which the negotiation of meaning of information that is embedded in local contexts and in multiple realities becomes visible. Therefore, we adopted an ethnographic approach that allowed us to study the richness of the sensemaking process and grasp enough detail of the context in which these processes take place (Yanow and Schwartz-Shea 2006). This approach (Hammersley 1995) is especially useful in unraveling the consequences of the actors' different institutional backgrounds as it enabled us to follow the real-life conversations and negotiations between the emergency responders.

We collected our data through visiting field command center exercises of the first response organizations in different safety regions in the Netherlands, as part of our contract research into the information management practices during emergency response operations. First results of this research are published in Stuurman (2011) and Wolbers, Boersma, and de Heer (2012). We observed 10 exercises in a field command center in which emergency officers in command of police, fire department, medical, and municipal authorities meet to share information and make decisions during an emergency. These consisted of both scenario driven and virtual (by means of computer simulations) exercises. The 10 incidents included a collision at sea, gas explosion, railroad accident, highway accident, hostage situation in a school and a helicopter crash on a water treatment plant. For each scenario, the officers practiced delegating tasks through their teams by communicating with officers from other emergency services. Although the incidents were fictional, the officers were confronted with time pressure, information overload and, most important for our study, with professionals from other organizations than their own. We therefore feel that the exercises illustrate the situations in which responders get confronted during real incidents and offer valuable research data

(Latiers and Jacques 2009). However, we must also mention the limits of using the data of exercises for analysis. Because the scenarios are removed from reality, there is limited recruitment delay, and participants are potentially protected from the ramifications of poor decision-making.

For this case material, we observed and recorded conversations in ten exercises, and afterwards eight officers were interviewed (see Stuurman 2011) who participated in the same group in multiple exercises. The officers were selected based on their presence in the same observed set of exercises and were asked to reflect upon the collaboration, communication, and their actions and decisions. In the observations, we recorded the interaction, and in the interviews, the officers were provided with parts of these dialogues and situations. In doing so, we did not make an evaluation as such, but our focus was on finding patterns in the first responders' actions and interactions in the context of their professional routines. By reflecting on actions and storytelling, we were able to unravel their sensemaking efforts during the multi-organizational response.

Besides the interviews and observations, we analyzed documents (including reports of the Inspectorate of Security and Justice, and the Dutch Safety Board) with the purpose of understanding the broader context in which the exercises were taking place. In addition, these reports were used to see whether our findings from the relative small sample of exercises are also reflected in real emergencies. Also, documents about procedures and responsibilities of the different emergency response agencies were analyzed to inform our data analysis, as well as documents about the multi-organizational coordination structure. Although these procedures are not referred to directly in the article, they did inform our analysis by helping us to get background information on the technical terminology (such as evacuation standards or water screens) and help us judge whether interactions between officers in the trading zone were regarded as appropriate or not.

The data collection resulted in 70 pages of interview transcripts and 140 pages of observation transcripts. The fully transcribed exercises allowed us to reconstruct the interactions of the officers with each other and the COP chronologically. We analyzed the transcriptions by adopting an interactional narrative analysis (Riessman 2005). This type of narrative analysis zooms in on the dialogue between teller and listener to analyze the dialogue as a process of co-construction, where teller and listener create meaning collaboratively (Riessman 2005). The transcripts from the interviews and the data from the observations were combined with the help of the data analysis tool MaxQDA to inform this analysis and to guide data reduction.

Analyzing narratives enabled us to zoom into the underlying cues, roles, scripts, and recurrent action that arise from the different institutional context of the emergency responders, as well as their organizational values (Gabriel 2000). Through their narratives, actors implicitly and sometimes explicitly negotiate about their interpretations and actions (Czarniawska 2004). Implicit problem conceptualizations are made tangible by signaling potential problems, clarifying misunderstandings and exchanging information (Putnam 1994). We used these cues to inform our analysis and identify challenges in sensemaking and negotiation between officers. With the help of (lexical) search in MaxQDA and close reading, we were able to identify interesting narratives.

We will present our data by focusing on three more in-depth narratives that occurred during the exercises to allow for enough detail in the descriptions. These narratives were selected based on the richness of the interactions between the actors that illustrated the negotiations of interpretations in the trading zone most clearly. In addition, these three scenarios were chosen because they are illustrations of how (implicit) contestations had immediate impact on action. It shows that the trading zone perspective is not just a scholarly, analytical perspective: problems with negotiation have a direct impact on the actual response operation.

4.4 'Trading zones': constructing the COP during emergency response operations

4.4.1 Setting the scene

The Dutch emergency management system consists of an emergent structure that can be scaled up after the emergency response center (ERC) alerts the police, fire and/or medical services. The ERC follows a set of predefined protocols to call the *officers-in-command* from these organizations to the incident scene. Each officer is responsible for commanding his or her own operational units on scene. Additionally, the *officer-in-command* is responsible for taking care of the inter-organizational coordination with other emergency services. To support this responsibility, a mobile field command center is installed on scene and staffed with the *officers-in-command* and the *field commander*. The core staff consists of the field commander, police officer, fire officer, medical officer, and municipal officer. If the nature of the incident requires additional expertise, other liaison officers of, for example, the Railroads or Waterworks can be added to the team.

In the Netherlands, exercises have the specific aim to improve the quality of multi-disciplinary collaboration. Evaluations of incidents have shown that *"in the heat of the moment employees temporarily lose sight of the interests of the other emergency services"* (Scholtens 2008, p. 200). As such, multidisciplinary collaboration should be effectuated at a much earlier stage, and exercises are aimed at effectuating these, both disciplinary and multidisciplinary, work practices (Bharosa et al. 2010).

In the following cases, we will study the *officers-in-command* and the *field commander* that operate in the mobile field command center. We will analyze the conversations between the *officers-in-command* in the field command center. We regard the process of constructing the COP as a trading zone in which the different interpretations and narratives about the incident are co-created and negotiated.

4.4.2 Case 1: "Is one hundred meters far enough?"

Several residents called 112: they smelled gas in the direct environment of a flat building. Moments earlier, a suicidal man in the house has opened the gas valve on his oven and tried to trigger an explosion. The dispatcher in the emergency room sends a fire engine to the scene to investigate the threat. On the spot, the fire fighters indeed measure a high concentration of gas in the building. They decided to scale up and call for the assistance of the fire, police, and medical officer. Next –according to the procedures of the Dutch emergency response– a field command center is created at the location of the incident. Soon after the officers of the police, fire brigade, and medical teams arrived at the scene, they organize a brief meeting. A possible evacuation of the apartment and the security of the first responders are central elements in the discussion.

4.4.3 Negotiations during the field command meeting

In the first meeting between the officers, we heard a discussion about the size of the area that has to be evacuated to protect the first responders and the bystanders:

Police officer	I think we still need to withdraw from the scene a bit further. Five hundred meters ...
Fire officer	Five hundred meters evacuation zone ...
Police officer	Okay then, at five hundred meters. And for our people: safety? Are we ... will you go ... we go in? Will there be gas in there?
Fire officer	We cannot measure the amount of gas, so we do not know how safe it is.
Police officer	So you will evacuate the building as well?
Fire officer	Yes.

Police officer	So then we will only set up the road blocks?
Fire officer	Yes and we will transfer the people who come out of the building to you.
Medical officer	There are some people waiting by the ambulance. I understand that five hundred meters away from the building is safe?
Fire officer	Yes, we now take those five hundred meters for safety.
Medical officer	Fine.

Central in this conversation is the safety of the first responders. The notion that 'we cannot have more victims (i.e., wounded rescue workers)' is central in their discussion. It is quite difficult, however, to estimate the risk of the incident and the size of the area that will be affected by a possible explosion. Because the fire fighters –the experts in such situations– cannot give closure about the risk, the police and other first responders decide to back off. Interestingly, the officers from the different response organizations use '*we*' in their conversations indicating that they talk about a problem that will affect all of the rescue workers regardless of their organizational background.

One important issue the officers have to negotiate about is the size of the area that has to be protected so that no one without protected clothing (including citizens and rescue workers) can enter the scene. It is quite difficult, however, to make that decision as the fire fighters can only estimate the risk –an explosion in the apartment is still one of the possibilities at the time of the first conversation. During the next meeting between the officers, we witnessed the following conversation:

Field commander	We have to sit down here a bit longer, because we still have no overall picture of the area and the distance of five hundred meters. There is not only a construction site, a separate building and a school, but there is a lot more. What are we going to do about it? *... a discussion between the different officers follows and the Field Commander makes a short résumé ...* Are we saying that we need to use the sirens in the area? Windows and doors closed? Or do we say that the risk is not big enough yet? Because we have to secure that whole area of five hundred meters ... that is a very big circle.
Fire officer	I won't take a risk; if the building explodes and collapses, parts will fly everywhere ... I have seen that once in Amsterdam, the pieces reach pretty far. And you cannot take any chances. It is certainly not advisable in this situation to protect an area less than five hundred meters.
Field commander	Okay, so basically you are saying, let the sirens go off?
Municipal officer	I do think we need to look closely at the communication ... And we also have the railroad. So there is also a little ...
Field commander	There is also a railroad?
Municipal officer	Yes. It is within five hundred meters.

4.4.4 Participant reflections on the negotiations

It becomes clear in this conversation that the officers have a dilemma here: the fire officer does not want to take any risk and advices to secure the area within the radius of 500 m. As the fire brigade is in charge of the evacuation within the zone, their advice is taken very seriously by the other first responders. However, it is quite impossible for the municipality and the police to implement the advice since that can only be done against high costs (literally): it is almost impossible to control an area that big. The police officer who was at the meeting explained us his feeling he had during the conversation:

> *"I would like to create a 500 meter radius around the area and I want no traffic coming through there. Get it done! Well, it really doesn't work that way. I mean, the problem is that it assumes that you are in control. But then you hear that there are many side roads that we cannot take care of, because they are in an area that we cannot reach by (police) car. Also, we learn that we have not enough people. This information all comes in and tends to overrule all the other information".*

A closer look at the use of language in the narratives reveals that the professionals start to use '*I*' instead of '*we*', indicating that they revert to their personal and/or own professional framework. In either case, this perspective is informed by their proficiency (education and/or experience). In this case, the officer of the fire brigade is referring to an earlier experience –not uncommon in such situations of uncertainty (e.g. Boje 1991). Towards the end of the meeting, however, it becomes clear during the negotiation that the concerns of the other officers challenge the decision of keeping a 500 m evacuation radius. The officers discover that the situation in Amsterdam, to which the fire officer referred, was in a much more open area. An explosion in such a situation would mean lots of flying pieces of material. However, in the area that would be affected by the explosion at hand are a lot of buildings, meaning that there are a lot of buffers in the area that will prevent material from flying around. The fire officer and the police officer give two contrasting perspectives on dealing with this threat. The fire officer explains his point of view in an interview.

> *"In first instance, a safe distance of 500 meters. A gas leakage. I have seen them in Amsterdam and on television. I don't know what's leaking and how big it is. I will take a large safety precaution of 500 meters, which we can reduce to 100 or 200 meters later on. But if I don't have enough information, then I will choose for safety, instead of moving up to 100 meters. We might see a chain reaction or explosion. I might have taken too much safety, but I'm always of making sure first".*

In a similar exercise a day later, a different police officer, who is also a team leader and expert on explosives and safety, estimates that an evacuation area of 500m is way too large for a gas explosion. He states that a gas explosion only damages an area around 25–50m, so a distance of 100m should be enough. In this exercise, a distance of 100m is chosen, and this way the police do not get into trouble with the large evacuation area.

> *"Well, this is a gas explosion. It will damage an area of 25–50 meters. But you must also check what's in front of the building. Is it an open space, or are there all kind of structures in the way? If there are buildings in the blast radius they will keep the explosion from going further. On the end of the explosion a window might shatter, but that's it. It will not go further".*

At first glance, this can be seen as a technical discussion about the effects of an explosion, but the negotiation is vital for the different professionals to come to an agreement about the actions that have to be undertaken. The interpretation of the risk and the actions, however, differs from the various professional backgrounds. The officers used the field command center meeting as a trading zone to develop a common understanding of the situation.

However, the professionals did not reach closure at this time. The different interpretations of the officers are not discussed in detail in the field command meetings. It did not become clear enough in what way the narratives are at odds and how they are complicating the response operation of other disciplines. The second narrative is mainly held in the personal 'I' framework, which gives room for different opinions, but does not show why some decisions are problematic for others.

4.4.5 Case 2: "Can we go on board?"

A captain on the ship Stavria reports to the coast guard that his ship has an engine failure and that he has run aground. Not soon after this, a fishing boat with 75 tourists on board reports that it had to avoid a collision with the Stavria and has also run aground. As a result of the sudden evasive manoeuvre, some passengers got injured; it is unclear how many and how serious. First ambulance crews on scene board a coast guard's ship to get to the incident scene. They enter the fishing boat to make an initial estimation of the amount of wounded passengers. Once on board, it appears that there are dozens of people injured.

4.4.6 Negotiations during the field command meeting

During the first meeting of the officers in the field command center, a liaison officer of the Dutch Waterworks joins them with the announcement that the Stavria is loaded with natural gas condensate, which has partially escaped. The highly toxic cloud of gas condensate threatens the passengers of the fishing boat. The natural gas condensate requires the officers to discuss the dangers for their units and the passengers:

Field commander	There is some additional information for the common operational picture ... Let's see ... Is it really urgent?
Waterworks officer	Yes, the Stavria is loaded with natural gas condensate.
Field commander	Jeez.
Waterworks officer	And it has escaped. Several passengers on board of the Stavria became ill. And they have to be treated, they are in danger. But my units have to stay upwind, at a safe distance from the Stavria.
Field commander	What is the direction of the wind at the moment?
Waterworks officer	South-east. And that means that the fishing boat is right in the midst of the smoke...
Medical officer	So the people cannot be disembarked?
Waterworks officer	No.
	Outside of the field command center, the fire officer and the officer of the Dutch Waterworks have an informal conversation.
Fire officer	... this situation requires a water screen. Do you have a fire boat at your disposal that can take care of this?
Waterworks officer	Yes ... yes, we have such a ship ... yes, we can make that screen.

The announcement of the natural gas condensate disturbs the consultation round in the field command meetings. The field commander immediately asks for more information about the wind direction to estimate the size of the threat. At this moment, the information forces the officers to be flexible and immediately start thinking of alternative solutions to protect not only the victims, but also the emergency crews responding to the incident. Meanwhile, ambulance crews have boarded the fishing boat to provide first aid and are now also under threat of the gas condensate.

4.4.7 Participant reflections on the negotiations

For the fire officer it is really important to understand the risk of the gas leak and how the danger can be reduced. This is, for a great deal, a technical problem for which he has the expert knowledge (as part of his institutional background). In an interview with us he argues:

> *"We are talking about natural gas condensate. I want to know: How is it stored? Is it condensed? Did it leak? At that moment this was not clear. So you ask: how much expertise do we have? And can you close the leak? But at the same time: I did not know how big the leak was and what the crew on the ship could do, whether they are trained to do this or not ... We have a fire boat with a large water cannon. Well, let me bring that to the scene. I order a water screen to be put in place, so they are safe. For the rest ... that ship has no emergency. Then we have enough time".*

However, the medical officer has other concerns because her ambulance crews are on the fishing boat. She wants to act as quickly as possible because both her people as well as the victims have to abandon the ships as soon as possible. Normally, the medical team distances itself from the scene if there is any danger to personnel: safety first.

> *"My people are on board of the ship. Only on the ship of the Dutch Waterworks they seem to be safe and from there they can work. We could not give any facts on the situation on board of the Stavria, since we have not been there. Then we got information about the ship, the wind, and so on: what is going on!? And then that misery that appeared in the field command center about the natural gas condensate... At that time we have a major safety issue for our own crews!! We have to save the victims, but because of the safety issue we couldn't do that. So we know that there will be more victims, because that fishing boat with eighteen people on board was still in the midst of the natural gas condensate".*

At this moment in the meeting, the officers have a different perception about the priorities, and as a result, about the amount of time that is left. These different perceptions are reflected in the way in which the officers engage in the negotiation. In contrast to the perception of the fire officer, who is convinced that placing a water screen buys him all the time he needs, the medical officer interprets the situation as much more threatening. Her narrative addresses the need to get the ambulance crews and victims out from the unsafe situation rapidly. Next to the rescue operation on the ship, the medical officer also anticipates a logistical problem when all the victims are brought on shore at once and need to be transported to the hospital. It is noteworthy that the discussions in the field command meeting focus solely on the rescue operations, but there is little attention for the care and transportation of the victims. This, however, is crucial information for the medical officer. While the rescue and safety operations are treated as a multi-disciplinary problem (i.e., all the disciplines have to be involved in the action), the further treatment of the victims as soon as they are ashore is seen as a problem only for the medical team.

> *"At the moment we have the water screen in place, we can only do one thing and that is rescue the victims from the ship as soon as possible. We cannot perform a full triage on all the victims and see who needs to go off the ship first. We even cannot use our*

> *normal work practice, that is stabilizing victims first and create a prioritization. I need all available coastguard and lifeguards to get everybody off the ship at once. Because at the moment the water screen ceases to exist we find ourselves in a potentially unsafe situation. I need a lot of help from other partners to do this, so a lot of ships, people, and hands. That also means that if we get to the harbor I get at least 60 victims on shore, that will be an utter chaos. I need all the help I can get to solve that problem".*

The reflections of the medical officer show that organizing a coherent triage and transportation of mass casualty scenarios is a daunting task (e.g. see: Tierney 1985, Koenig and Schultz 1994). She will need the help of all the available emergency agencies to structure this process. Yet, the fire crews themselves are busy dealing with keeping the water screens operational and taking care of the gas leakage on the Stavaria. In the field command meeting, the interests of medical and fire operations must be negotiated and balanced to organize a coherent response operation. This involves both getting the gas leakage under control and providing medical care and transportation for victims. The exercise example shows that organizing such a coherent response operation requires the officers to negotiate their interests, but also to value the mutual dependency on safety standards and operational capability with other emergency agencies.

4.4.8 Case 3: "How old are the kids?"

A man with a gun entered a high school and started shooting. He injured a couple of students; it is unknown how many. The man took some children and the teacher hostage in the chemistry classroom. In the chaotic situation that follows, one of the children switched on a smoke detector causing a fire alarm. The emergency response room receives the alarm and sends a fire engine to the school. At the same time, the concierge called 112. Next, the hostage taker releases a girl with a letter addressed to the management of the school. The girl is able to tell that the teacher is strapped to a chair and that the hostage taker threatens to set fire to the room. After the first responders arrived, the officers of the different disciplines gather in the field command center and they discuss a possible raid by the police SWAT (Special Weapons And Tactics) team. The medical officer wants to know more about the victims, so he can arrange enough ambulances and inform the hospitals.

4.4.9 Negotiations in the field command meeting

The first conversation between the officers of the different organizations unfolds:

Medical officer	Okay. How old are the students?
Police officer	I have no... no idea.
Field commander	High school students.
Medical officer	But twelve or seventeen years old makes a lot of difference to me...
Field commander	Uhm... there are twenty-seven pupils in total. Is that the only class that is still present in the school building? The rest of the building is evacuated?
Fire officer	Yes, I think so, but that is still an assumption.
Field commander	Okay. I would ask you then to verify if that assumption is correct or not. This is an action.
Police officer	Alright, that is clear. The concierge has removed all of the other kids and he only missed these children. So that is for sure.
Field commander	Okay. In any case, you know that you have to take care of twenty-seven students who are still in the building.

At first glance, this conversation does not seem to involve a direct negotiation of interest. Yet, the lack of a negotiation between the police and medical officer about the age of the students leads to a crucial challenge in the response operation. In this conversation, we see the medical officer asking for the exact age of the children – important information for his units. However, the dominant narrative in the field command center is about the number of children that are still in the building. For the others, at this time more dominant disciplines, this information is vital for their actions.

4.4.10 Participant reflections on the negotiations

The medical officer is a bit disappointed about this attitude. He argued:

> *"For us this information is extremely important to have... It really matters if the children are eleven or seventeen years old, in order for us to be prepared. In particular, it has an impact for the care in the hospitals. A hospital can easily accommodate five seventeen year olds, but five eleven year olds, that is another story. An eleven-year cannot be treated as an adult with medication and injections and so on... So therefore, for us the age of the children is quite important. And I really did not get a good answer to my question in this respect, no".*

In order to understand this problem, it is good to realize that the medical officer is always representing a network of organizations, including hospitals, ambulance services and medical doctors, and so on. These organizations have their own rules and procedures

implemented. For example, for the hospitals the children's age is crucial information: a pediatrician must be available to take care of under-age kids.

This aspect of the medical response operation is not understood by other professionals; at least, it is hard for them to understand how this affects the work of the medical team's officer at the location of the incident. The medical officer takes the decision –by himself– to not further discuss this point, but to let the actions of the other rescue organizations prevail. Although this might be a reasonable choice to keep initial speed in decision-making, failing to get the children's age might eventually backfire since it can lead to serious problems in transporting a yet unknown, but possible large amount of under-age victims to pediatric hospitals later on.

4.5 Discussion and conclusion

In this article, we have analyzed how emergency responders interpret information by using the metaphor of the trading zone and have shown how this affects their collective sensemaking. In the trading zone, the officers reach coordination by telling each other stories about their actions and perceptions (e.g., of risk and the evolution of an incident). The cases illustrate the way in which information is traded, based on its contextualized meaning to different professional communities, during the negotiations between officers in the field command center. In response to an explosion with asbestos, a collision on sea, and a hostage situation in a school, it becomes clear that not just the information itself is important for coordination, but particularly the way in which information is interpreted and subsequently guides the operations of the emergency responders. We have shown that information is not univocal, but incorporates different professional languages and is often incomplete as the situation it represents is in constant flux. In addition, information must be made actionable to its different users to support the inter-organizational coordination efforts in emergency response. Therefore, information management during emergency response operations is about interpreting information and negotiating its relevance for different professions. In our analysis, we have encountered mainly two problems with the interpretation and negotiation of information between officers in the trading zone.

First, in the trading zone, there can be a limited understanding of what consequences information has for the action and needs of other professionals. The officers identify each other's specialized knowledge and roles differently throughout the incident response

operation because the officers can represent different specialized clusters of organizations during the response operation. This occurs, for instance, in case 3 when the medical officer resembles a wide network of medical care institutions of which, especially the different back offices, are not known to the other officers. Consequently, the other officers do not identify pediatric care as an important agency. This example shows that the relevance of information to others is coupled to the identification and understanding of different roles, thus a problem of referral that requires knowledge about functions.

Second, in the trading zone, a dominant narrative can develop that does not allow different interpretations of information to become visible. In their dialogue, the officers are confronted with different professional languages, that is, knowledge of each other's specialized jargon, roles, and norms. These are sometimes visible (i.e., the fire fighters refer to specific procedures) but also include non-visible elements, such as standards of work practice and preferences about priorities. For instance, the efficacy of a water screen is contested in case 2. These kinds of problems show that different meanings are attributed to information in action, calling for a way to trigger reflection on the origin of these meanings.

We do recognize the limitations of our relative small set of narratives for supporting this claim. Still, we believe that these examples can be illustrative for social dynamics seen during negotiations in real-life response scenarios. We found evidence of similar negotiation issues in evaluation reports on actual incidents that support the trustworthiness of our claims. For instance, during a large headland fire on the 'Strabrechtse Heide' in 2010, police and fire officers had trouble with negotiating about the necessity and timing of installing roadblocks on a smoke affected highway (Inspectorate of Security and Justice 2011a). Also, during the response to the chemical fire in the Dutch city Moerdijk, privatized fire crews and crews from different regions had trouble negotiating the amount of fire extinguishing water necessary for balancing between controlling the fire and preventing environmental damage (Inspectorate of Security and Justice 2011b). Finally, the medical response to the Turkish airlines crash in 2009 shows negotiations about the need for Mobile Trauma Teams between medical officers and the emergency response centers (Dutch Safety Board 2010). Requests for mobile trauma teams were declined in the first half hour of the incident due to incorrect priorities. While these cases (taken from investigation reports) illustrate negotiation practices at a higher level of abstraction, the cases we studied gave us the opportunity to zoom in on similar negotiations in detail.

4.5.1 Actionable knowledge and reflexivity

The two information management challenges about understanding the consequences of information and the existence of a dominant narrative show that making information widely available is not enough for effective crisis management. It is the development of shared understanding, based on information exchange, which is essential for the coordination between multiple organizations. As a result, the 'warehouse metaphor' is not appropriate: our proposed metaphor of the 'trading zone' is more adequate. By putting the negotiation of information central, the metaphor of the trading zone reveals that information sharing inhibits knowledge that needs to be put into action and requires reflexivity about its meaning to different groups. Therefore, we will discuss two concepts that take this inference further: making information usable by developing *actionable knowledge* and enhancing shared understanding by supporting *reflexivity-in-action*.

First, actionable knowledge is knowledge that *"leads to immediate progress on a current task or assignment"* (Cross and Sproull 2004, p. 446). Developing actionable knowledge can support the connection between information itself and the way information is seen as input for action. Since in the trading zone it appears that there is a limited understanding of what consequences information has for the actions in different organizations, developing actionable knowledge can help build this understanding. In detail, five components of actionable knowledge can be identified: solutions (both know-what and know-how), referrals to people or databases, problem reformulation, validation, and legitimization (Cross and Sproull 2004). Making knowledge actionable by engaging with these components allows one to collaboratively create a shared understanding by addressing the implications of shared information.

Secondly, enhancing reflexivity is a crucial condition to address the problem of dominant narratives during information sharing in the trading zone. Reflexivity and *knowing-in-action* (Schön 1983) can make differences in the interpretation explicit. Knowing-in-action is about not only including one perspective in a story, but to include the other professional perspectives as well. Reflexivity allows the professional to redirect his or her decisions without being hindered by professional boundaries. This, of course, is a learning process that (literally) needs training and education (Schön 1987) to see the constraining and enabling characteristics of multi-organizational work. Reflection, as Schön (1983) has argued, starts with the recognition of the problem and continues with the development of affective responses and empathy.

Therefore, a multi-organizational emergency response operation involves asking and answering the questions (Yanow 1997): What do I do? Why do I do it? What does it mean for me, as a professional and for the other professionals I work with and for? In this way, emergency responders can become more sensible of each other's sensemaking processes and the meaning of information for action. Reflexivity-in-action and actionable knowledge are two additional concepts that we address to unpack the process of negotiating information in the trading zone. Still, taking this scope on information sharing and collective sensemaking might leave out other dynamics.

4.5.2 Further research

Further research towards other mechanisms in the trading zone is required to contribute to a broader understand of information sharing in crisis and disaster management. Examples of other mechanisms in the trading zone that might be unpacked are *cognitive*, such as mental models (Majchrzak et al. 2007); *social*, such as groupthink (Walle and Turoff 2008); *power*, such as orchestrations of interests (Kellogg et al. 2006); and *linguistic*, such as the creolization of a mutually comprehensible language to support negotiation in the trading zone (Galison 1997). Besides attention for other mechanisms in the trading zone, further research might also touch upon the idea that multiple trading zones can exist at different levels of the disaster response organization. As a consequence of the modular nature of the up-scaling process during emergency response, different teams at different locations need to coordinate their actions. In this way, different, possibly overlapping, trading zones exist that might employ different kind of 'trades', such as more strategic or political sensitive decision-making processes.

4.5.3 Implications for practice

Next to the implications for theory, the perspective of sensemaking in the trading zone also houses tangible implications for practice. The narratives in the exercises illustrate that it is important to allow time for the stories that contain different interpretations of the officers. Field command meetings are often characterized by quick decision-making based on the separate professional frameworks of the officers. In effect, their different interpretations of the same information do not always show. Narratives are not completely told, or there is not enough recognition of other interpretations or work practices. Yet, it is important to share narratives in field command meetings. This claim appears to be at odds with the goal to keep field command meetings short and decisive so that officers

can return 'to the field'. However, in our empirical study, we found that problems will appear later in the response operation if shared sensemaking is neglected. So, in the field command meetings, moments of reflection must be created to overcome differences in interpretation.

Learning how to become reflexive-in-action requires practitioners to rethink operational training and education. Training sessions might explicitly focus on telling narratives about bottlenecks in the response operation to make interpretations of information from different professional frameworks explicit. We witnessed that the focus of training sessions often lies on increasing the speed of decision-making. Our recommendation, however, is to find a balance between promptness and the quality of decision-making that incorporates multiple perspectives. To allow this, officers must bide the time for reflexivity. We recognize that balancing between speed of decision-making and reflexivity is difficult. Still, it is important that team members listen and learn from each other's perspectives and allow time to think 'out of the box'. In the end, making better-informed decisions avoids problems later on in the response operation and can only save time.

In this article, we have illustrated that the perspective of the trading zone offers a new approach to study information management that puts collective sensemaking to the fore and offers lessons both for theory and for practice. We feel that it is time to employ such a perspective to increase our understanding of the complex information sharing and meaning-making processes in emergency management. The trading zone perspective is a crucial and missing perspective, which is needed to reflect upon the complex problems in emergency response. It is necessary to employ multiple perspectives to understand these complex phenomena. The trading zone perspective can be combined with other perspectives (e.g., decision-making and learning) to better understand and support the multifaceted social processes behind the challenging task of information management during emergency response operations.

5. Incorporating Time Dynamics in the Analysis of Social Networks in Emergency Management [4]

Summary

Timely and adequate communication is essential for the response to emergency situations. The current vision on emergency response embraces the networked organization as an answer to the dilemmas of communication and information flows in crisis situations. With stabilization of the network paradigm, the focus question turns into how networks are perceived and in what manner they function. We argue that there is a need to attend to the way networks and their functioning are assessed. Derived from this research agenda, attention is paid to the manner in which the time critical nature of the communication during emergency situations can be captured in network terms. The focus on how network interaction unfolds over time is demonstrated by attending to a case of a tunnel incident in the Netherlands. It is argued that a structure-oriented network analysis misses much of the actions, and that using the data to probe the communication patterns with additional methods for time dependency enhances our insights. Three approaches, time slices, two-mode analysis and information pathways, are introduced and the outcomes are interpreted.

4 Published as: Wolbers, J., P. Groenewegen, J. Molle, J. Bim. 2013. Incorporating Time Dynamics in the analysis of Social Networks in Emergency Management, *Journal of Homeland Security and Emergency Management*, **10**(2): 1-31.

5.1 Introduction

Emergency situations require timely and adequate communication. During an emergency response operation, information needs to be updated through a variety of channels between different parties involved. These communication patterns between the response organizations can be studied from a network perspective. From an organizational perspective, emergency response networks are an interesting phenomenon, because they show a constantly changing pattern of emergent inter-organizational interactions. The types and number of organizations involved are different for each incident, making the response network highly contingent on the situation at hand. In addition, information exchange during emergency response operations is difficult because each organization in the response network has operational field units at different levels, different functional command structures, and separate back offices for information and resource management (Comfort and Kapucu 2006). Information exchange in the network is characterized by a constantly changing pattern of communications that is necessary to connect and update the new organizations responding to the incident. As information flows through the network from various positions at different times and new organizations are included in the network, the communication patterns become increasingly complex. In the theoretical debate this problem is conceptualized around the question how to coordinate the actions of all types of organizations active during the response operation (Comfort 2007, Militello et al. 2007, Kapucu 2009).

In response to this question, a mix of two governance structures is discussed in the emergency management debate. Centralized command and control structures are pitted against network structures as archetypical differences in governance (Kapucu 2006, Moynihan 2009, Janssen et al. 2010). However, in most emergency situations these structures operate next to each other depending on the dynamics of the crisis. This unveils a design paradox for emergency management. On the one hand, unambiguous command is needed for the timely direction of the involved units (Bigley and Roberts 2001). On the other hand, the collaboration with (unforeseen) emergency partners requires a loosely coupled network that functions by virtue of flexibility, on-the-spot decision-making, and adaptation towards the continuously changing situation.

The mixed use of governance structures during response operations makes an accurate explanation of incident response dynamics by scholars rather challenging. In response, several researchers have turned to the tools and techniques of social network

analysis to explain how organizations connect with each other and share information in response operations (Kapucu 2006, Uhr and Johansson 2007, Uhr et al. 2008). Some have concluded that emergent network structures better explain collaboration and coordination as it actually occurs (Neal and Phillips 1995, Waugh and Streib 2006). Experimental studies have also concluded that network structures permit more accurate information exchanges, resulting in improved decision-making (Schraagen et al. 2010).

However, other reports from the field indicate that network studies do not provide a fully satisfactory explanation of emergent organizing patterns. It has been argued that networked activity in exercises leads to information overload and disorganization even if information-sharing principles have been well established (Militello et al. 2007). As such, the manner in which the organization of command and information sharing has an effect on the outcomes of networked emergency management has not yet been fully addressed (Hossain and Kuti 2010).

Part of the problem is that in most network studies the incident response dynamics are not represented accurately enough. If we zoom in on the way in which these dynamic processes are depicted, we notice that in most network studies rather static and descriptive measures are used to illustrate emergency response operations. There is not enough recognition that social network analysis is in essence a static analysis, since it only provides a temporary snapshot of the interactions that are occurring (Choi and Brower 2006). Thus, the dynamic and emergent organizing practices are often only taken as conditional and are essentially left out of the analyses.

We respond to the call of Abbasi and Kapucu (2012, p. 1) who state that "*tools and measures are missing to evaluate the efficiency of inter-organizational response networks in the rapidly evolving and changing environment of disasters*". Building on this, we argue that answers need to be obtained by employing a more relevant network toolset. The search for this toolset lies at the heart of our research. The body of research to date has not fully addressed the relationship between the structure of governance (viewed as a continuum between "centralized" and "networked"), the execution of information sharing (another continuum ranging from highly restrictive "need to know" to completely open "responsibility to share") and the operational outcomes in emergency management situations. An important unaddressed need is the selection of a useful method for capturing the dynamical processes within an emergency management network. Therefore we ask the research question: how does network interaction unfold over time and in what manner can the network process that unfolds in different phases of an emergency best be captured?

In the next section, we discuss the existing methods for capturing the emergency network's dynamical processes and discuss its merits and limitations. We employ three new network tools to account for the dynamic organizing patterns: time slices, two-mode analysis, and information pathways. Our objective is to illustrate how these tools work and better depict network dynamics by using a case study of an emergency response operation in the Amsterdam Airport Schiphol train tunnel. In this case many different actors are involved that need to collaborate in a short time span. We will argue that traditional social network analysis (SNA) gives a limited depiction of incident response dynamics and show how this problem can be addressed by using other network analytical tools.

Before we move on to the case study, we will show in more detail how the social network analysis has been applied to the analysis of emergency response to depict the emergent organizing patterns.

5.2 The Use of Social Network Analysis to Depict Emergency Response Operations

In emergency management the decentralized character of networks is proposed to be the favored response to information and decisional challenges under pressure (Moynihan 2008b, 2009). In such situations, the fundamental form envisioned for networked operations is aimed at establishing an authority-based lateral and vertical flow of information, which has the ability to guide a rapidly evolving network of responding organizations. This network of organizational actors is based upon mutual independence, where one unit is not merely the formal subordinate of the others in some large hierarchical arrangement (O'Toole 1997). As such, networks operate according to their own logic, in which *"a basic normative characteristic of networks is that they are not hierarchical, relying on lateral linkages and self-regulation"* (Alter and Hage 1992, in: Moynihan 2008a, p. 208).

As structures that are based upon self-regulation and lateral linkages, networks are dynamic and comprise multiple organizations that can be located in geographically different sites (Kapucu and Garayev 2013). In the field of public administration these characteristics are used to explain how networks function as governance structures. Bigley and Roberts (2001) describe the Incident Command System (ICS) as nucleus of a fast response network. Similarly, Moynihan (2009) describes the governance structure of the ICS as a network of multiple response organizations operating under a temporary

central authority with a hierarchical structure. The hybrid governance structure of the ICS maintains clear lines of authority, while offering scalability and the ability to self-adjust according to members' specific expertise and local circumstances.

One of the merits of network structures is its enhanced capacity for adaptation to fluctuations in the environment. Especially in emergency management dynamic change, achieved communication quality and emergent conditions play a crucial role in how response operations take shape. Responsive, high quality decision making based upon up-to-date information is an operational necessity for emergency management organizations, which must operate, collaborate and quickly adapt within a challenging, dynamic and pressure-filled environment. The reliability and pace of information flow among the many organizational nodes are, therefore, vital to success. This state of affairs places a premium on understanding how those flows are structured and how that structure changes over time.

During the response, operational structuring of the network depends on the assessment of the available information about the incident. When we regard the network structuring as dependent on information flow between responders, the deployment and delineation of the networked response organization might thus best be depicted by starting the analysis of the network with the first responding unit. One way to do this is to track the addition and subtraction of member nodes and the attendant information flows over time. This reveals that response networks evolve in a modular fashion, and that the key to effective response lies in effective collaboration and decision-making enabled by a combination of flexibility, clear lines of authority, and clear delineation of responsibilities throughout the incident. This view is also embedded in the developmental and modular nature of modern incident command systems that are designed to govern through networked social and technical infrastructures. The most widely known example is the standard organizational templates that are proposed by the FEMA (Federal Emergency Management Agency) in the ICS (Kapucu and Garayev 2013).

Given that emergency response networks can evolve over time, researchers need access to a set of tools to help them represent, track and analyze that evolution. As the remainder of this section will show, our research indicates that very few emergency management studies address this need in a serious manner (Choi and Brower 2006).

We have assessed the emergency management literature to get a better idea on what network studies focus. We conducted a search on Web of Science based on the keywords: "emergency management OR disaster", and refined these results by

"network analysis". This resulted in 27 hits. In addition, we searched the main emergency management journals *(Journal of Contingencies and Crisis Management, Journal of Homeland Security and Emergency Management, International Journal of Emergency Management, International Journal of Mass Emergencies and Disasters, Disasters)* with the same keywords, since these journals are not all indexed completely in Web of Science. This resulted in another 56 hits, of which only the relevant social network publications were selected.

Our review of the use of SNA in emergency management shows that one of the major issues is that it provides only a static snapshot of a situation in flux. The majority of these studies depict the network in terms of its different centrality measures (Mendonca and Wallace 2004, Kapucu 2005, Kapucu 2009, Houghton et al. 2006), connectedness (Hensgen et al. 2006), and subsets (Loosemore and Hughes 2001, Hensgen et al. 2006, Kapucu et al. 2010), or how actors are connected in different types of networks (Uhr et al. 2008). The measures used serve as good indicators of the composition and structure of the networks, but scarcely any attention is paid to the dynamic nature of the process of networking.

Broadly speaking, we found three types of studies that employ a different set of social networks measures to explain collaboration patterns during emergencies or disasters. First, there are studies that use networks as conceptual logic that focus on structural representation of emergent organizing structures. Second, there is an extensive set of studies describing network governance structures in large-scale response networks. Third, there are a few studies that use social network theory to explain the different kind of relations (e.g., trust, advice, and friendship) between first responders during response operations.

In the first category, an early example of a network study is the work by Drabek and colleagues, which focuses on network structures and uses block modeling and centrality as tools (Drabek et al. 1981) to study information sharing between first responders, citizens, and authorities. In a qualitative analysis they linked these data to the sense of stability or the dynamics of the communication networks. In a later study, Topper and Carley (1999) analyzed the emergency organizations as an emergent (integrated) network organization after the oil spill in Alaska by the Exxon Valdez. They based their study on two sources: the Coast Guard reconstruction of the incident and the newspaper reporting. Both studies focused on connectedness and ordering of information in the emergency management core (Drabek et al. 1981, Topper and Carley 1999). While these studies

focus on a structural representation, and not on the dynamic features of networks under pressure, they already discuss the addition of volunteer and other organizations that are active in the overall response network. This point is also illustrated in the analysis of the radio communication after the 9/11 attacks where the dynamic emergence of primary and secondary hubs is described (Butts et al. 2007). Another network study that focuses on structural representation is the work of Gillespie and Murty (1994) who analyze a post-disaster inter-organizational network and identify cracks in the network by looking at central and peripheral actors in a structural equivalence analysis. Finally, Uddin and Hossain (2011) show a disaster preparedness network of soft target organizations (retail malls), and discuss degree centrality measures and tie strength. They conclude that malls with high a level of connectedness and strong ties tend to be better prepared for disaster response.

The second category is dominated by the work of Kapucu and others (Kapucu 2009, Kapucu and Demiroz 2011) that do an extensive job of analyzing large-scale (governmental) response networks to multiple hurricanes in the US. Kapucu et al. (2013) discuss the response of organizations in the Emergency Management Assistance Compact network to hurricanes Katrina and Rita. Degree, closeness, and betweenness centrality analysis of the two networks shows that in the more successful response to hurricane Rita, more cohesion and coordination were present in the network. This analysis is supported by the earlier similar analysis of the same hurricanes, where the authors found out that local levels are shown to be faster in response than federal and national authorities (Kapucu et al. 2010). The finding that local levels are better connected is also shown by Andrew and Carr (2013), who analyze closeness and betweenness centrality in preparedness planning communication networks in the Dallas–Fort Worth–Denton area. Finally, Kapucu et al. (2010) use a similar centrality analysis to show differences in centrality in the response to four subsequent hurricanes in Florida. Interestingly, this analysis shows that there was no significant difference among coordinated response to four hurricanes. In other words, there was a failure to learn at the network level.

The analysis of network governance structures is also used to study non-US cases. Vasavada (2013) analyzed network governance structures of the total network active during earthquake recovery in the state of Gujarat, India. Different centrality measures are used to conclude that the existence of a network administrative organization that functions independently of the network is not a reflection of how the response is actually organized. Instead, as the response operation unfolds, a lead organization-governed structure is created. This increases trust and goal consensus in the network. A similar

analysis is performed by Kapucu (2011), who analyzes the large differences in the structure of international UN response networks to the Nargis cyclone in Myanmar and the China earthquake in Sichuan province. Moore et al. (2003) also study network governance positions to understand the response network active during the 2000 Mozambique floods. They show, by using betweenness centrality and two-mode analysis, that local NGOs remained peripheral to the coordination process, while the Mozambique Red Cross took a more central position and had significantly more out-degree connections.

In general, we see that in the second category of network governance studies mainly centrality measures (degree, closeness, and betweenness) are used to understand the networked collaboration. These measures do serve as a good indication of the composition and structure of the networks, but scarcely any attention is given to the dynamic nature of the process of networking. These analyses focus more on providing an overall score of the relative position of actors throughout the entire response operation (Kim et al. 2013). The possibility that this position is subject to change in different phases of the response operation is not reflected in the analysis.

The third category focuses on mapping social networks as an indication of the mechanisms underlying the patterns of communication between responders in emergency response operations (Uhr and Johansson 2007, 2008). Uhr and Johansson (2008) show what role informal connections play in the response network formed for a chemical spill in Sweden, by analyzing trust, advice, and friendship networks during the same response operation. They conclude that analyzing these different types of networks uncovered hidden social dynamics in the response operation. Actors structured their advice network based upon friendship and trust (past work experience) and not so much upon formal work requirements. Interestingly, Uhr and Johansson also argue in their discussion that a limitation to their work is that they failed to illustrate how the network evolves over time. The friendship network does not account for the situation that people were sometimes not active at the same time. Here we see the similar problem that degree centrality provides only a summary of the course of events. This issue is also visible in the work of Harris and Clements (2007), who apply degree and betweenness centrality to map the personal relations of the Missouri public health emergency professionals using a planning system in 2006. They find that most planners communicated regularly with planners in their region, but seldom with planners outside their region. Because their argument is based upon a longer planning period, this limitation of degree centrality measure is not that influential to their argument.

In these three different categories of network studies in emergency management literature, we see the limitation that network analysis is mostly used to provide a static summary of interaction patterns. Yet, we also see a number of recent studies emerging that are shifting their attention to the dynamic processes occurring in the response networks (Abrahamsson et al. 2010, Hossain and Kuti 2010, Abbasi and Kapucu 2012). Also, Conti and Doreian (2010) recently discussed a number of cases, one of which is from the original studies by Drabek, in which they conclude that a variety of network analytical methods are necessary to capture the geographic contingent nature of communication in emergency situations. We can add to this development by explaining the dynamic nature of network processes. To better understand the nature of networked coordination, we need to move away from the somewhat static conceptualizations that most network studies offer us.

We argue that applying dynamic social network methods, which are new to the area of emergency management, should provide room for analyzing the time dependency of the processes occurring in the network. This follows the assertion that timing of communication in response is a key factor to take into account in assessing the effectiveness of networked emergency response. Tools for a dynamic network analysis should focus on the flow of information based on the frequencies on linkages in different time periods in the network, to allow an analysis of information spreading from a time perspective.

5.3 Towards a Network Toolset to Measure Network Dynamics

We propose three different network tools that together provide a toolset to measure network dynamics. Our objective is to introduce to the domain of emergency management applicable tools that have been proven to work in other fields. We hope that this cross-fertilization of methods will enable emergency management researchers and practitioners to transcend the limits of static depictions, thereby gaining a clearer understanding of the dynamics of response operations communications.

First, we propose to use time slices of actual interactions to get a better idea of how the network develops over time in different stages. Each time slice consists of all of the node-to-node information exchanges that occur among network nodes within the network in a defined period of time. The network is thus chopped into different periods of interaction. This type of analysis allows the researcher to get a better idea about how the network develops over time and what changes appear in the network

structure. It does require data (about incidents or disasters) that include time stamps or time indications to be able to discern the different periods. Time slices have been used before to depict the dynamics of the structure of social networks over time (Eckmann et al. 2004, Moody et al. 2005, Butts et al. 2007). These, however, depict changes in positions and do not necessarily take into account the dynamic patterns of communication. We feel that employing time slices to communication patterns contributes to the analysis of information sharing dynamics in networks.

Second, we propose a two-mode analysis based upon the time slices. In two-mode analysis there are two modes, in which mode 1 consists of the time periods and mode 2 consists of the actors. A link between time (mode 1) and actor (mode 2) shows who is active at what time. This allows us to display in one picture the most active actors not only in each time slice, but also across larger sets of time slices. By using two-mode analysis, we can see at what points in time the network takes different shapes and how the actors are connected to each other. Thus, in contrast to the more generally used centrality measures, two-mode analysis allows us to see how the centrality of actors changes over time. Likewise, two-mode analysis was used by Moore et al. (2003) to analyze the response network during the Mozambique floods.

Third, we propose to use information pathways to specifically follow the information spreading from a time perspective. Information pathways are used to track the information flows through the network and analyze how flows are connected to each other at different points in time. We have argued that the effectiveness of the collaboration structure is contingent on the timely assessment of the available information. To analyze the spreading of information from a time perspective, one should incorporate the frequencies of contact along different linkages in the network. This is what Kossinets et al. (2008) describe when they focus on analyzing information pathways in a network dependent on the time of interaction. They state that overall measures of connectedness are not applicable to the study of network information flows, but whether and to whom information spreads is dependent on the timing of interactions.

Information pathways are based upon edges and indirect paths. The edges are the direct connections between nodes, thus the connection between node *i–j*. Indirect paths are connections that move through another actor, for instance *i–k–j*. This is relevant in terms of timeliness of information exchange, because the quickest path with the most up-to-date information can also move through another node. For example, this occurs when actor *i* exchanges information with actor *k* at t^1 who informs actor *j* at t^2. If actors *i–j* have a

direct link only at t^3, the indirect path is quicker in exchanging information than the edge. So the indirect path is the optimal information pathway. This means that despite a direct connection might be visible between *i–j* in the overall degree centrality network, in fact the quickest information pathway moves through *i–k–j*. In this way, *"some of the direct connections in the network become much longer, due to low rates of communication, while other multi-step paths become much shorter, due to the rapidity with which information can flow along them"* (Kossinets et al. 2008, p. 442). Analyzing only degree centrality to calculate information flow might thus be misleading. By using information pathways, we can see how actors are connected or isolated through timing, which determines how information can flow through the network. The next section introduces the case study we use to demonstrate the effectiveness of the proposed tools.

5.4 The Case of the Amsterdam Schiphol Airport Train Tunnel Fire

During the afternoon rush hour of 2 July 2009, a fire incident took place in the Amsterdam Airport Schiphol train tunnel. In one of the two adjacent tunnel tubes, dirt collecting in a cable tray next to a railway track, ignited by a spark released from the braking wheels of a passing train, started to smoulder. The smoke caused by the smouldering dirt was first noticed by train drivers of trains passing through the tube. Together with reports of malfunctioning signals, the signs of fire were communicated to the remotely operating Railway Traffic Controller, who responded by stopping the train traffic in the direction of Schiphol, requesting the Switching & Report Center to dispatch a technician, and preparing a possible evacuation of the tunnel.

At the same time, the smoke and the smell of the fire were noticed by a train driver and a Schiphol employee at one of the platforms. The latter informed the Coordination Center Schiphol, which immediately began requesting several emergency services to dispatch. In addition, both the Royal Military Police and the National Railways received alarms from one of their employees. Triggered by these alarms, the emergency response was put in motion in a scattered fashion. Several involved parties quickly started the evacuation of the platforms, but the decision to start evacuating the tunnels was delayed by uncertainties about the severity of the signs of the fire, the positions of the trains held in the tunnel tubes, and the fire fighters' intention to explore the tunnel.

Although the fire turned out to be harmless, as it died out by itself, the inadequate coordination between the parties impeded a coherent emergency response. Consequently, three trains full of passengers were held in the tunnel under fearsome circumstances, which would have had potential lethal consequences if the fire had posed an actual threat.

One important aspect of the tunnel at Schiphol Airport is that the authority above the ground and underground differs. The tunnels and overall rail traffic in the tunnel are the responsibility of *ProRail*, the body responsible for the rail infrastructure. Passenger trains in the tunnels and station are the responsibility of the *National Railways,* and safety concerns rest with the *railway police,* a specialized National Police unit. In addition, *Schiphol Airport* as an entity has a separate legal status, and its own fire service, while its police are a part of the border guarding Royal Military Police *KMAR* and are at the same time responsible for safety and security in the airport area. In addition, Schiphol is located in the *safety region Kennemerland,* which is generally responsible for emergency operations and sending additional capacity for all three emergency services, fire fighters, medics, and police.

Summarizing, in this specific situation responsibility for alarming, dispatching, and decision-making rests with six different organizational realms with their own safety and communication centers: ProRail, National Railways, Royal Military Police (KMAR), Railway Police, Safety Region Kennemerland, and Schiphol Airport Emergency Services. Figure 14, originating from the official investigation report, gives the structure of official communication lines (solid black) and the crucial connections for responders occurring during the incident (dotted blue). The red actors belong to the fire department, white belong to ambulance services, blue to police and yellow are the railway organizations. The purple actors in the middle are the dispatch rooms of safety region Kennemerland and Schiphol Airport. The Airport Fire Officer (AFO) has the authority over the fire department response on site. The AL is responsible for coordination between the railway actors.

The case under investigation was selected for several reasons. First of all, it concerns an operation that involved actors from various organizations, which shows clearly how the networked collaboration problem arises. In addition, the incident is well delimited in time. It starts with the first detection of the fire and it ends with a sign "fire under control", all of which takes place within approximately 1 hour. Finally, during this period the interactions between the organizations are documented in detail in a public inquiry report (Inspectorate of Security and Justice 2009b) that describes the emergency response from three perspectives, which enhances the validity of the research.

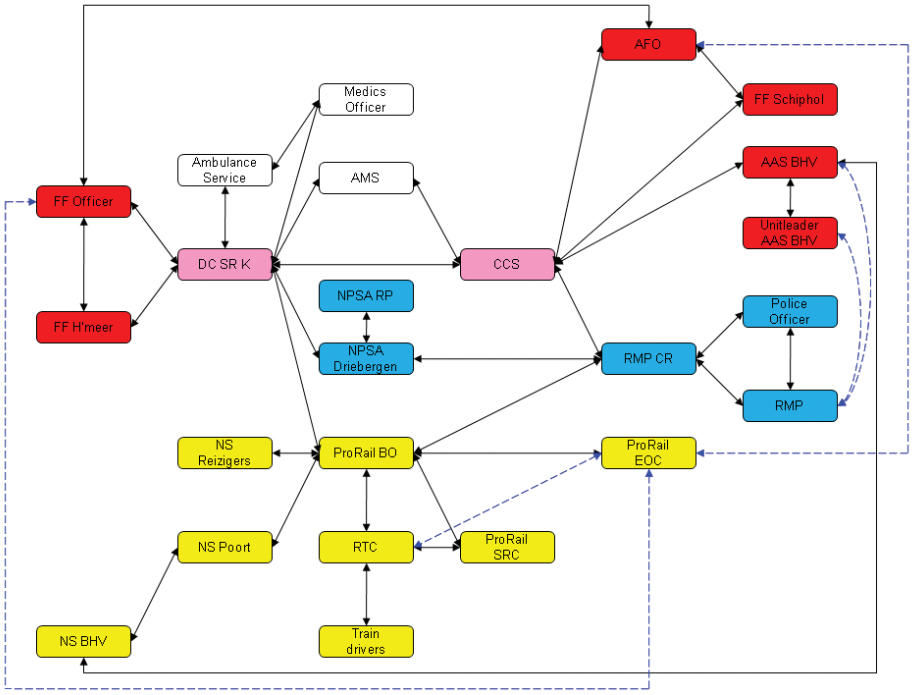


Figure 14. Communication Network from the Incident Report (Inspectorate of Security and Justice 2009b, p. 62)

5.5 Methods

The framework used to guide the process from the input data to the results consists of three steps, as depicted in Figure 15. The first two steps, the formalization and transformation of the data, are explained in Section 5.5.1. The last step, the data analysis, is described in Section 5.5.2.

5.5.1 Data Collection

The analysis of the emergency response to the Schiphol train tunnel fire incident is primarily based on information from a public inquiry report (Inspectorate of Security and Justice 2009b).

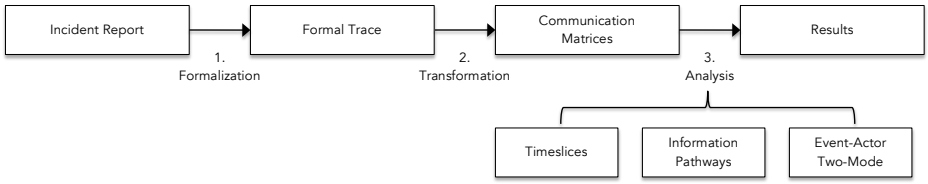


Figure 15. Data Formalization, Transformation and Analysis

In the report, the course of events is summarized in three story lines, each described from a different perspective, namely from the perspective of the Dutch organization for maintenance of the railway infrastructure (ProRail), from the perspective of the Dutch principal passenger railway operator (National Railways), and from the perspective of the police, the fire fighters and the medical services. In earlier work, these three story lines were merged and formalized with the help of the software Leadsto (Bosse et al. 2006) in order to create a so-called formal trace of the emergency response (Passenier et al. 2012). This formalization process is the first step in the data construction. It amounts to translating the mostly qualitative report data into a computer-readable format, resulting in decisions to represent the events more exactly than described in the public incident report. Figure 16 shows a fragment of the resulting formal trace. Each time interval in this trace represents half a minute, starting with t = 0 at 17:25 h. Hence, Figure 16 shows the events between 18:16 h and 18:17 h.

In order to depict the course of events in a convenient format for the analysis of the types of communication during the emergency response, this formal trace, together with the explanatory notes of the authors on the side, was used to reconstruct the events into one story line in natural language.

The trace itself is not necessarily a complete representation of all actual communication during the incident, because not all communication was recorded by the Inspectorate of Security and Justice. Although it is necessary to mention the limits of the use of this secondary data, as discussed in Passenier et al. (2012), we are convinced that the case itself can function as a good example of showcasing a new network toolset to depict the dynamics of communication processes during emergency response operations.

```
interval
  R: range(102, 104)
  F and
    communication_from_to(ProRail_EOC, RTC2, request(info(at_location(trains(two, holding), tunnel2A))))
    communication_from_to(RTC2, ProRail_EOC, at_location(trains(zero, holding), tunnel2A))
    communication_from_to(RTC2, ProRail_EOC, sign_clear(trains))
    communication_from_to(ProRail_EOC, RTC2, intention(FE340, enter(tunnel2A)))
    communication_from_to(ProRail_EOC, RTC2, intention(FE341, enter(tunnel2A)))
```

Figure 16. Formal Trace of Communication Patterns in Time Range 102–104

The second step in the data construction consisted of the transition between the formal trace and the matrices that served as input for the analysis. The communication matrices could be composed automatically, because the trace contains all relevant information about which actor communicated with whom and at which time point, in a computer-readable format. We used Matlab to read the trace and generate the matrices, which were stored in Microsoft Excel.

For our analysis, two types of matrices were constructed. First, we created asymmetric actor-by-actor matrices covering the duration of the communication between two actors. In such a matrix, a field *i, j* describes the duration of the communication (in number of time steps) from actor *i* to actor *j*. In contrast to conventional network matrices, the automatically generated matrices were not constructed for the complete emergency response, but instead, we generated a separate matrix for each time step. This resulted in a three-dimensional matrix (actor × actor × time) that allowed us to merge the actor-by-actor matrices to longer time intervals according to our needs. Second, we created actor-by-time matrices covering the individual activity of actors per time step. Here, a field *i, j* contains a 1 if actor *j* was involved in a communication at time step *i*, and a 0 otherwise. We used varying durations from 30 s to 2.5 min and marked activity of actors with a 1 or 0 depending on whether an actor was active in that time period (1) or not (0). Subsequently, the data were analyzed with different social network methods to reach convergence in our interpretation.

5.5.2 Data Analysis

We have proposed three different tools to analyze the case: time slices, two-mode analysis and information pathways. These tools can be used separately, although the time slices are the input for the last two analyses.

First, time slices are used to chop the network of interactions in different time periods. The length of the intervals can vary according to the researchers' needs and the

number of changes in network structure per unit of time in the network. We searched for the most convenient intervals to represent the communication dynamics in the network to balance the ability to detect changes in network structure with the level of detail. We found that both 2.5 and 5 min time slices showed us a convenient overview of the structural changes. Figure 21 displays the traces created by using the 5 min time slices. The traces are based on the sequential data in the incident report.

Second, the two-mode analysis is conducted to assess the information about the event periods in which the various parts of the emergency system play an active role and in what manner. Centrality in two-mode networks consists of two different maximum values of centrality. The first is the number of time periods regarded as events in which actors operate. The second is the number of actors that can be active in a given time period (Everett and Borgatti 2005, Borgatti and Halgin 2011). In our case the various actors form one mode, while events form the other mode. A link is considered to exist by connecting actors active in a specific event period to that event. One methodological caveat is that we assume that in our two-mode calculations the actions of various parties at the different moments have some transparency to the others actively exchanging information at the same time. This is warranted because a large part of the information exchange takes place in a dedicated information system, and also the emergency room functioned as a switch board between operating teams and decision-makers. In addition, we have included similar actors into higher order categories. For example, individual fire engines are collectively labeled fire engine, similar for train drivers. This is warranted as first responders at the place of the incident can listen in on the communication between the other parties in action, at least in their own domain.

In one part of the analysis, we used degree centrality of an actor to measure the frequency with which actors were present in different communication (update) events. Betweenness centrality introduces the degree to which actors are present at time periods with a unique character. Therefore, these actors are able to digest and distribute information in other time periods that others attend which shows the consistency of the engagement of the actors over time (Everett and Borgatti 2005). This provides us with an indication (regardless of the content of the communication) of which actors have been critical in providing communication opportunities between actors, because they have been present at critical update events. The other part of the analysis is the assessment of which of these event periods connects most of the actors. We ran our analysis originally with event periods specified as 30s intervals. However, regarding the overall patterns 2.5

min intervals seem to be more reasonable. Longer intervals introduce the problem that the information at the beginning of the interval considered might already be outdated. A high-time degree centrality for update events measures how many actors are involved in communication in that period (Everett and Borgatti 2005, p. 63). Also for the event periods we can compute the betweenness centrality indicating the critical moments in time where actors in the network may relay information to others.

Third, we use information pathways to follow the path of information streams moving through the network in different time periods. First, we use the time slices to create different intervals in the network. Next, we analyzed the edges and indirect paths (based on the time slices) between actors in the network (Wassermann and Faust 1994) to follow different information pathways between the nodes in the different time periods. To get a better understanding of what is communicated in the network, we combined the structure of the information pathways with the content of the communication from the formal traces to reconstruct the storyline. This allowed us to add a qualitatively informed analysis to the information pathways. The software tool VennMaker was used to convert the results of the analysis into Figure 20 that shows information pathways between different time periods. This combination of data allowed us to see how and what kind of messages were spread through the network.

5.6 Results

5.6.1 Network Tool 1: Time Slices

The first reconstruction of the communication networks is based on time slices of 5 min. The sequential pictures depicted in Appendix 1 (Figure 21) at 5 min intervals show which parties (labels in Appendix: Table 13) were actively exchanging information with each other in each of the phases. The network structure represents the sequence of communication. The first time slice includes conversations between two train drivers and two different train traffic controllers. Each conversation includes mention of a possible fire. The next phase is characterized by a relatively slow build-up of information exchange in a more densely connected network, which fully integrates the functionally different groups only in time slice T5 after 21 min. The central components in these different time slices vary, as do the central actors. It takes quite some time before the calamity officer of the rail network shows up.

Timeframe in minutes	Rail	Emergency coordination	others
1: 1-5			
2: 6-10	Railway Traffic Controller 1		
3: 11-15	Railway Traffic Controller 2	Coordination Center Schiphol	
4: 16-20	Railway Traffic Controller 2	Coordination Center Schiphol	KMAR (Military Police)
5: 21-25	ProRail Back Office Rail Traffic Controller 2 ProRail Emergency Coordinator	Dispatch Center Kennemerland	
6: 26-30	ProRail Emergency Coordinator	Dispatch Center Kennemerland	

Table 11. Central Actors in the Critical First Half Hour

Overall, 26 min elapse before the information is exchanged in the necessary core network of Dispatch Center Kennemerland, Railway Traffic Controller, ProRail Emergency Operations Coordinator and Airport Fire Officer. In the meantime sub-networks have dealt with the questions and concerns of the train drivers and the public. In summary, the time slices show a developing network that lacks common central actors, which may be responsible for producing a fragmented response effort. Table 11 shows different actors that were most central in communication in the first half hour of the incident. The lack of a stable core is noteworthy. Based on the design of existing emergency response systems (actors, responsibilities and authorities) this is not what one should expect, since this system calls for a constant central core to support coordination. The lack of stability in the core in this case shows the complicated authority structures in the Schiphol train tunnel. It also shows that the actors fail to communicate across the boundaries of their own agencies throughout the first part of the response.

The centrality measures showed that the most central node was different in each time slice. In the representation of the networks we can compare those (see Figure 17 and Figure 18) with earlier suggestions by Topper and Carley (1999) about three organizational scenarios: (1) emergent with increasing connectivity and order, (2) highly structured around one node thus central, and (3) increased and near-complete connectivity between all nodes. We can see the second scenario *"highly structured around one node thus central"* in Figure 17 (in T3) and the network is fragmented into two separate parts. The

separate networks consist of the emergency services in the left cluster and the railway actors in the right cluster. In Figure 18 (in T5) the two separate networks connect to each other, and we move back towards the first scenario: *"emergent with increasing connectivity and order"*. In the remainder of the incident the evolving network structure remains mostly *"emergent with increasing connectivity"*, and perhaps due to the short duration of the incident, it does not stabilize into a fixed pattern.

In conclusion, the time slices show us that the networks are multi-centered throughout the incident. There is not one central actor, but different clusters that each have a different central actor. Several moments of increased connectivity can be seen, but the network also fragments into different clusters in several time slices (see Figure 21). This is partly in contrast with the sequence of the scenarios suggested by Topper and Carley (1999).

In Figure 19 (red circles are time periods of 2.5 min, blue squares are the consolidated actors), it can be seen that during the time periods B1–B5 there is very sparse to no communication, and if there is, it is only between train drivers and railway organizations. In the patterning of the red event nodes there is communication between two different segments of the network, in general the two parties that we also saw in the time slices. In the upper part we see a start-up of communication in B6 and B7, and a cluster of activity around B8, B9, B11, B16 and B17, suggesting moments where cross connection across the broader segments of the network took place without coordinating centers involved. When the emergency comes to an end, the time periods B24, B25, and B26 indicate low or no activity of a majority of actors. The coordinating role of the ProRail Emergency Operations Coordinator (ProRail_EOC), and the Dispatch Center of Safety Region Kennemerland (DC_SR_K) shows a higher representation of these actors over other periods B8, B9 and B16, B17. Besides, also more peripheral actors can be distinguished, such as the fire fighters (FE) and their commanding officers (AFO; FF_O; FF_HO), as well as the connection of worried passengers (PSGN) through the national police emergency call center (NPSA).

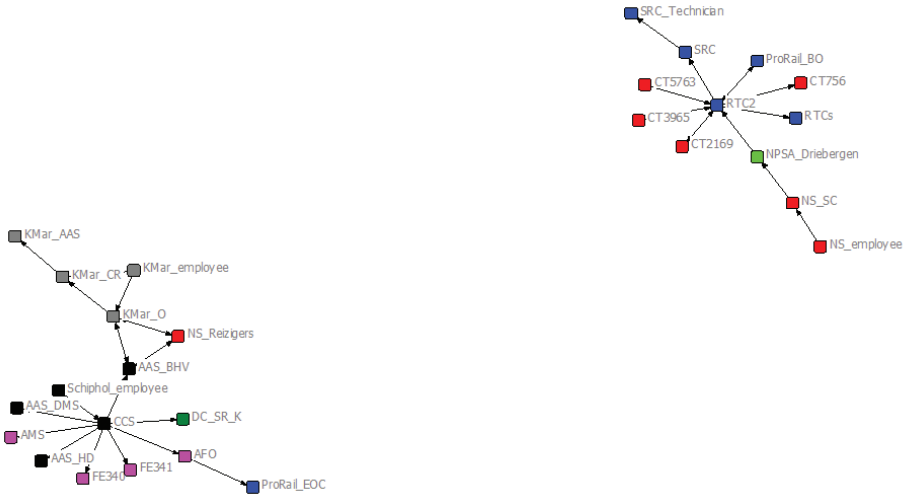


Figure 17. Two Centralized Clusters of Schiphol Emergency Actors and Railroad Actors in T3

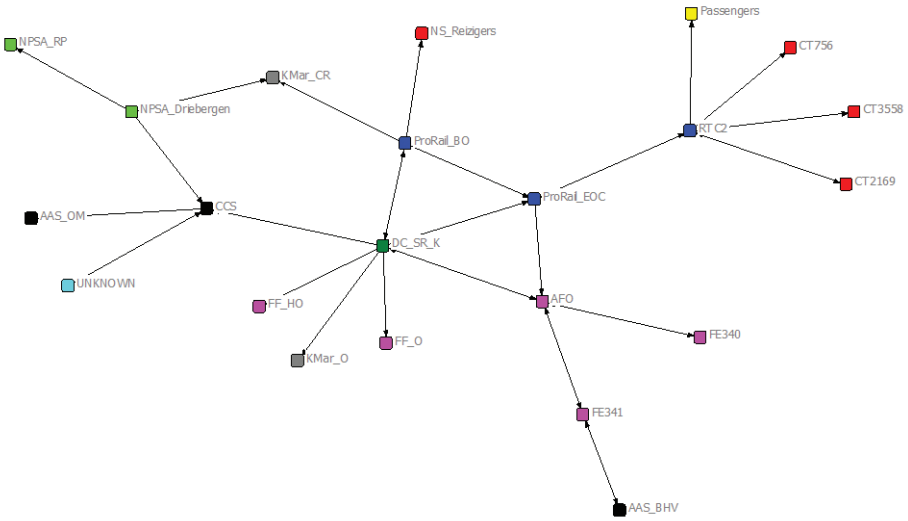


Figure 18. Increasing Connectivity in the Network in T5

5.6.2 Network Tool 2: Event-Actor Two-Mode Analysis

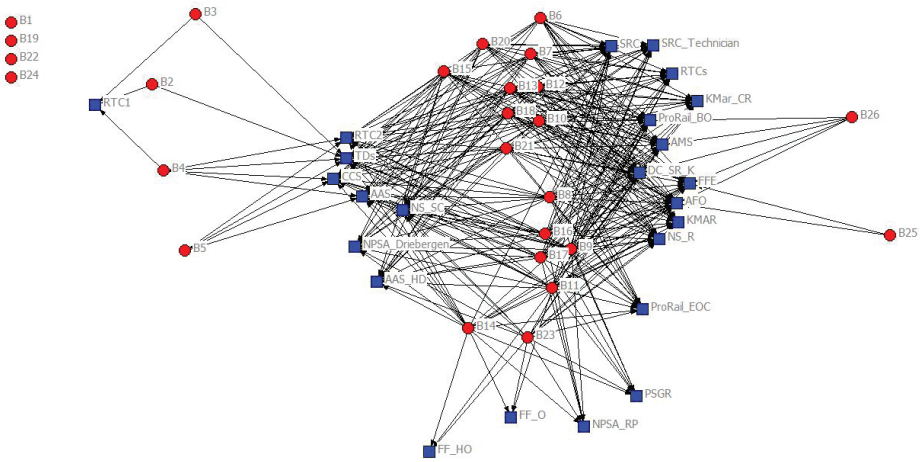


Figure 19. Two-Mode Network of 2.5 min Intervals

Thus, in the figure of event periods, the core moments of coordination can be seen clearly, and they add to the insight in the dynamics of the crisis in a different manner than a phase description would. This is confirmed by the calculation of degree centrality and by the betweenness centrality (see Table 12), showing the crucial period in more detail. It can be seen that periods B8–B11 and B16–17 score higher on degree centrality, thus connecting more actors together. In addition, the betweenness centrality measures show that time B11 and B14 remain a bit more critical periods for combining various actors and allowing information sharing.

In the two-mode analysis the critical points in time can be shown. The insights from the time slices in paragraph 5.6.1 are confirmed by our indication of critical time periods in Table 12. In contrast to stabilization in the command and control perspective, we observe the fluctuating nature of information flows between actors in the network.

Time Period	Degree Centrality	Closeness Centrality	Betweenness Centrality	Eigenvector
B1	0.000	0.000	0.000	0.000
B2	0.083	0.649	0.006	0.015
B3	0.083	0.649	0.006	0.015
B4	0.208	0.685	0.025	0.057
B5	0.167	0.673	0.001	0.057
B6	0.667	0.902	0.014	0.218
B7	0.750	0.949	0.017	0.245
B8	0.833	1.000	0.024	0.263
B9	0.875	1.028	0.030	0.268
B10	0.792	0.974	0.019	0.257
B11	0.958	1.088	0.061	0.273
B12	0.792	0.974	0.019	0.257
B13	0.792	0.974	0.019	0.257
B14	0.750	0.949	0.040	0.210
B15	0.667	0.902	0.013	0.221
B16	0.875	1.028	0.030	0.268
B17	0.875	1.028	0.030	0.268
B18	0.792	0.974	0.019	0.257
B19	0.000	0.000	0.000	0.000
B20	0.750	0.949	0.017	0.245
B21	0.792	0.974	0.019	0.257
B22	0.000	0.000	0.000	0.000
B23	0.708	0.925	0.036	0.196
B24	0.000	0.000	0.000	0.000
B25	0.083	0.617	0.000	0.029
B26	0.208	0.649	0.001	0.070

Table 12. Two-Mode Time Periods Centrality Measures in 2.5 min Event Periods

5.6.3 Network Tool 3: Information Pathways

Our analysis so far has shown that the communication in the response network is fragmented at different times. The central actors from ProRail and the emergency organizations in time periods T3 (11–15) and T4 (16–20) (see Table 12 and Figure 17) are located in subsets of the network that are disconnected from each other. In these time periods these actors communicate solely in their own networks. In time periods T5 (21–25) (see Figure 18), T6 (26–30), and T8 (36–40), these subsets are connected to each other.

The central problem described in the incident report is a miscommunication between the Airport Fire Officer (AFO), ProRail Emergency Operations Coordinator, and the Railway Traffic Controller (RTC). The miscommunication concerns the location of the trains and fire fighters in the tunnel tubes. The fire fighters are under the impression that all trains have been evacuated and enter the tunnel, while the ProRail Coordinator and RTC are under the impression that fire fighters are already on the tracks and do not dare to move the trains. To address this misunderstanding, we use information pathways to describe in what order the actors are connected to each other in different time periods. Information pathways are the edges connected to each other in relation to the sequence of time stamps (Kossinets et al. 2008). Figure 20 shows how the information spreads through the network between the time slices.

In T5, the Airport Fire Officer (AFO) asks the Dispatch Center Kennemerland (DC_ SR_K) whether the tunnel can be cleared of trains. The Dispatch Center Kennemerland relays this message back to the ProRail Coordinator (ProRail_ EOC) who communicates this with his Railway Traffic Controller (RTC). The RTC asks the ProRail Coordinator if the fire department wants the trains to be moved out of the tunnel before the fire fighters enter. The ProRail Coordinator himself is unsure, based on the communication with the Dispatch Center, whether he can move the trains or whether there are already fire fighters in the tunnel, so the order to evacuate the trains is not given. This misunderstanding keeps reverberating in the following time periods. The information pathways between the actors with the information (RTC about the location of the trains and AFO about the location of the fire fighters) show that these actors are not connected directly to each other, but through the ProRail Coordinator and the Dispatch Center Kennemerland. This is distorting the communication in this time period.

Figure 20. Information Pathways Between the Different Time Periods

In T6, the AFO is directly connected to the ProRail Coordinator. The ProRail Coordinator informs the AFO that there are three trains in tunnel tube 2A but none in tube 1A, which they can explore. The AFO acts on this information and orders his two fire engine crews (FE) to explore tube 1A. The ProRail Coordinator is now aware that he cannot move the trains because fire fighters are in the tunnel.

Next, in T7 and T8, the smoke clouds are spreading throughout the tunnel, causing a panic in the trains. The train drivers request the RTC to provide clearance to leave the tunnel immediately. However, the RTC and ProRail Coordinator are unsure where the fire fighters are located in the tunnel and do not execute this request. In T7, the fire fighters communicate to the AFO that they are surprised to still find trains in the tunnel, and they pull back to let the trains be evacuated. Finally, in T9, 45 min after the start of the fire, the trains are evacuated from the tunnel.

The analysis of the information pathways informs us about the influence of direct and indirect information flows. The indirect information flow between the AFO and the EOC in T5 and T6 shows how the lack of communications can seriously impede the emergency response. This can only be seen if we connect the direct and indirect flows

between the different time slices to each other, by using information pathways. This also provides a new perspective to study the connectedness between nodes across time.

5.7 Conclusion and Discussion

As it has been argued in the theory and methods sections of this paper, it is crucial to incorporate timeliness of information exchange in social network studies of emergency response to more accurately represent incident response dynamics. We have shown that the reconstruction of communication and interaction between parties relevant to the emergency operations is not necessarily straightforward (Abrahamsson et al. 2010). We have added to the network tools available and have shown different aspects of the dynamics of one specific emergency event.

In summary, we have now the following information derived from the chain of communication events. From the evolving structure of the communication network it was clear that in this brief time span, *emergence* was dominant over other models proposed by Topper and Carley (1999). With regard to the consistency of communication it can be made clear, on the basis of the two-mode analysis, that different time periods in the middle of sorting out the emergency exhibit characteristics of a distribution over actors, as well as critical moments in information flow. This corroborates the pervasive qualitative story of the incident report, which showed confusing periods during the incident. Our analysis adds a more detailed insight into the patterns and actors present during these critical moments.

Analysis of the information pathways shows how sequences of connections between actors are important to explain communication patterns in the network. Information pathways illustrate how the timeliness of communication can seriously impede the effectiveness of networked collaboration. Not only do direct connections between actors explain the flow of information, but also indirect paths appeared crucial to information flow and for the explanation of confusion in the network. Thus, in emergency situations, different phases with different communication problems and their effects need to be discerned.

The origin and spread of the misunderstanding in the network supports our argument that we need a more dynamic network toolset to understand the development of the communication network. Using just a single overall measure for centrality fails to depict the emergent nature in which the network develops. Actors are connected differently to each other in different time periods that result in irregular flows of information

through the network. In our case, this irregular synchronization of information allows the misunderstanding between fire fighters and rail traffic controllers to reverberate throughout the network.

The toolset provides us with a more fine-grained insight in when and where (in the network) sources for confusion emerged. As such, we indicated the patterns of communication that could help to analyze and counteract well-known problems in the first half hour of community response, such as employing the first acting responder as a coordinator instead of the strategically most logical alternative, given the situation (Berlin and Carlström 2011). Also, in reconstructing the information pathways we have shown in what manner various organizations were lacking access to information. Reconstructing information pathways that take the timeliness of information into account are essential to understand how the miscommunication could spread through the network.

Our solution to analyze the process of information sharing during emergency response operations has been to look at the temporary nature of the networks and characterize the manner in which this temporality influenced the availability of information in an actual incident situation. In this respect, timeliness is an important construct that can be analyzed further by looking at the information pathways in the network (Kossinets et al. 2008). We approached the network analysis not solely through a static set of (centrality) measures, but stressed a more process-oriented analysis that better captures the dynamic nature of information sharing in crisis situations.

This does not only hold for the scientific community, but we also want to extend this message to the inspectorates and incident evaluation community. When network studies are incorporated in formal incident evaluation reports, these often lack recognition for incident response dynamics in their network depictions. The research report we analyzed in our case study is also an example of this. Employing only static (degree) centrality measures obscures the real incident dynamics and origin of the communication and coordination problems. Using static network analysis diagrams to represent the emergence of connections might lead towards the inaccurate assertion that improving the direct information flow is key to an effective response. Yet, the analysis of information pathways shows us that it is also important to better understand the indirect information flow, since indirect paths might prove to be the quickest connections across time periods.

There are of course also limitations to our work. First, we have used only one case study that functions as an illustration of our network toolset, and not as a validation of the toolset. This choice is justifiable, because each network tool is tested and used in the

fields of network studies and computer science. Therefore, we feel that the results of one case study can be useful in creating awareness of the issue of dynamics and for applying this emerging dynamic method in the field of emergency response studies. Still, applying the toolset to more and different kinds of cases is necessary to see whether new inferences can be made about incident response dynamics. First, this is necessary to shed a new light on the previous network analysis of incident response scenarios that we discussed in our theory section. Second, although there were no victims, the sensitivity of potential mass disruption of a densely traveled network and the anxiety with the potential incidents in a tunnel warranted a high level of scrutiny of which the report itself is a witness. This sensitivity might also have colored both the interviews with the actors in the crisis and the reconstruction. Third, in reconstructing we have solved the ambiguity in the crisis by independent coding of the information elements contained in messages. This certainly has influenced the way we could construct the networks. Lastly, in this unique case some of the processes seem to have been influenced strongly by the conflicting organizational and institutional positioning of key actors. The report has resulted in recommendations and ensuing actions that redress these imbalances. Moreover, train drivers are now better trained than before to handle tunnel incidents.

We have shown that a broader set of network tools can help to understand the dynamics of communication and collaboration in a crisis situation. Applying different methods from the social network analysis and network science toolbox may shed a different light on the role of actors and communication flows during emergency situations. Our toolbox adds to the useful insights that are already made with structural analysis of the organizational networks and the people working in them (Uhr and Johansson 2007). We add dynamics in our toolbox, while acknowledging the necessity to include elements such as trust and the ability to work with the information provided by others. Of course applying such an analysis to one case with limited complexity does not do justice to the potential. Moreover, in complex situations it might be helpful to address the emerging patterns of interaction with other tools such as those applied to large networks and addressing processes aspects, such as event-based analysis (Butts et al. 2007).

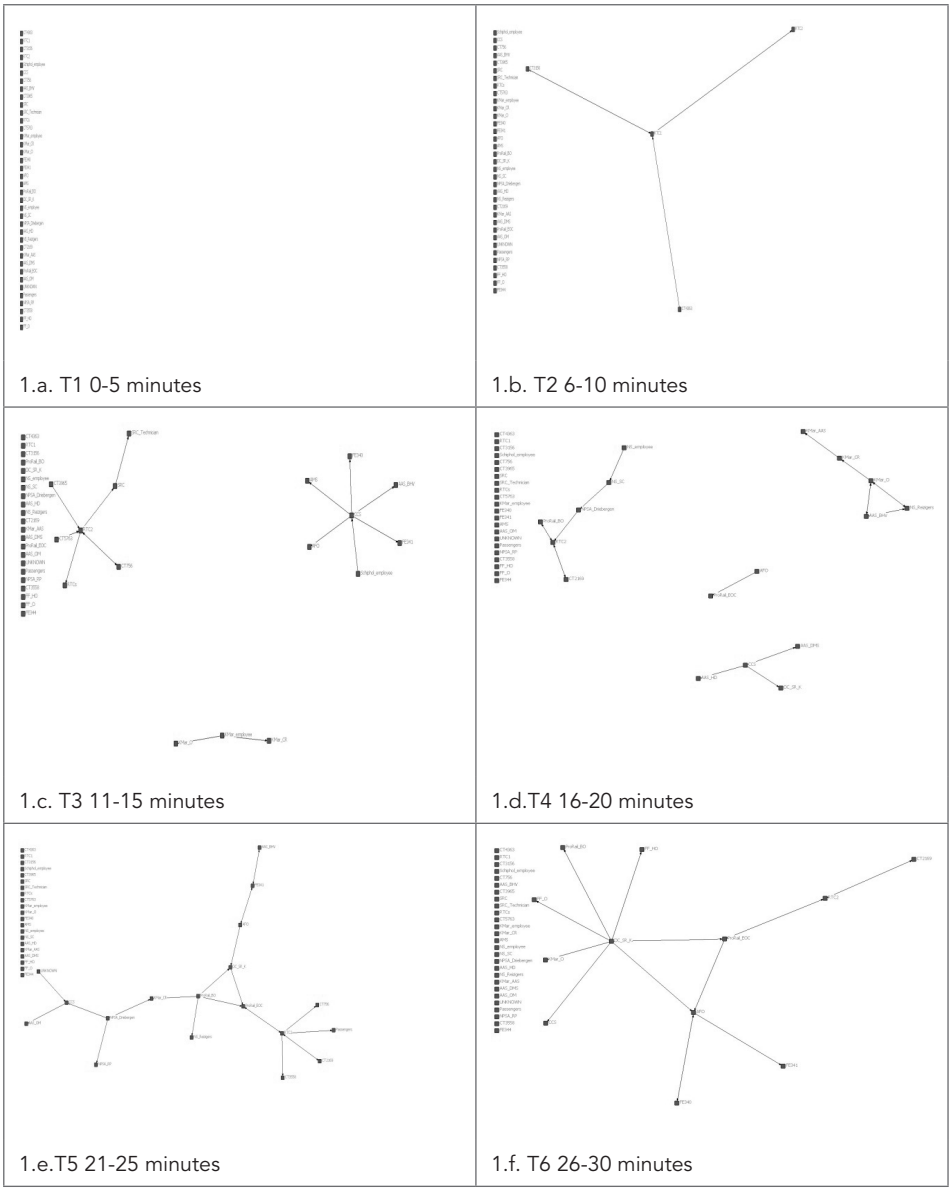
5.8 Appendix

Abbreviation	Organization	Function	Main Responsibility in network (collector, aggregator or disseminator of information)
AAS	Schiphol	Amsterdam Airport Schiphol Employees	Collect information
AFO	Schiphol	Airport Fire Officer	Aggregate information
AMS	Medics	Airport Medical Services	Collect information
CCS	Schiphol	Coordination Center Schiphol	Disseminate information
DC_SR_K	Dispatch Center	Dispatch Center Safety Region Kennemerland	Disseminate information
FE	Fire service	Fire engines	Collect information
FF_HO	Fire service	Fire fighters Head Officer	Aggregate information
FF_O	Fire service	Fire fighters Officer	Aggregate information
KMar	RMP	Royal Military Police District Amsterdam Airport Schiphol	Collect information
KMar_CR	RMP	Royal Military Police Control Room	Disseminate information
NPSA	Police	National Police Services Agency in Driebergen	Disseminate information
NPSA_RP	Railway police	National Railway Police	Collect information
NS_SC	NS Rail	National Railway Command Center	Disseminate information
NS_Service	NS Rail	National Railway service personnel	Collect information
PSGR	Passengers	Passengers	Collect information
ProRail_BO	ProRail	ProRail Back Office	Disseminate information
ProRail_EOC	ProRail	Emergency Operations Coordinator	Aggregate information
RTC1	ProRail	Rail Traffic Controller 1	Disseminate information
RTC2	ProRail	Rail Traffic Controller 2	Disseminate information
SRC	ProRail	Switching & Report Center	Disseminate information
SRC_ Technician	ProRail	Switching & Report Center Technician	Collect information
TD	NS	Traindriver(s)	Collect information

Table 13. Summary of Main Actors

Number	Actor	Degree Centrality	Closeness Centrality	Betweenness Centrality	Eigenvector
1	FFE	0.692	0.923	0.036	0.242
2	TDs	0.769	1.000	0.116	0.245
3	AAS	0.692	0.947	0.033	0.243
4	KMAR	0.615	0.878	0.010	0.236
5	NS_R	0.615	0.878	0.010	0.236
6	PSGR	0.269	0.720	0.002	0.104
7	RTC1	0.115	0.486	0.002	0.005
8	RTC2	0.654	0.923	0.028	0.231
9	CCS	0.654	0.923	0.028	0.231
10	SRC	0.577	0.857	0.008	0.224
11	SRC_Technician	0.500	0.818	0.005	0.199
12	RTCs	0.500	0.818	0.005	0.199
13	KMAR_CR	0.500	0.818	0.005	0.199
14	AFO	0.692	0.923	0.036	0.242
15	AMS	0.615	0.878	0.014	0.228
16	ProRail_BO	0.615	0.878	0.014	0.228
17	DC_SR_K	0.654	0.900	0.017	0.240
18	NS_SC	0.615	0.878	0.010	0.236
19	NPSA_Driebergen	0.577	0.857	0.008	0.223
20	AAS_HD	0.577	0.857	0.008	0.223
21	ProRail_EOC	0.500	0.818	0.006	0.194
22	NPSA_RP	0.231	0.706	0.001	0.089
23	FF_HO	0.115	0.667	0.000	0.041
24	FF_O	0.115	0.667	0.000	0.041

Table 14. Two-Mode Actor Overall Centrality Measures



1.a. T1 0-5 minutes

1.b. T2 6-10 minutes

1.c. T3 11-15 minutes

1.d.T4 16-20 minutes

1.e.T5 21-25 minutes

1.f. T6 26-30 minutes

Figure 21. Network Diagrams on 5 min Intervals

6. Conclusion

6.1 Towards a fragmentation perspective on cross-boundary coordination

In my dissertation I have set out to discover how emergency officers coordinate across the boundaries of their organization in an environment that is characterized by rapidly changing conditions, increasing uncertainty, and spatial task dispersion. In this final chapter I will *draw the line* and consolidate the results. Based on the findings and conclusions from each chapter, I will answer the main research question: *how do emergency responders coordinate the response operation across the boundaries of their organizations in fast-paced environments?*

The image that emerges from the previous chapters is that it's impossible to reach coordination solely based on integration in emergency management. While in the preparation phase for emergencies organizational designs are created, plans and protocols are administrated, and centralized command structures are instated, a different modus operandi appears during the response operation itself. The four empirical studies in this dissertation show that coordination takes the character of emergent adaptation, deference to expertise, and spontaneous networking across the boundaries of organizations in response to changing interdependencies. In the introduction I have presented these aspects of cross-boundary coordination during the response operation as paradoxes:

Integration logic	Fragmentation logic
Designed Coordination	Emergent Coordination
Administrative Coordination	Expertise Coordination
Centralized Coordination	Networked Coordination

Table 15. Coordination paradoxes

The analysis of the after-action reports from the Turkish Airlines crash combined with insights from current literature showed that these paradoxes emerge in the 'hot phase' of response operations. Now at the end of my dissertation they feature again, but with the deeper understanding now reached, I can add an important insight to them: the way in which emergency managers deal with the coordination paradoxes leads to the dominance of a fragmentation logic during the response phase. Initially emergency managers tend

to consider and prepare for the response phase coordination based upon an integration logic, in which the organizational structures for the response phase are *designed*, procedures are *administrated*, and *centralized* command structures are instated. Yet, this is contrary to the dynamics that are actually visible during this phase itself.

Coordination during the response operation itself shows a different logic, in which *emergent* adaptations, the negotiation of the relevance of *expert* judgments, and the changing configuration of a multi-organizational response *network* features. This entails that during emergency response operations coordination is not a state of integration that can be achieved, but that coordination efforts are consciously aimed at segmentation to keep sufficient speed in the response operation. As adaptations are occurring at multiple locations simultaneously in a distributed environment, there is no clear 'whole', only a changing set of interdependent actions performed by different organizations in parallel. Therefore, treating cross-boundary coordination in the response phase of emergencies aimed at achieving one integrated set of actions seems to be an illusion. If integration is not possible under fast-paced circumstances, how does the alternative of fragmentation look like? To answer this question I will return to the three paradoxes presented in the introduction that emerged from the analysis of the response operation to the Turkish Airlines crash.

6.1.1 The paradox between designed and emergent coordination

The first paradox focuses on the tension between designed and emergent coordination. During coordination in the response phase emergency responders are confronted with unexpected events that challenge existing procedures, which forces officers in command to develop emergent solutions on-scene. This results in paradoxical demands between following the designed coordination mechanisms and opting for an emergent solution that deviates from the design. This paradox is visible in several chapters. In chapter two, the coordination practices of *distancing* and *switching tactics* can be regarded as ways for dealing with this paradox. The practice of distancing is employed to get an overview of the response operation. By distancing from the response operation the officers gained situational awareness, but at the expense of control. The practice of switching tactics is employed to adjust to changing conditions. Switching between different tactics allowed the officers to operate and retain control in a changing environment by adapting to unexpected events, but at the cost of predictability. These two coordination practices show that in this study emergent coordination is occurring at the level of authority and at the level of action. In an attempt to manage loss of control and predictability in an

environment in flux, the officers engaged in boundary work. They actively reinstated functional and normative boundaries allowing them to regain control and reestablish standards. Based on this boundary work the officers succeeded in initiating fast action by momentarily putting interdependencies with other officers from different response organizations on hold. By reinstating normative and functional boundaries in the course of coordinating, the officers established separate pockets of control and restructured ad-hoc adaptations. However, paradoxically, by reinstating functional and normative boundaries the officers contributed to the very fragmentation they were trying to overcome.

In contrast to the findings of chapter two, in which the officers reinstated boundaries to retain speed of action, in chapter three attempts of boundary bridging are more central as here the analysis focuses on the common operational picture that participants developed in field command meetings. In this chapter we witness a different dynamic in the boundary work of the officers, one that takes place at the level of information sharing. The officers take time to develop their common operational picture in the form of a shared representation to support the coordination process: a boundary object. The common operational picture is a map of the disaster scene constructed by the officers to depict the progress of the response operation. During the construction of this boundary object the officers employed four different coordination modes to suit the crossing of a particular kind of boundary they experienced: *selecting tasks*, *phasing action*, *standardizing information* and *transforming understanding*. The timeline charts in this chapter showed that the boundary object is tailored differently to bridge the functional, spatiotemporal, normative, or knowledge boundaries the officers' experienced. Still, the attempts to bridge these boundaries were often not successful, as the officers ran into coordination issues when tailoring the configuration of the boundary object from different modes. As a result the officers failed to bridge the different kinds of boundaries they experienced. In contrast, when the officers tailored the boundary object from similar coordination modes, it supported the coordination process because the configuration of the object matches the boundaries the officers' experience. These findings indicated that successful cross-boundary coordination does not depend on the capacity of the boundary object per se, but on the relationality between the modes, temporal adjustment of the boundary object, and the intentions that are incorporated in its users coordination modes for tailoring the configuration of the boundary object.

What stands out from this analysis is that cross-boundary coordination is not defined by the capacities of the boundary object itself, but by the emergent coordination process

through which the boundary objects' configuration is tailored to match the boundaries the officers experienced. It signals that during emergent coordination new task sequences are negotiated in action that deviate from designed coordination mechanisms. This is supported by the subsequent Markov analysis, which indicated that the dominant mode in which the boundary object was tailored is *phasing action*. The coordination mode of phasing action is used by the officers to create an ad-hoc working order to manage changing interdependencies. This suggests that in the fast-paced environment of emergency response most cross-boundary coordination efforts are focused on arranging task sequences, which is an act of segmentation. Especially in fast-paced environments, segmenting tasks is a more effective solution to divide work, instead of using the boundary object to foster shared understanding, which takes too much time.

In sum, both empirical studies showed the importance of emergent coordination processes that deviated from designed coordination mechanisms. Emergent coordination is a layered process that takes place at the level of authority, action, and information sharing. The paradox between designed and emergent coordination is managed by the officers in command through a negotiation process that occurs either during action on scene, or during field command meetings with help of a boundary object. This shows that *negotiation* is an essential way of coping with the paradox between designed and emergent coordination. Emergent coordination unfolds in a landscape of changing interdependencies in which different sorts of boundaries appear that need to be renegotiated time after time to adapt to changing contingencies. This continuous renegotiation creates equivocality that is part of a situation in flux. In this situation in flux cross-boundary coordination can only be a temporal synchronization process that finds its roots in the negotiation of boundaries the officers' experience. This is central to a fragmentation perspective on coordination. Therefore, cross-boundary coordination processes in fast-paced environments cannot result in a coherent, univocal set of actions, but are characterized by the temporal negotiation of boundaries that emerge during the coordination process.

6.1.2 The paradox between administrative and expertise coordination

The second paradox originating from the analysis of the Turkish airlines crash in the introduction focuses on the tension between administrative and expertise coordination. When the officers encountered unknown circumstances on scene, expertise judgment often coincided with existing administrative procedures. Common understanding is

partly codified in the logic of administrative procedures, but when experts reassess the requirements for coordination this understanding becomes contested in action. The findings in the first three empirical chapters indicated that when expertise coordination occurred across organizational boundaries, common understanding was usually compromised. In chapter two the coordination practice of *demarcating expertise* was the common response for dealing with unknown situations. When the officers encountered an unknown situation their initial aim was to assess the danger. While each organization has specific procedures for dealing with dangerous situations, the assessment was generally left to the officer with the most expertise. For instance, in situations with hazardous materials this was the Fire Officer, but for assessing the amount of wounded the Medical Officer claimed expertise. The officers actively reinforced knowledge boundaries to demarcate the expertise which reaffirmed their capacity to assess the situation. Reinforcing knowledge boundaries is an important element of expertise coordination, which kept speed in the operation by limiting the necessity for other officers to intervene or question the response. Yet, the indirect consequence of this practice is that when other officers are kept out of the assessment, or literally away from a dangerous area for their own safety, it limited their own capacity to assess the situation. As these officers do have to develop their own understanding of the situation to coordinate the response of their own units, employing this practice led to a multiplicity of interpretations and issue specific coalitions. Multiplicity and coalitions are central aspects of coordination viewed from a fragmentation perspective. This shows that common understanding can be compromised when officers coordinate by reinforcing their knowledge boundaries.

Also in chapter three, when the officers engaged in developing shared representations in the form of boundary objects in field command meetings, discussions about dangerous situations were high on the agenda. To develop a shared understanding of the situation the officers engaged in the coordination mode of *transforming understanding*. What stands out from this chapter is that this coordination mode is only successful for developing shared understanding when the officers are engaging in this mode collectively to bridge the same knowledge boundary. The analysis of the transitions between the coordination modes during the configuration of the boundary object, however, shows that usually different modes are employed simultaneously, to suit different coordination needs. Tailoring the boundary object for coordination is thus a relational process in which actors engage with different intentions. Moreover, developing shared understanding during the coordination process often took too much time when fast action was required,

so the officers preferred to engage in modes of selecting tasks or phasing action so that they could coordinate their own units first. When officers tailored the boundary object from these different coordination modes, transforming understanding was often not successful and multiple interpretations featured that increased equivocality. Equivocality is an important feature of a fragmentation perspective, as it leads to a flux of issue specific coalitions. It shows that even when collectively engaging in developing boundary objects to support cross-boundary coordination, different coordination modes feature which make it difficult to reach shared understanding in field command meetings under high time pressure. When equivocality arises and multiple interpretations feature different issue specific coalitions form that share a specific understanding of the situation. This is not necessarily negative because expertise coordination does enable fast action in turbulent environments. Furthermore, expertise coordination stimulates the officers to negotiate the relevance of their perspective between issue specific coalitions when confronted with differences that compromise the coordination of the response operation. As such, expertise coordination takes place at the level of information and knowledge sharing, and finds its roots in the negotiation of interpretations.

In chapter four I zoomed in on these negotiations between the officers in and around field command meetings, based on the concept of the *'trading zone'*. In this chapter I have linked the idea of boundary work to the formalization of crisis information management systems, based on a sensemaking perspective. To manage the information sharing during emergency response operations information systems are created that support the development of a Common Operational Picture that can be shared and updated at different command centers. Yet, the technology is implemented from a warehouse logic that focuses on the storage of information, but neglects the sensemaking process that is crucial for the enactment of coordination. The findings in this chapter illustrate that during emergency response operations there is often only a limited understanding of what consequences information has for the action and needs of other professionals. Information is not univocal, but equivocal and incorporates different professional languages and is often incomplete as the situation it represents is in constant flux. In addition, information must be made actionable to its different users to support the inter-organizational coordination efforts in emergency response.

Moreover, one representation of information can dominate others. Information from other emergency response organizations is put aside for sake of fast coordination, but this can also marginalize the problems other response organizations face. Disciplines and

experts acquire dominance over other disciplines through building a central narrative about the response operation. However, this narrative can obscure the perspectives of other response organizations that are also relevant. The narrative analysis of meetings that seemingly lead to integration in the first place, actually shows negotiations and contestation during the coordination process. These differences are not always solved or recognized, illustrating some of the power dynamics impeding coordination. Swiftness is required to attend to urgent coordination issues, but not taking enough time to negotiate the meaning of information and be reflexive about its consequences can boomerang the coordination issue in its full strength. Therefore, cross-boundary coordination during emergency response operations is about interpreting information and negotiating its relevance for different professions in a 'trading zone'.

6.1.3 The paradox between centralized and networked coordination

The third paradox originating from the analysis of the Turkish airlines crash in the introduction focuses on the tension between centralized and networked coordination. During response operations the number of actors that need to coordinate their actions often expands beyond the span of control that is arranged in centralized command structures. While command structures provide clear lines of authority for the three key emergency response organizations of fire department, police, and medical services, other actors are not included in these formal lines of command. When the number of additional actors increases centralized coordination lies under increasing pressure as decisions by other stakeholders, taken at different locations, become increasingly relevant. Therefore, centralized coordination is no longer fully possible as the response network exceeds the span of control of the officers in command. As such centralized coordination insufficiently accounts for the decentralization and flexibility that is required during the response operation.

While the network expands beyond the borders of the centralized system, the command structures themselves remain a dominant coordination mechanism, as new partners are attached as liaisons to the command structure. The paradox between centralized and networked coordination entails that while the response systems expands beyond the span of control from the centralized system, it requires a network governance model with a different coordination logic. Networked coordination is based on mutual dependencies and trust instead of formal commands, as the organizations in the network have limited authority on the actions of others. This leads to coordination tensions, as the key response organizations stick to formal command structures and command

meetings, but also become increasingly dependent on the expertise and capacities of other organizations that operate outside the command system.

This paradox features most dominantly in chapter five. Here I have zoomed out towards the network level in the analysis of the multi-organizational response to a fire in the Schiphol train tunnel. The network analysis indicated that the network of response organizations segments at different points in time. As the network segments, various organizations were lacking access to information at different times during the response operation. In these situations boundary work cannot take place, simply because the actors fail to reach each other. The result is that during this incident five full passenger trains are stranded in a train tunnel full of smoke, because the power supply is cut off to allow the fire fighters to explore the tunnel. The misunderstanding between the railway services and the fire department emerged because the Airport Fire Officer on scene was dependent on coordination with the railway emergency operations coordinator, but he was not directly included in his network at crucial decision moments. This situation shows the limited applicability of centralized coordination during response operations, because crucial partners are often situated outside the centralized command system. Even when these actors are included in the network as liaison officers, their operational work practices and procedures tend to deviate, which requires a different coordination approach. In networked coordination actors have to recognize crucial interdependencies that need to be coordinated, and subsequently negotiate their interest to align their actions. Networked coordination thus takes place at the level of information sharing combined with the application of authority or jurisdiction.

6.1.4 Coordination paradoxes as part of a fragmentation perspective

The combination of all four empirical studies shows the multi-layeredness and dynamics of coordination processes during emergency response operations. Coordination is multi-layered because it incorporates coordination of activities, information, expertise, and relations. A combination of these layers that constitute the overall coordination processes is visible in each chapter. While each empirical study is zooming in on different aspects of coordination, in practice these coordination processes occur simultaneously and have a direct impact on each other, like we witnessed in the analysis of the Turkish Airlines crash from the introduction. As such, coordination occurs in an environment that is prone to escalate and where continuous adaptations towards a changing situation are required. Based on these dynamics, cross-boundary coordination cannot be seen as one integrated

whole, or as comprised of several sub-units performing separate tasks in parallel, but has a fragmented nature in which interdependencies are continuously renegotiated and temporally synchronized. These negotiation processes occur in an ambiguous environment, where different sensemaking processes lead to equivocality, that gives rise to a multiplicity of interpretations, and a flux of issue specific coalitions. During the coordination process different practices and coordination modes are employed, and their relevance negotiated, which to a large extend determines whether officers in command engage in attempts to bridge or reinforce the boundaries they are experiencing. Therefore, cross boundary coordination in fast-paced environments is characterized by a *temporal* and *relational negotiation* process. This is a multi-layered process because it occurs at the level of authority, information, action, and knowledge at the same time. It is temporal because interdependencies keep changing. It is relational because interdependencies are redefined in action based on the intentions and needs of the actors that are coordinating. Therefore I regard cross-boundary coordination as: *a temporal and relational process of negotiating what kind of interdependencies shape the interaction beyond a perceived boundary.*

In sum, my analysis of cross-boundary coordination during response operations show that designed, administrative, and centralized coordination cannot be dismissed, but that these elements are taken up and adopted differently in action. Cross-boundary coordination in action takes the shape of an emergent, expertise based, and networked process. This leads to tensions during the coordination process that I have described as paradoxes. These paradoxes are not occurring in isolation, but they also influence each other. The combination of dealing with these three paradoxes leads to a situation in flux and stresses the importance of a fragmentation perspective for explaining cross-boundary coordination in fast-paced environments.

Although I present a fragmentation perspective as an important alternative for the integration perspective on coordination, its normative associations are generally negative. To be regarded as a serious alternative for coordination the term 'fragmentation' requires *amelioration*: the transformation of a negative connotation to a positive one. Fragmentation implies breakage, disconnection, incompleteness, and disjointedness. These are terms that presuppose that an entity once whole has since been broken up and to seek integration is therefore the natural solution to return to the status quo (Chisholm 1989). This requires bringing together the broken parts and disjointed connections into one harmonious whole. Such a normative connotation thus sees a fragmented organizational arrangement as something to be fixed.

If we take the negative connotation of fragmentation away and treat it as the status quo, it's possible to advance a description of cross-boundary coordination that corresponds much closer to the actual coordination dynamics during emergency response operations. During an emergency response operation a multitude of organizations coordinate by constituting a loosely coupled network of emergent interactions. During this coordination process actors make sense of the situation based on deference to expertise, and negotiate the relevance of their perspectives to retain sensitivity to operations. In addition, they actively switch between bridging and reinforcing their boundaries to balance between overcoming differences and retaining speed of operations. When I rearticulate the coordination dynamics during a response operation in terms that are central in my dissertation, the system in need of remedy is absent. This framing requires attention, precisely because it matches much closer to the reality emergency responders experience. Therefore, it's important not to dismiss the fragmentation that we witness as failure, because it is an inevitable aspect of organizing under conditions typical for crises and disasters. Let's not close our eyes to something that has a negative connotation that stems from the misapprehension of the coordination process in the response phase itself. To understand the coordination process in fast-paced and dynamic environments in its full complexity, we need to move beyond the integration bias, and accept that fragmentation is a necessity to cope with the complex set of changing interdependencies that arise during emergencies. This has important implications for how coordination needs to be conceptualized in both organizational, management, and disaster management theories.

6.2 Theoretical Implications for Disaster Management[5]

A parallel can be drawn between the discussion on coordination based on integration and fragmentation, and the current paradigms in traditional sociological disaster management literature. The leading paradigm in disaster management has generally been Chaos, Command and Control. The assumption is that disasters cause 'Chaos',

5 Parts of this section are published in:
Boersma K., J. Ferguson, P. Groenewegen, J. Wolbers. 2014. Beyond the Myth of Control: toward network switching in disaster management. In: S.R. Hiltz, M.S. Pfaff, L. Plotnick, and A.C. Robinson (Eds.), *Proceedings of the 11th International Conference on Information Systems for Crisis Response and Management ISCRAM 2014*. University Park, Pennsylvania, USA, May 2014: 125-129

which can be put under 'Control', by employing a strict centralized 'Command' structure (Quarantelli and Dynes 1977). The command and control paradigm is rooted in military doctrines, and known for its hierarchical decision capacities and clear role structures, and is a powerful instrument for accomplishing tasks characterized by repetition and uniformity. This paradigm has been firmly established in disaster management agencies and as a planning logic for a response operation. It has become the underlying rationale during emergency response operations.

However, based on extensive sociological research into the behavior of affected populations and response management during disasters and crisis situations this control model has proven to be unrealistic decades ago (Dynes 1994, Quarantelli 1997). Recent discussions in disaster management indicate that approaching disaster response merely through command and control (Quarantelli and Dynes 1977) is too limited (Moynihan 2008, Dynes 1994). The command and control paradigm insufficiently accounts for the decentralization and flexibility that are required during response operations in a technically complex and turbulent social environment. In a response to these limitations, a different paradigm developed that finds its roots in networked operations, instead of top-down, bureaucratic organizing: Continuity, Cooperation and Coordination. This alternative model is based on the '*continuation*' of societal and organizational structures after a disaster occurs, despite the severe pressure on these structures. As the capabilities of network partners generally remain in place, responses must be '*coordinated*' with different stakeholders, on the basis of '*cooperation*' to deal with the disaster effects (Dynes 1994, Helsloot and Ruitenberg 2004). A virtue of this paradigm is its decentralized flexibility, but it can underestimate the consequences of slow consensus building in a turbulent environment where fast decisions are necessary to organize coherent and sustainable response operations (Moynihan 2009).

Despite the advances that have been made, the command and control paradigm is still alive and well (Suparamaniam and Dekker 2003). Most of the literature that is based on the command and control paradigm centers around command structures that resemble the logic of the United States 'Incident Command System' (ICS). In the United States, FEMA (Federal Emergency Management Agency) invested profoundly in developing Incident Command Systems as a temporal structure to prevent the next 'disaster-after-the-disaster' (Bigley and Roberts 2001, Moynihan 2009). In ICS the common response for treating ambiguity is resolving it through standardization by defining roles and standard operating procedures. The result is that, as ICS are implemented nation-wide in the US by *standardizing* command systems, it loses the very flexibility that was proclaimed as its initial success during

the Californian bush fires (Boersma et al. 2014). Hence, almost a decade after Hurricane Katrina exposed the shortcomings of the American command system to deal with a large-scale disaster, an elaborate movement towards integration is exactly the development we witness. This is problematic as my results, focusing on relatively bounded situations, are in line with studies that show that in crisis management unambiguous command is needed for the timely direction of the involved units, but at the same time flexibility, on-the-spot decision making and adaptation towards the continuously changing situation are required (Bigley and Roberts 2001, Moynihan 2009, Comfort 2007, Majchrzak et al. 2007). By preparing only for standardization and administration, the command paradigm in the incident command system neglects the importance of flexibility and ongoing adaptation.

While the limits of the command and control paradigm have been documented on several occasions, many studies of disaster management operations still reason based on the command and control paradigm. In these studies the search is for technical solutions that help to overcome the shortcomings of this paradigm (Comfort 2007, Bharosa et al. 2010). There is a strong belief in information technology for delivering the correct information to the command layers, thereby increasing situational awareness for bringing crisis situation under control (Comfort 2007). The information system are often based upon geographical plots, or Geographical Information Systems (GIS), combined with digital situational reports that help to foster overview and 'control'. But, like I have argued in chapter 4, these studies are based on an information warehouse principle, in which the central premise is that gathering accurate information will enable effective coordination.

I contribute to these debates by showing that the information warehousing logic leads to the 'myth of control', which assumes that chaos can be controlled by instating command structures which require sufficient information to build a complete overview of the response operation (Boersma et al. 2014). I have shown that this is problematic because people have different and fluctuating strategies of representing information, and actively negotiate its meaning. Therefore, technological information sharing platforms are not the solution, but might be at best the input for negotiation processes that take place in the trading zone. Furthermore, during the negotiation of information dominant narratives might develop that promote a certain strategy, expertise might raise knowledge boundaries, and segmentation in emergent networks might obstruct the flow of information. Thus, the implication for disaster management literature is not seeking for more ways to harness control, but to look for ways in which the negotiation processes taking place in the trading zone might be supported.

6.3 Theoretical Implications for Organization and Management Science

I will argue for three implications for Organization and Management theories based on the three paradoxes between designed and emergent coordination, administrative and expertise coordination, and centralized and networked coordination. Combined these paradoxes show that cross-boundary coordination is based on a *negotiation* process, which has a *relational* and *temporal* dynamic.

6.3.1 Emergent Coordination: the importance of temporality during negotiation processes
Coordination has often been treated in the literature as pertaining to an 'end state', in which the result of coordination was when interdependencies have been managed and a generally accepted working order has appeared (Okhuysen and Bechky 2009). By treating coordination not as a state to be achieved, but as a temporally unfolding process I have given insight into coordination dynamics. Rapid changes and time critical processes that occur during emergency response operations call for its users to quickly perform the actions that are negotiated in the field. This makes the process of coordination highly contingent on the current state of events. As the emergency response operation unfolds and new information is received, the agreements made moments ago must be adapted, and as such, new information needs arise that stoke the coordination process. These demands for flexibility, speed, and uncertainty that organizations face, make them focus on adaptive capacity rather than specialized routines (Kellogg et al. 2006).

When operating in an environment that is characterized by fluidity, a flexible form of organizing is required to deal with processes which never settle down and are in constant flux (Schreyögg and Sydow 2010) or are chronically 'unfrozen' (Weick 1977). Fluidity enables organizations to adapt to changing environments through reconfiguration of structures and practices. Studies that stress the role of fluidity in organization also reflect on the necessity of certain points of stabilization. Schreyögg and Sydow (2010) argue that organizations cannot be totally fluid, but require at least minimal structure and routines. For its members to understand the ongoing adaptations to the changing environment the organization must establish and maintain some sort of interpretative action patterns. One of the main findings from the analysis of cross-boundary coordination processes during emergency response operations is that these interpretive action patters are made up from a negotiated order of issue specific coalitions. The outcome of negotiation processes

provides a certain level of consolidation in an environment in flux through moments of stabilization. This implies that the negotiations during cross-boundary coordination are necessary to provide the moments of temporal closure that consolidate the coordination process. As this closure is only temporal and occurs simultaneously at different locations around the incident site, it leads to distributed action and deviating interpretations. Negotiation is a key aspect of emergent coordination (Vaughan 1999, Galison 1997). It enables actors to recognize and explore their different positions, and develop a temporal working order. This enables them to act without full consensus, because developing common understanding takes too much time.

6.3.2 Expertise Coordination: the importance of relationality in boundary work

Previous studies have shown that during emergency response operations sensitivity to operations and deference to expertise are key aspects of reliable performance (Weick and Sutcliffe 2011). In my dissertation I have shown that these elements of expertise coordination are relational processes, i.e. they are effectuated by an ongoing interaction between different coordination modes and practices. The concept of relationality is to some extend taken up in the coordination debate in the form of relational coordination (Gittell 2002). However, the way in which Gittell (2002) treats relational coordination is rather static, as she places it next to other coordination mechanisms based on an information processing logic. In the information processing logic coordination mechanisms are categorized from having a low to a high information processing capacity (Lawrence et al 1976, Van de Ven et al. 1976). Procedures have a low information processing capacity, and forms of consultation have a high information processing capacity. Relational coordination is characterized by Gittel (2002) as having a high information processing capacity. This, however, still treats relationality based on its information processing capacity, which can be assessed and measured. This offers a static and objectivistic approach on relationality, and it neglects emergent and more dynamic relations.

The findings in my dissertation show a more dynamic notion of relationality, which cannot be assessed in advance, but arises emergently during the contextualized cross-boundary coordination process at the disaster site. Boundaries form an important aspect of why coordination can be temporarily obstructed in multi-organizational settings. Relationality is key in this process, as actors experience different boundaries during the same coordination process, and therefore can employ different coordination approaches simultaneously. This occurs either through employing different coordination practices,

enacting different coordination modes in the configuration of a boundary object, or negotiating the relevance of information. These findings imply that expertise coordination is not just about how boundaries are perceived, but especially important is how actors together shape the coordinative action beyond a perceived boundary. In accordance with a more dynamic approach on relationality, boundaries are relational and change as they are perceived differently by different actors at different times. An important implication in this dissertation is that during the coordination process boundaries become contested and their relevance is negotiated based on how they are perceived. Next to the dominant idea that boundaries have to be bridged to coordinate interdependencies, I found that also reinstating boundaries is central to coordination (Faraj and Yan 2009). Officers reinstated the functional or knowledge boundaries when they reclaimed their accountability or expertise over certain parts of the response operation. This made other officers aware of these boundaries because differences in responsibility or knowledge were sharpened. Therefore when reinforced, these boundaries became buffers through a strategy of disengagement to limit the actions of other officers. Generally, such strategies are considered to harm the coordination processes, as this limits common understanding and predictability (Okhuysen and Bechky 2009). However, the findings in my dissertation indicate something different. For coordination in fast-paced environment boundary reinforcement can in fact be an effective strategy, because it enables actors to make faster decisions by temporarily keeping others out and thus putting interdependencies 'on hold'. Cross-boundary coordination is thus not only about boundary spanning, but also very much about keeping boundaries in place to force fast action.

6.3.3 Networked Coordination: the importance of time dynamic for assessing coordination in networks

Temporality is an important aspect during emergency response operations. The way in which actors experience time pressure influences at what level they will engage in coordination processes. Especially in social network studies in disaster management time is a crucial factor in the analysis of network dynamics. However, most disaster management network studies depict network relations without making specific references to time (Kapucu 2005). Response networks are normally represented as the summary of relations that occurred over the course of time. Yet, the fast-paced coordination dynamics during emergency response in chapter 5 show the importance of relating communication and coordination network dynamics to the time when they took place. The time slice

analysis of the Schiphol tunnel fire response shows that the network evolved and changed significantly over the course of time. This implies that overall (centrality) measures have a low explanatory value for studying coordination in fast-paced environments, as these centrality values vary significantly across time. This is important, because this entails that network analytical explanations about if actors can or cannot be reached, and through which pathways information can flow, need to be based upon shorter sequences of interaction. Analyzing these temporal structures can provide detailed insights into the evolution of the network. It's important to note that in the dynamic environment of emergency management the network is continuously in a state of becoming, therefore its structural primacy is only temporal and will rapidly change and become obsolete.

In addition, the analysis of network dynamics in chapter 5 indicates that *indirect* ties in relation to their occurrence in time are crucial to understand the coordination dynamics. This adds an important insight to the common premise in social network analysis of disaster response operations: centrality measures that are based upon direct connections miss out coordination dynamics in reference to time that are vital in response networks. In the Schiphol tunnel fire response network emergence is the dominant mode in network formation. This entails that network connections are unstable and show a dynamic of connection and disconnection over time during the construction of the network. It means that when looking at the flow of information based on information pathways, a combination of indirect paths that occur earlier in time can be quicker for information sharing as a direct link between nodes that occurs in a later stage. When calculating centrality measures without the reference of time, these possibilities for indirect information sharing are not taken up in the analysis. When taking in account the network relations according to the time when they took place, it shows a more dynamic and varied network formation process. One can see the emergence of different hubs and cliques, in which the interaction shows a flux of irregular synchronizations of information. Consequently, my analysis implicates that indirect pathways in relation to time need to be analyzed in addition to direct ties, as these may elicit alternative information pathways across the network over time.

6.4 Implications for Practice

Not only does a fragmentation perspective on cross-boundary coordination offer a new perspective for academic debates on cross-boundary coordination, it also has important implications for practice. As is often argued in formal incident evaluations: coordination is the problem and we require better coordination. When we return to the official incident investigations of the Dutch Safety Board (DSB) and the Inspectorate of Justice and Safety (IoJS) on the Turkish Airlines crash used in the introduction, we can recognize the claim that coordination issues appear due to the shortcomings in preparation for and the execution of coordination.

First, both the DSB and the IoJS indicated there was a lack of structure in the command meetings, because an insufficient use of uniform action *protocols* and *standardized* situational reports resulted in a failure to coordinate. According to the IoJS the emergency response was too dependent on the performance of individual actors. In addition the DSB noted that there is a lack in the *design* of national standards for the command of medical response and trauma teams. Second, the IoJS indicated a lack of integrated information management, because incident data was collected on multiple sites and in multiple teams. The IoJS noted that the current work practice did not entail that these data are collected and shared on a *central* location in order to inform all actors and teams (IoJS 2009a, p.28). Third, both investigation boards noted problems with the registration of victims. The IoJS described in detail how changing triage numbers did not reach the Operational Leader, and therefore were not communicated to the Regional Medical Commander. The advice of the IoJS was to increase the *centralization* of the communication towards the Operational Leader. In summary, both investigation boards indicated a lack of centralized control during the operation, and a failure to commit to administrative protocols and victim registration procedures. To prevent these problems from reappearing in future emergency response operations, a better integration of interdependencies is required. As a response to these failures, the Safety Board and the Inspectorate claimed that more effort is needed for preparation and execution of inter-organizational standards.

When looking for the terms highlighted in italic in the previous paragraph, one can see a consistent pattern emerging. All problems and solutions suggested by the investigation boards are based upon the central tenets of the integration perspective: design, administration and centralization. One can try to overcome problems of integration

by advocating more sophisticated integration, but in the end it's very likely that it leads to the repetition of the same tautological conclusions in future incident reports. In general, the emergency management field does not sufficiently recognize that integration is very hard to achieve in a complex and changing environment, and might not be the most feasible way forward.

The results of my PhD dissertation indicate that if we can accept that emergent, expertise and networked coordination are key characteristics of emergency response operations, one can start to prepare and tune the emergency response organization to practice coordination that accounts for fragmentation. Still, it is difficult to provide recommendations to deal with fragmentation, because one of the hallmarks of fragmentation is that its corresponding coordination practices and processes are emergent, they develop temporally and relationally on scene. Thus preparations do not lie in creating structures in advance, but to train for adaptive capacity that can be utilized in the 'hot' response phase. The results of my dissertation provide several clues to the underlying processes that can be trained for. Based on the findings in the previous chapters I will discuss five practical implications:

6.4.1 Allow for coordination based on fragmentation

One of the most important insights from my research is that striving for coordination based on integration is not viable in the fast-paced environment of emergency management. In the preparation phase a lot of attention is paid to procedures, roles and command structures, but as the results of my dissertation show these partly become obsolete during the response operation. In addition to designed, administrative, and centralized coordination, emergency managers have to prepare for emergent, expertise, and networked coordination. This requires a different training that helps to develop skills for negotiation, boundary work, and the management of expertise. Together these aspects can help to increase the flexibility and adaptive capacity that is required for cross-boundary coordination in fast-paced environments. Emergency managers have to account for fragmentation as it is an inevitable part of managing a response operation. This requires more recognition of the inevitability of separate pockets of control, and a multiplicity of interpretations that emerge because of ad-hoc adaptations. Preparing for coordination based on fragmentation will increase awareness amongst field commanders and officers about the importance of emergent adaptations, expert judgment, and changing network relations.

6.4.2 Train for Negotiation and Reflection in Field Command Centers.

In the exercise sessions I studied the focus often was on increasing the speed of the decision-making processes, and on limiting the duration of the overall meeting. In effect, different interpretations of the same information did not always show, because narratives were not completely told, or there was not enough recognition of each other's concerns and needs. The analysis in my dissertation indicates that coordination problems will appear later in the response operation if shared sensemaking processes are neglected. Time is required to allow for reflection and to explicate and negotiate the different interpretations of the situation. Negotiation is a crucial aspect of coordination in fast-paced environments, because during the negotiation process standpoints and positions of actors become clear. This forces the actors that are negotiating to take account of each other's position, which can stimulate better awareness of their motives and demands. Reflexivity is an important aspect of this negotiation process to increase awareness for each other's positions. Enhancing reflexivity can be trained for, based on asking questions as: what am I doing, what can I do, and why do I do that? As negotiations in chapter 4 showed, failing to see the interdependencies with other organizations leads to coordination issues. Reflecting on exercises and training sessions by asking questions of reflexivity allows emergency managers to learn to value the relevance of the perspectives of others. My recommendation is to allow for moments of reflection in the field command meetings to allow officers in command to explicate differences in interpretation. Although I recognize that it is difficult to find a balance between promptness and the quality of decision-making, taking time to negotiate different interpretations can actually support coordination in the long run, and allow the officers in command to win time in the end as misunderstandings might be prevented.

6.4.3 Frame the capacities and limitations of a Common Operational Picture

In the last decade we can witness a sharp increase in the development of technological tools that visualize the progress of the response operation, that are based upon the idea of a Common Operational Picture. The Common Operational Picture (COP) is often introduced as a complete and univocal solution: there is one *common* operational picture that gives a complete overview of the emergency response operation. Yet, the results in my dissertation indicate that the COP cannot adhere to the promise of providing the perfect overview, this is a 'myth of control'. Instead, my findings indicate that information shared on a Common Operational Picture is interpreted differently: coordination is

embedded in sensemaking and negotiation. The COP functions as a boundary object that allows the crisis managers to negotiate the relevance of the information and their understanding of the situation. This idea of the COP as a trading zone, is important to share. The COP is not a solution that provides a complete overview, but a helpful tool in supporting negotiations to develop shared sensemaking. Information is not univocal, but equivocal and needs to be negotiated in order to support the coordination process. It's important to share this framing, and to avoid too mechanistic approaches of the COP that might lead to the myth of control.

6.4.4 Limit the number of officers in command.

Developing a shared situated understanding is an emergent process that can only take place at the incident site. Still, learning the basics of what it takes to coordinate emergency response operations can also take place in advance by shared training sessions and developing knowledge about each other's routines and procedures. Yet, building sufficient knowledge and experience about emergency management operations, stands in sharp contrast to the large number of officers in command that can perform stand-by duties. To develop a more trained and experienced set of officers in command that already know each other, the number of officers that can perform stand-by duties need to be reduced.

6.4.5 Take stock of information flows and network dynamics

In recent incident reports communication patterns are being analyzed by depicting them in network relations, and by developing visual representations of these structures. The advantage of visualizing the communication dynamics is that it gives an idea of the communication network throughout the incident. Still, results in chapter 5 of my dissertation indicate that using static or universal network analysis diagrams to represent the emergence of connections is not accurate enough to depict the network dynamics during the response operation. Static network analysis might lead towards the inaccurate assertion that improving only the direct information flow is key to an effective response. It's important to note that the analysis of information pathways shows that it is especially important to understand network connections in relation to time. When incorporating time dynamics it becomes possible to map the indirect information flow, since indirect paths might prove to be the quickest connections across time periods. Therefore, it is crucial to depict time dynamics in network analysis of emergency response operations.

6.5 Methodological reflection

In this dissertation a have used a diverse set of methods to capture the coordination dynamics during emergency response operations in different ways. As each research method has a specific focus and is tuned towards a particular goal, these choices also come with a cost. I will reflect on the consequences of three important methodological choices I have made.

First, in three empirical studies I have taken an actor perspective and observed and interviewed officers in command about the challenges they experienced when practicing cross-boundary coordination. This gave insight into coordination practices, on scene conversations, actions, and considerations. While zooming in on the cross-boundary coordination dynamics between different actors, I lost overview on the other sections of the response operation. In that respect it's important to consider that the actor view is also a partial view. As I learned in retrospective interviews, these micro level observations are –alone– not sufficient to explain the coordination dynamics, since responders are also limited by access to information and their involvement in decision making cycles. Therefore, I chose in a later stage to develop a combination between detailed micro level data and studying coordination patterns on a network level.

Second, in different chapters I have reflected on the use of exercise observations versus real-life response operations. Scenario-based exercise sessions approach the reality of the disaster response operation as they start with a predefined script, but continue in any possible direction as the events unfold. These exercises differ from training sessions in that events are not interrupted for moments of reflection. Still, the scenarios are removed from reality and therefore may lack the same emotional aspects, decision impact and in some cases delay in the recruitment of units (Latiers and Jacques 2009). The advantage of studying field exercises is that it allowed me to roam around the terrain freely, shadow officers in command, and listen in on their conversations. This would have been impossible to do during real-life response operations, since I would be in the way and risk jeopardizing the response operations itself. To account for the difference between exercises situations and real-life response operations I interviewed the officers in command in retrospect and asked them to reflect on their involvement in recent emergencies. In addition, I have studied disaster reports from the Turkish Airlines crash, Schiphol train tunnel fire, Moerdijk Chemical Fire, and others, to compare the coordination dynamics I observed with the analysis made in these reports. The similarities

between the coordination issues described here, and the once I witnessed in the field exercises convinced me important parallels could be drawn, despite of the differences in pressure and decision impact.

Third, I have researched coordination in emergency response in the Netherlands. While there are mid-sized emergencies in the Netherlands on a regular basis, there are (luckily) no big disasters. Still, it's important to ask what the scope of my findings is in relation to studies on larger disasters. Disaster management literature generally analyses and draws lessons from response operations to large-scale catastrophic events, such as the earthquake in Haiti, the hurricanes Katrina and Sandy in the United States, and the Typhoon Haiyan in the Philippines (Morris et al. 2007, Solnit 2010, Tierney et al. 2006, Van de Walle et al. 2015). During these disasters 'regular' disaster response structures, such as Incident Command Systems, are likely to be compromised. In all of the previous disasters the main challenge was that a large part of the local emergency response infrastructure was also hit and taken out by the disaster. Needless to say the response operation then comes to lie in the hands of other social structures, such as emergent citizen communities, or even international NGO's and United Nations involvement. These response dynamics occur at a total different scale as the response dynamics witnessed in the Netherlands. Still, the micro level and network dynamics that I have witnessed can be of importance, even to these situations. In large-scale catastrophic events actions still have to be coordinated by the remaining networks of communities and the responding international community. Studies of colleagues in the aftermath of Typhoon Haiyan indicated that, for instance, local on-site coordination meetings were set up, that showed similarities to the negotiations in field command meetings I have studied (Van de Walle and Comes 2015). This indicates that field command coordination dynamics are, at heart, not that different, despite the larger magnitude of a disaster. Even in these meetings the same issues are at stake, such as problems with situational awareness, information overload, and coordination neglect. Therefore, despite of the large differences in the magnitude of the situation, I am convinced that analyzing coordination dynamics in field command meetings on a conceptual level, in situations with a smaller scale, also helps to build knowledge that is relevant for explaining coordination dynamics at the incident level during large scale disasters. In addition, fragmentation might be an even more relevant perspective during these large-scale catastrophic events, as the response operation literally takes place in different geographical areas, and is therefore very difficult to coordinate.

6.6 Directions for future research

Now that I have introduced a new perspective on cross-boundary coordination, and argued for its relevance, a new research area appears: how does research into coordination based on a fragmentation perspective look like? I will discuss 3 directions for further research to explore this issue: process analysis, negotiation, and involving citizens in new forms of governance.

6.6.1 Processual studies

One of the central premises in my dissertation is that coordination needs to be regarded as a process. By using a process ontology (Tsoukas and Chia 2002), I departed from the idea that all coordinative action consists of an ongoing flow of interactions. Therefore, one of the most important directions for further research is to increase our toolset to map and explore the nature of these coordination processes (Langley 1999). In this dissertation I have used a mixed methods approach to uncover submerged patterns in conversations streams with the help of Markov analysis and phase charts. In addition, I have uncovered the importance of time in the constitution of communication patterns in an evolving emergency response network. The direction for further research is based on these analytical grounds. To uncover patterns in the coordination processes it is crucial to look for new process methods to acquire a deeper understand of how and why coordination unfolds over time and how boundaries are at play in this process.

An interesting notion is to see how coordination unfolds at different locations simultaneously and how coordination processes influence each other. As I collected most of my data on my own, I only collected observational data about processes in depth at one location in a field command setting. It would be intriguing to collect data on different locations simultaneously to see how processes unfold across different locations and how they influence patterns of distributed action. As one of the main characteristics of emergency response coordination is that actions are distributed and different understandings emerge, a crucial way forward is to unravel this flux. In this flux coordination hotspots arise and disappear again at different locations, based on changing issue specific coalitions. Discovering why and how coordination hotspots emerge at different locations could be an exciting way forward to see how emergent coordination comes into being. In these coordination hotspots the underlying patterns of emergent coordination might be detected by employing different sorts of process methods (Langley 1999).

6.6.2 Pushing forward on the political dimension: negotiation in the trading zone.
On several occasions in the empirical studies power dynamics were at play. In my attempt to unravel the dynamics of coordination in-action during emergency response operations I have emphasized negotiations in the trading zone that are used to give meaning to information and ongoing coordination processes. Instead of the execution of coercive power along hierarchical lines, in the trading zone we witness a more subtle power play that manifests as a continuous struggle for meaning. The trading zone is a space where actors influence the coordination processes by opting for a specific framing of the situation, based on their cognitive and social resources at that time (Vaughan 1999). As the power dimension represents an ongoing and mutually determined interplay between various actors, certain framings are continuously redefined during the negotiations for coordination. In this framing process actors include or exclude others in the coordination process, and use the discussions to legitimate and/or de-legitimize their actions.

In other words, multiple dimensions of power are visible in the coordination process, for example coercion and agenda setting. Yet, according to Lukes (2005) power is at its most effective when least observable, therefore he introduces the third dimension of power: *"the power to prevent people, to whatever degree, from having grievances by shaping their perceptions, cognitions and preferences"* (Lukes 2005, p. 11). During the negotiations in the trading zone we can witness power dynamics at all these three levels: e.g. first, letting the field commander decide what actions to take; second, giving room to specific actors to frame the incident and determine priorities; and third, letting a certain framing about safety dominate the incident response operation so that it is literally stopped by other emergency management organizations without any hesitation. In addition, the perception of boundaries are a key aspect of negotiation during cross-boundary coordination processes. As the relevance of certain types of boundaries are negotiated in the trading zone, they may or may not be depicted on a Common Operational Picture. Therefore, deciding why and when to bridge or reinforce boundaries during cross-boundary coordination might be an additional key aspect in unraveling the power dynamics of cross-boundary coordination.

In future studies such a layered power analysis can help in unraveling the political dimension of emergency response coordination, because power is exercised at multiple levels and manifests in more and less observable modes. The concept of the trading zone can figure as a vocal point that embodies the space of *legitimation* for decision making processes, and a space of *framing*, where novel configurations of ideas and norms about

the response operation arise. Therefore, the exchange of information in the trading zone is not only about *dialogic coordination* (Faraj and Xiao 2006), but is also a *discursive practice* (Foucault 1980) that is based on a historically and culturally specific set of rules for organizing and producing different forms of knowledge. As we learned in previous chapters, negotiation is central to cross-boundary coordination in action. The next step is to analyze in more detail which (unobtrusive) power dynamics are at play that influence the outcome of the negotiation processes.

6.6.3 Smart Governance: moving beyond the boundaries of emergency management organizations [6]

Like the analysis of the Schiphol tunnel fire in chapter 5 already showed, as emergencies become larger multiple sets of stakeholders become involved in the response operation. During disasters, emergent and unforeseen collaborations appear, especially when demands are not met by existing response organizations, or when responses are insufficient or inappropriate (Drabek and McEntire 2003). This idea is also embedded in the Continuity, Coordination and Cooperation paradigm, which entails that emergency management organizations have to make use of existing social structures and collaborate with other stakeholders, local communities, and citizens during the response operation. It is based on the experience that very often your neighbor is the first emergency responder on scene.

Emergent networks fill an important void that cannot be filled by command and control approaches to disaster response (Tierney et al. 2001). Namely, they comprise adaptive, networked partnerships that did not exist before the disaster struck, and can continuously adapt to an environment in flux. At the same time, emergent networks are also characterized by fleeting membership, dispersed leadership, unclear boundaries, and unstable task definitions (Majchrzak et al. 2007). One characteristic of emergent community responses which makes it hard to manage is that these initiatives emerge in a situation where different types of networks co-occur. Emergent community networks have varying functions (e.g. logistics, shelter, aid), and have different origins (e.g.

6 Parts of this section are published in:
Boersma K., J. Ferguson, P. Groenewegen, J. Wolbers. 2014. Beyond the Myth of Control: toward network switching in disaster management. In: S.R. Hiltz, M.S. Pfaff, L. Plotnick, and A.C. Robinson (Eds.), *Proceedings of the 11th International Conference on Information Systems for Crisis Response and Management ISCRAM 2014*. University Park, Pennsylvania, USA, May 2014: 125-129

neighborhood, religious, local (sports)clubs and partly (re)organize in response to disaster, or are reconfigured by key emergent actors to interconnect with one another. Their initiatives are therefore difficult to recognize, govern, and support from within existing response organizations.

As a result, the functioning of distributed, emergent coordination is not yet fully understood (Topper and Carley 1999). Including local communities in the response network and facilitating their efforts is nonetheless a critical aspect of disaster governance. Local involvement potentially enables professional disaster managers to harness the capacities of existing societal structures, leaving local communities to deal with tasks that managers are overburdened with, and allowing managers to focus on other relevant activities. To deal with disaster effects responses must be coordinated by heterogeneous stakeholders, in cooperation with citizens (Dynes 1994, Helsloot and Ruitenberg 2004). Communities thus become part of the disaster manager's resources, since they know how to solve local problems much better than outsiders.

Still, in general, emergency response agencies tend to resort to means of control for protecting the established social structures and to restore public order (Quarantelli and Dynes 1977, Tierney et al. 2006). The paradoxical result is that the resilience of communities during disasters tends to be hampered, rather than supported by government responses, due to their quest for control (Solnit 2010). To impose an authoritarian structure on a disaster is limiting, because it fails to integrate the overall community response. While the command and control remains a powerful instrument for accomplishing tasks characterized by repetition and uniformity, it insufficiently accounts for the response capacity of communities.

Overall, the consequences of citizen participation are still highly unknown (Roberts 2011). How to govern the disaster management operation together with all kinds of social stakeholders, including emergent citizen communities, is an open research issue, that I will attempt tackle as a Postdoctoral Researcher in the coming four years in the NWO awarded smart governance research program: *"Enhancing smart disaster governance: Assessing the potential of the net-centric approach"*.

7. List of Figures

8. List of Tables

9. References

Abbasi, A., N. Kapucu. 2012. Structural dynamics of organizations during the evolution of interorganizational networks in disaster response. *Journal of Homeland Security and Emergency Management*, **9**(1).

Abrahamsson, M., H. Hassel, H. Tehler. 2010. Towards a system-oriented framework for analysing and evaluating emergency response. *Journal of Contingencies and Crisis Management*, **18**(1)14-25.

Akkerman, S. F., A. Bakker. 2011. Boundary crossing and boundary objects. *Review of Educational Research*, **81**(2) 132-169.

Alvesson, M., D. Kärreman. 2007. Constructing mystery: Empirical matters in theory development. *The Academy of Management Review,* **32**(4) 1265-1281.

Andrew, S. A., J. B. Carr. 2013. Mitigating uncertainty and risk in planning for regional preparedness: The role of bonding and bridging relationships. *Urban Studies*, **50**(4)709-724.

Argote, L. 1982. Input uncertainty and organizational coordination in hospital emergency units. *Administrative Science Quarterly*, **27**(3) 420-434.

Artman, H., Y. Wærn. 1999. Distributed cognition in an emergency co-ordination center. *Cognition, Technology & Work*, **1**(4) 237-246.

Barley, S. R., G. Kunda. 2001. Bringing work back in. *Organization Science,* **12**(1) 76-95.

Barley, W. C., P. M. Leonardi, D. E. Bailey. (2012). Engineering objects for collaboration: Strategies of ambiguity and clarity at knowledge boundaries. *Human Communication Research*, **38**(3) 280-308.

Barrett, M., E. Oborn. 2010. Boundary object use in cross-cultural software development teams. *Human Relations,* **63**(8) 1199-1221.

Bechky, B. A. 2003. Sharing meaning across occupational communities: The transformation of understanding on a production floor. *Organization Science,* **14**(3) 312-330.

Bechky, B. A. 2006. Gaffers, gofers, and grips: Role-based coordination in temporary organizations. *Organization Science*, **17**(1) 3-21.

Bechky, B. A., G. A. Okhuysen. 2011. Expecting the unexpected? How SWAT officers and film crews handle surprises. *Academy of Management Journal*, **54**(2), 239-261.

Berlin, J. M., E. D. Carlström. 2011. Why is collaboration minimised at the accident scene? A critical study of a hidden phenomenon. *Disaster Prevention and Management*, **20**(2)159-171.

Bharosa, N., J. Lee, M. Janssen. 2010. Challenges and obstacles in sharing and coordinating information during multi-agency disaster response: Propositions from field exercises. *Information Systems Frontiers*, **12**(1) 49-65.

Bigley, G. A., K. H. Roberts. 2001. The Incident Command System: High-reliability organizing for complex and volatile task environments, *The Academy of Management Journal*, **44**(6) 1281-1299.

Bjørn, P., S. Burgoyne, V. Crompton, T. MacDonald, B. Pickering, S. Munro. 2009. Boundary factors and contextual contingencies: configuring electronic templates for healthcare professionals. *European Journal of Information Systems,* **18**(5) 428-441.

Black, L. J., D. F. Andersen. 2012. Using visual representations as boundary objects to resolve conflict in collaborative model-building approaches. *Systems Research and Behavioral Science,* **29**(2) 194-208.

Boersma, K., P. Wagenaar, J. Wolbers. 2012. Negotiating the trading zone. Creating a shared information infrastructure in the Dutch public safety sector. *Journal of Homeland Security and Emergency Management*, **9**(2) 1-25.

Boersma K., J. Ferguson, P. Groenewegen, J. Wolbers. 2014. Beyond the myth of control: Toward network switching in disaster management. In: S.R. Hiltz, M.S. Pfaff, L. Plotnick, and A.C. Robinson (Eds.), *Proceedings of the 11th International Conference on Information Systems for Crisis Response and Management ISCRAM 2014. University Park, Pennsylvania*, USA, May 2014, 125-129.

Boersma, F. K., L. K. Comfort, J. Groenendaal, J. Wolbers. 2014. Incident Command Systems, A dynamic tension among goals and rules. *Journal of Contingencies and Crisis Management*, **22**(1): 1-4

Bourdieu, P. 1990. *The logic of practice*. Stanford University Press, California.

Boje, D. M. 1991. The storytelling organization: A study of story performance in an office-supply firm. *Administrative Science Quarterly,* **36**(1) 106-126.

Borgatti, S. P., D. S. Halgin. 2011. Analyzing affiliation networks. In: J. Scott and P. J. Carrington, eds. *The SAGE Handbook of Social Network Analysis*. London: SAGE, 417-433.

Bosse, T., C. M. Jonker, L. van der Meij, J. Treur. 2006. A language and environment for analysis of dynamics by simulation. *International Journal on Artificial Intelligence Tools*, **20**(10) 1-31.

Brinberg, D., J. E. McGrath. 1985. *Validity and the research process.* Sage Publications, Thousand Oaks, California.

Broberg, O., V. Andersen, R. Seim. 2011. Participatory ergonomics in design processes: The role of boundary objects. *Applied Ergonomics,* **42**(3) 464-472.

Brown, J. S., P. Duguid. 2001. Knowledge and organization: A social-practice perspective. *Organization Science*, **12**(2) 198-213.

Brusoni, S., A. Prencipe. 2001. Managing knowledge in loosely coupled networks: Exploring the links between product and knowledge dynamics. *Journal of Management Studies*, **38**(7) 1019-1035.

Butts, C., M. Petrescu-Prahova, B. R. Cross. 2007. Responder communication networks in the World Trade Center disaster: Implications for modeling of communication within emergency settings. *Journal of Mathematical Sociology*, **31**(2) 121-147.

Carley, K. M. 2002. *Inhibiting Adaptation*, DTIC Document.

Carlile, P. R. 2002. A pragmatic view of knowledge and boundaries: Boundary objects in new product development. *Organization Science,* **13**(4) 442-455.

Carlile, P. R. 2004. Transferring, translating, and transforming: An integrative framework for managing knowledge across boundaries. *Organization Science,* **15**(5) 555-568.

Choi, S. O., R. S. Brower. 2006. When practice matters more than government plans: A network analysis of local emergency management. *Administration & Society*, **37**(6) 651-678.

Clark, H. H., S. E. Brennan. 1991. Grounding in communication. *Perspectives on Socially Shared Cognition*, **13** 127-149.

Comfort, L. K. 2007. Crisis management in hindsight: Cognition, communication, coordination, and control. *Public Administration Review,* **67**(s1) 189-197.

Comfort, L. K., N. Kapucu. 2006. Inter-organizational coordination in extreme events: The World Trade Center attacks, September 11, 2001. *Natural Hazards,* **39**(2) 309-327.

Conti, N., P. Doreian. 2010. Social network engineering and race in a Police Academy: A longitudinal analysis. *Social Networks*, **32**(1) 30-43.

Cook, A. H. 2009. Towards an emergency response report card: Evaluating the response to the I-35W bridge collapse. *Journal of Homeland Security and Emergency Management*, **6**(1) 1-22.

Cooper, R. 2011. In praise of the prescription: The symbolic and boundary object value of the traditional prescription in the electronic age. *Health Sociology Review,* **20**(4) 462-474.

Copeland, J. 2008. *Emergency response: Unity of effort through a Common Operational Picture*, DTIC Document.

Corbin, J. M., A. L. Strauss. 2008. *Basics of qualitative research: Techniques and procedures for developing grounded theory*. Sage Publications, Thousand Oaks, California.

Chisholm, D. 1989. *Coordination without hierarchy. Informal Structures in Multiorganizational Systems*. University of California Press, Berkeley, United States.

Cross, R., L. Sproull. 2004. More than an answer: Information relationships for actionable knowledge. *Organization Science*, **15**(4) 446-462.

Crowston, K. 1997. A coordination theory approach to organizational process design. *Organization Science*, **8**(2) 157-175.

Czarniawska, B. 2004. On time, space, and action nets. *Organization*, **11**(6) 773-791.

D'Adderio, L. 2001. Crafting the virtual prototype: how firms integrate knowledge and capabilities across organisational boundaries. *Research Policy,* **30**(9) 1409-1424.

Davenport, T. H. 1993. *Process Innovation: Reengineering Work through Information Technology*. Harvard Business Press, Boston, MA.

Dearstyne, B. 2007. The FDNY on 9/11: Information and decision making in crisis. *Government Information Quarterly*, **24**(1) 29-46.

DeSanctis, G., M. S. Poole. 1994. Capturing the complexity in advanced technology use: Adaptive structuration theory. *Organization Science*, **5**(2) 121-147.

Donahue, A. K., R. V. Tuohy 2006. Lessons we don't learn: A study of the lessons of disasters, why we repeat them, and how we can learn them. *Homeland Security Affairs*, **2**(2) 1-28.

Doolin, B., L. McLeod. 2012. Sociomateriality and boundary objects in information systems development. *European Journal of Information Systems,* **21**(5) 570-586.

Drabek, T. E., H. L. Tamminga, T. S. Kilijanek, C. R. Adams. 1981. *Managing multi-organizational emergency responses: Emergent search and rescue networks in natural disaster and remote area settings*. Boulder, CO: Institute of Behavioral Science, University of Colorado.

Drabek, T. E. 1985. Managing the emergency response. *Public Administration Review*, **45**(s1) 85-92.

Drabek, T. E., D. A. McEntire. 2003. Emergent phenomena and the sociology of disaster: lessons, trends and opportunities from the research literature. *Disaster Prevention and Management: An International Journal*, **12**(2) 97-112.

Dutch Safety Board. 2010. *Hulpverlening na vliegtuigongeval Turkish Airlines,*

Haarlemmermeer. 25 Februari 2009, Den Haag.

Dynes, R. R., B. E. Aguirre. 1979. Organizational adaptation to crises: Mechanisms of coordination and structural change. *Disasters*, **3**(1) 71-74.

Dynes, R. R. 1994. Community emergency planning: False assumptions and inappropriate analogies. *International Journal of Mass Emergencies and Disasters*, 12 141-158.

Eckmann, J. P., E. Moses, D. Sergi. 2004. Entropy of dialogues creates coherent structures in e-mail traffic. *Proceedings of the National Academy of Sciences of the United States of America*, **101**(40) 14333-14337.

Eisenhardt, K. M. 1989. Building theories from case study research. *Academy of Management Review*, **14**(4) 532-550.

Endsley, M. R. 1995. Toward a theory of situation awareness in dynamic systems. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, **37**(1) 32-64.

Espinosa, J. A., J. Lerch, R. Kraut. 2004. Explicit vs. implicit coordination mechanisms and task dependencies: One size does not fit all. In: Salas, E., S. M. Fiore (Eds.), *Team cognition: Understanding the factors that drive process and performance*, 107-129. APA Books, Washington, United States.

Everett, M. G., S. P. Borgatti 2005. Extending centrality. *Models and Methods in Social Network Analysis*, **35**(1) 57-76.

Faraj, S., Y. Xiao. 2006. Coordination in fast-response organizations. *Management Science*, **52**(8) 1155-1169.

Faraj, S., A, Yan. 2009. Boundary work in knowledge teams. *Journal of Applied Psychology*, **94**(3) 604-617.

Faraj, S., L. Sproull. 2000. Coordinating expertise in software development teams. *Management Science*, **46**(12) 1554-1568.

Fayol, H. 1949. *General and industrial administration*. Pitman, New York, United States.

Feldman, M. S., W. J. Orlikowski. 2011. Theorizing practice and practicing theory. *Organization Science*, **22**(5) 1240-1253.

FEMA. 2009. *National Incident Management System (NIMS) Student Manual IS-700.A. Communication and Information Management*.

Foucault, M. 1980. *Power/knowledge: Selected interviews and other writings*, 1972-1977. Pantheon.

Fujimura, J. H. 1992. Crafting science: Standardized packages, boundary objects, and "translation". A. Pickering, eds. *Science as practice and culture*, The University of Chicago Press, Chicago, 168-211.

Gabriel, Y. 2000. *Storytelling in organizations: facts, fictions, and fantasies*. Oxford University Press, Oxford, NC.

Galbraith, J. 1973. *Designing complex organizations*. Addison Wesley, Reading.

Galison, P. 1997. *Image and logic: A material culture of microphysics*. The University of Chicago Press, Chicago, IL.

Genschel, P. 1997. How fragmentation can improve co-ordination: setting standards in international telecommunications. *Organization Studies*, **18**(4), 603-622.

Gkeredakis, E. 2014. The constitutive role of conventions in accomplishing coordination: Insights from a complex contract award project. *Organization Studies*, **35**(10) 1473-1505.

Gillespie, D. F., S. A. Murty. 1994. Cracks in a post disaster service delivery network. *American Journal of Community Psychology*, **22**(5) 639-660.

Gioia, D. A., K. G. Corley, A. L. Hamilton. 2012. Seeking rigor in inductive research: Notes on Gioia methodology. *Organizational Research Methods*, **16**(1) 15-31.

Gittell, J. H. 2002. Coordinating mechanisms in care provider groups: Relational coordination as a mediator and input uncertainty as a moderator of performance effects. *Management Science*, **48**(11) 1408-1426.

Hammersley, M. 1995. *Ethnography: Principles in Practice*. Routledge, NY.

Harris, J. K., B. Clements. 2007. Using Social Network Analysis to understand Missouri's system of public health emergency planners. *Public Health Reports*, **122**(4) 488-498.

Harrison, S. H., E. D. Rouse. 2014. Let's dance! Elastic coordination in creative group work: A qualitative study of modern dancers. *Academy of Management Journal*, **57**(5), 1256-1283.

Heath, C., N. Staudenmayer. 2000. Coordination neglect: How lay theories of organizing complicate coordination in organizations. *Research in organizational behavior*, **22** 153-191.

Helsloot, I., A. Ruitenberg. 2004. Citizen response to disasters: a survey of literature and some practical implications. *Journal of Contingencies and Crisis Management*, **12**(3) 98-111.

Henderson, K. 1991. Flexible sketches and inflexible data bases: Visual communication, conscription devices, and boundary objects in design engineering. *Science, Technology and Human Values*, **16**(4) 448-473.

Hensgen, T., K. C. Desouza, M. Durland. 2006. Initial crisis agent-response impact syndrome (ICARIS). *Journal of Contingencies and Crisis Management*, **14**(4) 190-198.

Hossain, L., M. Kuti. 2010. Disaster response preparedness coordination through social networks. *Disasters*, **34**(3) 755-786.

Houghton, R. J., C. Baber, R. McMaster, N. A. Stanton, P. Salmon, R. Stewart. 2006. Command and Control in emergency services operations: a social network analysis. *Ergonomics*, **49**(12) 1204-1225.

Houghton, P., D. K. Leedom, J. Miles. 2002. *Command information infrastructure and sense-making*. Paper presented at the 7th International Command and Control Research and Technology Symposium, September, Quebec City, Canada.

Hsiao, R. L., D. H. Tsai, C. F. Lee. 2012. Collaborative knowing: The Aadaptive nature of cross-boundary spanning. *Journal of Management Studies*, **49**(3) 463-491.

Huvila, I. 2011. The politics of boundary objects: hegemonic interventions and the making of a document. *Journal of the American Society for information Science and Technology*, **62**(12) 2528-2539.

Inspectorate of Security and Justice. 2009a. *Poldercrash 25 Februari 2009*. Een onderzoek door de Inspectie Openbare Orde en Veiligheid in samenwerking met de Inspectie voor de Gezondheidszorg. IOOV, Den Haag.

Inspectorate of Security and Justice. 2009b. *Calamity in the Schiphol tunnel*. Research towards the response to a fire call. IOOV, Den Haag.

Inspectorate of Security and Justice. 2011a. *Brand Strabrechtse Heide. Deel 1 De hoofdstructuur van de rampenbestrijding*. IOOV, Den Haag.

Inspectorate of Security and Justice. 2011b. *Brand Chemie-Pack Moerdijk*. IOOV, Den Haag.

Janssen, M., J. Lee, N. Bharosa, A. Cresswell. 2010. Advances in multi-agency disaster management: Key elements in disaster research. *Information Systems Frontiers*, **12**(1) 1-7.

Jarzabkowski, P. A., J. K. Lê, M. S. Feldman. 2012. Toward a theory of coordinating: Creating coordinating mechanisms in practice. *Organization Science*, **23**(4) 907-927.

Kapucu, N. 2005. Interorganizational Coordination in dynamic context: Networks in emergency response management. *Connections*, **26**(2) 33-48.

Kapucu, N. 2006. Interagency communication networks during emergencies: Boundary spanners in multiagency coordination. *The American Review of Public Administration*, **36**(2) 207-225.

Kapucu, N. 2009. Interorganizational coordination in complex environments of disasters: The evolution of intergovernmental disaster response systems. *Journal of Homeland Security and Emergency Management*, **6**(1).

Kapucu, N. 2011. Collaborative governance in international disasters: Nargis cyclone in Myanmar and Sichuan earthquake in China cases. *International Journal of Emergency Management*, 8(1) 1-25.

Kapucu, N., F. Demiroz. 2011. Measuring performance for collaborative public management using network analysis methods and tools. *Public Performance & Management Review*, 34(4) 549-579.

Kapucu, N., V. Garayev 2013. Designing, managing, and sustaining functionally collaborative emergency management networks. *American Review of Public Administration*, 43(3) 312-330.

Kapucu, N., T. Arslan, M. L. Collins. 2010. Examining intergovernmental and interorganizational response to catastrophic disasters: Toward a network-centered approach. *Administration and Society*, 42(2) 222-247.

Kapucu, N., T. Bryer, V. Garayev, T. Arslan. 2010. Interorganizational network coordination under stress caused by repeated threats of disasters. *Journal of Homeland Security and Emergency Management*, 7(1).

Kellogg, K. C., W. J. Orlikowski, J. Yates. 2006. Life in the trading zone: Structuring coordination across boundaries in postbureaucratic organizations. *Organization Science,* 17(1) 22-44.

Kettl, D. F. 2003. Contingent coordination practical and theoretical puzzles for Homeland Security. *The American Review of Public Administration*, 33(3) 253-277.

Kim, K. D., L. Hossain, S. Uddin. 2013. Situated response and learning of distributed bushfire coordinating teams. *Journal of Homeland Security and Emergency Management*, 10(1).

Kimble, C., C. Grenier, K. Goglio-Primard. 2010. Innovation and knowledge sharing across professional boundaries: Political interplay between boundary objects and brokers. *International Journal of Information Management,* 30(5) 437-444.

Klein, K. J., J. C Ziegert., A. P. Knight, Y. Xiao. 2006. Dynamic delegation: Shared, hierarchical, and deindividualized leadership in extreme action teams. *Administrative Science Quarterly*, 51(4), 590-621.

Koenig, K. L., C. H. Schultz. 1994. Disaster medicine: Advances in local catastrophic disaster response. *Academic Emergency Medicine*, 1(2) 133-136.

Kossinets, G., J. Kleinberg, D. Watts. 2008. The Structure of information pathways in a social communication network. *Proceeding of the 14th ACM SIGKDD International Conference on Knowledge Discovery and Data Mining*, ACM, New York.

Lamont, M., V. Molnár. 2002. The study of boundaries in the social sciences. *Annual review of sociology*, **28**(1) 167-195.

Langley, A., J. Truax. 1994. A process study of new technology adoption in smaller manufacturing firms. *Journal of Management Studies*, **31**(5) 619-652.

Langley, A. 1999. Strategies for theorizing from process data. *The Academy of Management Review,* **24**(4) 691-710.

Langley, A., C. Smallman, H. Tsoukas, A. H. Van de Ven. 2013. Process studies of change in organization and management: unveiling temporality, activity, and flow. *Academy of Management Journal*, **56**(1) 1-13.

Latiers, M., J. M. Jacques. 2009. Emergency and crisis exercises: methodology for understanding safety dimensions. *International Journal of Emergency Management,* **6**(1) 73-84.

Lave, J., E. Wenger. 1990. *Situated learning: Legitimate peripheral participation*. Cambridge University Press, Cambridge, United Kingdom.

Lawrence, P. R., J. W. Lorsch, J. S. Garrison. 1967. *Organization and environment: Managing differentiation and integration*. Division of Research, Graduate School of Business Administration, Harvard University, Boston.

Lee, C. P. 2007. Boundary negotiating artifacts: Unbinding the routine of boundary objects and embracing chaos in collaborative work. *Computer Supported Cooperative Work (CSCW)*, **16**(3) 307-339.

Leedom, D. K. 2003. Functional Analysis of the next generation Common Operating Picture. *Analysis*, **69**(2) 149-163.

Leonardi, P. M. 2011. Innovation blindness: Culture, frames, and cross-boundary problem construction in the development of new technology concepts. *Organization Science,* **22**(2) 347-369.

Levina, N., E. Vaast. 2005. The emergence of boundary spanning competence in practice: implications for implementation and use of information systems. *MIS Quarterly*, **29**(2) 335-363.

Lind, B. E., M. Tirado, C. T. Butts, M. Petrescu-Prahova. 2008. Brokerage roles in disaster response: organisational mediation in the wake of Hurricane Katrina. *International Journal of Emergency Management*, **5**(1) 75-99.

Lindkvist, L., J. Soderlund, F. Tell. 1998. Managing product development projects: on the significance of fountains and deadlines. *Organization Studies,* **19**(6) 931-951.

Loosemore, M., W. P. Hughes. 2001. Confronting social defense mechanisms: Avoiding disorganisation during crises. *Journal of Contingencies and Crisis Management*, **9**(2) 73-87.

Lukes, S. 2005. Power: A radical view (2nd). Palgrave Macmillan, Hampshire, United Kingdom.

Mackintosh, N., J. Sandall. 2010. Overcoming gendered and professional hierarchies in order to facilitate escalation of care in emergency situations: The role of standardised communication protocols. *Social Science & Medicine,* **71**(9) 1683-1686.

Maitlis, S., S. Sonenshein. 2010. Sensemaking in crisis and change: Inspiration and insights from Weick (1988). *Journal of Management Studies*, **47**(3) 551-580.

Majchrzak, A., S. L. Jarvenpaa, A. B. Hollingshead. 2007. Coordinating expertise among emergent groups responding to disasters. *Organization Science*, **18**(1) 147-161.

Majchrzak, A., P. H. More, S. Faraj. 2012. Transcending knowledge differences in cross-functional teams. *Organization Science*, **23**(4) 951-970.

Malone, T. W., K. Crowston. 1994. The interdisciplinary study of coordination. *ACM Computing Surveys*, **26**(1) 87-119.

Manzi, C., M .J. Powers, K. Zetterlund. 2002. *Critical information flows in the Alfred P. Murrah Building bombing: A case study*, Chemical and Biological Arms Control Institute, Washington, D.C.

March, J. G., H. A. Simon. 1958. *Organizations*. Wiley, New York.

Marincioni, F. 2007. Information technologies and the sharing of disaster knowledge: The critical role of professional culture. *Disasters*, **31**(4) 459-476.

Marks, M. A., J. E. Mathieu, S. J. Zaccaro. 2001. A temporally based framework and taxonomy of team processes. *Academy of Management Review,* **26**(3) 356-376.

Martens, B. V. 2011. Approaching the anti-collection. *Library Trends,* **59**(4) 568-587.

Martin, J. 1992. *Cultures in organizations: Three perspectives*. Oxford University Press, Oxford, United Kingdom.

Matthews, J. P. 1970. A central limit theorem for absorbing markov chains, *Biometrika*, **57**(1) 129-139.

McGrath, J. E., J. Martin, R. A. Kulka. 1982. *Judgment calls in research*. Sage Publications, Beverly Hills, California.

Meissner, A., T. Luckenbach, T. Risse, T. Kirste, H. Kirchner. 2002. *Design challenges for an integrated disaster management communication and information system*. Paper presented at the First IEEE Workshop on Disaster Recovery Networks (DIREN 2002).

Mendonca, D., W. A. Wallace. 2004. Studying organizationally-situated improvisation in response to extreme events. *International Journal of Mass Emergencies and Disasters*, **22**(2) 5-30.

Meyer, R. E., M. A. Höllerer, D. Jancsary, T. van Leeuwen. 2013. The visual dimension in organizing, organization, and organization research: Core ideas, current developments, and promising avenues. *The Academy of Management Annals*, **7**(1) 487-553.

Militello, L. G., E. S. Patterson, L. Bowman, R. Wears. 2007. Information flow during crisis management: Challenges to coordination in the emergency operations center. *Cognition, Technology & Work*, **9**(1) 25-31.

Moody, J., D. McFarland, S. Bender-deMoll. 2005. Dynamic network visualization. *American Journal of Sociology*, **110**(4) 1206–1240.

Moore, S., E. Eng, M. Daniel. 2003. International NGOs and the role of network centrality in humanitarian aid operations: A case study of coordination during the 2000 Mozambique floods. *Disasters*, **27**(4) 305-318.

Morris, J. C., E. D. Morris, D. M. Jones. 2007. Reaching for the philosophers stone: Contingent coordination and the military response to hurricane Katrina. *Public Administration Review*, **67**(s1) 94-106.

Moynihan, D. P. 2008a. Combining structural forms in the search for policy tools: Incident Command Systems in US crisis management. *Governance*, **21**(2) 205-229.

Moynihan, D. P. 2008b. Learning under uncertainty: Networks in crisis management. *Public Administration Review*, **68**(2) 350–365.

Moynihan, D. P. 2009. The network governance of crisis response: Case studies of Incident Command Systems. *Journal of Public Administration Research and Theory*, **19**(4) 895-915.

Neal, D. M., B. D. Phillips. 1995. Effective emergency management: Reconsidering the bureaucratic approach. *Disasters*, **19**(4) 327-337.

Netten, N., M. van Someren. 2011. Improving communication in crisis management by evaluating the relevance of messages. *Journal of Contingencies and Crisis Management*, **19**(2) 75-85.

Nicolini, D. 2009. Zooming in and out: Studying practices by switching theoretical lenses and trailing connections. *Organization Studies,* **30**(12) 1391-1418.

Nicolini, D. 2012. *Practice theory, work, and organization: An introduction*. Oxford University Press, Oxford, United Kingdom.

Nolen, S. B., I. S. Horn, C. J. Ward, S. A. Childers. 2011. Novice teacher learning and motivation across contexts: assessment tools as boundary objects. *Cognition and Instruction,* 29(1) 88-122.

Okhuysen, G. A., K. D. Elsbach. 2005. Understanding group behavior: How a police SWAT team creates, changes, and manages group routines. *Qualitative Organizational Research*, 139-168.

Okhuysen, G. A., B. A. Bechky. 2009. Coordination in organizations: An integrative perspective. *The Academy of Management Annals,* 3(1) 463-502.

Orlikowski, W. J. 2000. Using technology and constituting structures: A practice lens for studying technology in organizations. *Organization Science*, 11(4) 404-428.

Orlikowski, W. J. 2002. Knowing in practice: Enacting a collective capability in distributed organizing. *Organization Science,* 13(3) 249-273.

Orr, J. E. 1998. Images of work. *Science, Technology and Human Values*, 23(4) 439-455.

O'Toole, L. J. 1997. Treating networks seriously: Practical and research-based agenda's in Public Administration. *Public Administration Review*, 57(1) 45-52.

Passenier, D., J. Molle, J. Wolbers, K. Boersma, P. Groenewegen (2012) Formalization of crisis response coordination from a public inquiry report. In: L. Rothkrantz, J. Ristvej and Z. Franco, eds. *Proceedings of the 9th International Conference on Information Systems for Crisis Response and Management ISCRAM*. Vancouver, 1–5.

Pickering, A. 2003. On becoming: imagination, metaphysics and the mangle. D. Ihde, E. Selinger, eds. *Chasing technoscience: Matrix for materiality*, Indiana University Press, Bloomington, Indiana, 96-116.

Poehls, K. 2010. Zeitgeisty Exhibits? Migration, a boundary object in the museum. *Zeitschrift Fur Volkskunde,* 106(2) 225-245.

Poole, M. S., A. H. Van De Ven. 1989. Using paradox to build management and organization theories, *The Academy of Management Review*, 14(4) 562-578.

Poole, M. S., A. H. Van de Ven, K. Dooley, M. E. Holmes. 2000. *Organizational change and innovation processes: Theory and methods for research*. Oxford University Press, New York, New York.

Putnam, L. L. 1994. Productive conflict: Negotiation as implicit coordination. *International Journal of Conflict Management*, 5(3) 284-298.

Quarantelli, E. L., R. R. Dynes. 1977. Response to social crisis and disaster, *Annual Review of Sociology*, 3 23-49.

Quarantelli, E. L. 1997. Problematical aspects of the information and communication revolution for disaster planning and research: Ten non-technical issues and questions. *Disaster Prevention and Management*, **6**(2) 94-106.

Rake, E. L., O. Nja. 2009. Perceptions and performances of experienced incident commanders. *Journal of Risk Research*, **12**(5) 665-685.

Reagans, R., L. Argote, D. Brooks. 2005. Individual experience and experience working together: Predicting learning rates from knowing who knows what and knowing how to work together. *Management Science*, **51**(6) 869-881.

Rico, R., M. Sánchez-Manzanares, F. Gil, C. Gibson. 2008. Team implicit coordination processes: A team knowledge–based approach. *Academy of Management Review*, **33**(1) 163-184.

Riessman, C. K. 2005. Narrative Analysis, in: Kelly, N., C. Horrocks, K. Milnes, B. Roberts, D. Robinson (eds.), *Narrative, Memory Everyday Live*, University of Huddersfield, Huddersfield, 1-7.

Rimstad, R., S. J. Sollid. 2015. A retrospective observational study of medical incident command and decision-making in the 2011 Oslo bombing. *International Journal of Emergency Medicine*, **8**(1) 1-10.

Roberts, N. C. 2011. Beyond smokestacks and silos: Open source, web enabled coordination in organizations and networks, *Public Administration Review*, **71**(5) 677-693.

Sanchez, R., J. T. Mahoney. 1996. Modularity, flexibility, and knowledge management in product and organization design. *Strategic Management Journal*, **17**(s2) 63-76.

Sapsed, J., A. Salter. 2004. Postcards from the edge: local communities, global programs and boundary objects. *Organization Studies,* **25**(9) 1515-1534.

Schatzki, T. R., K. Knorr-Cetina, E. von Savigny (Eds.). 2001. *The practice turn in contemporary theory*. Psychology Press, London.

Scheff, T. J. 1967. Toward a sociological model of consensus. *American Sociological Review*, **32**(1), 32-46.

Scholtens, A. 2008. Controlled collaboration in disaster and crisis management in the Netherlands, History and practice of an overestimated and underestimated concept. *Journal of Contingencies and Crisis Management*, **16**(4) 195-207.

Schön, D. A. 1983. *The reflective practitioner: How professionals think in action*. Basic Books, New York.

Schön, D. A. 1987. *Educating the reflective practitioner*. Jossey-Bass, San Francisco.

Schooley, B. L., T. A. Horan. 2007. Towards end-to-end government performance management: Case study of inter-organizational information integration in Emergency Medical Services (EMS). *Government Information Quarterly*, 24(4) 755-784.

Schraagen, J. M., M. H. Veld, L. De Koning. 2010. Information sharing during crisis management in hierarchical vs. network teams. *Journal of Contingencies and Crisis Management*, 18(2) 117-127.

Schreyögg, G., J. Sydow. 2010. Crossroads: Organizing for fluidity? Dilemmas of new organizational forms. *Organization Science*, 21(6) 1251-1262.

Srikanth, K., P. Puranam. 2011. Integrating distributed work: comparing task design, communication, and tacit coordination mechanisms. *Strategic Management Journal*, 32(8) 849-875.

Schwartz-Shea, P., D. Yanow. 2009. Reading and writing as method: in search of trustworthy texts. S. Ybema, D. Yanow, H. Wels, F. Kamsteeg, eds. *Organizational Ethnography: Studying the Complexities of Everyday Life.* Sage Publications Ltd., London, 56-82.

Sinha, K. K., A. H. Van de Ven. 2005. Designing work within and between organizations. *Organization Science*, 16(4) 389-408.

Smith, W. K., M. W. Lewis. 2011. Toward a theory of paradox: A dynamic equilibrium model of organizing, *Academy of Management Review*, 36(2) 381-403.

Solnit, R. 2010. *A paradise built in hell: The extraordinary communities that arise in disaster*. Viking, New York, United States.

Star, S. L. 2010. This is not a boundary object: Reflections on the origin of a concept. *Science, Technology and Human Values,* 35(5) 601-617.

Star, S. L., J. R. Griesemer. 1989. Institutional ecology, 'translations' and boundary objects: Amateurs and professionals in Berkeley's Museum of Vertebrate Zoology, 1907-39. *Social Studies of Science,* 19(3) 387-420.

Strauss, A., J. M. Corbin. 1990. *Basics of qualitative research: Grounded theory procedures and techniques.* Sage Publications Incorporate, California, United States.

Stuurman, M. (2011), *Crisis management and actionable knowledge*. Master thesis, VU Amsterdam. http://www.ubvu.vu.nl/pub/fulltext/scripties/26_1963538.pdf (accessed 18 September 2013).

Subrahmanian, E., I. Monarch, S. Konda, H. Granger, R. Milliken, A. Westerberg. 2003. Boundary objects and prototypes at the interfaces of engineering design. *Computer Supported Cooperative Work (CSCW),* 12(2) 185-203.

Suparamaniam, N., S. Dekker. 2003. Paradoxes of power: The separation of knowledge and authority in international disaster relief work. *Disaster Prevention and Management: An International Journal*, **12**(4) 312-318.

Taber, N., D. Plumb, S. Jolemore. 2008. Grey areas and organized chaos in emergency response. *Journal of Workplace Learning*, **20**(4) 272-285.

Taylor, F. W. 1914. *The principles of scientific management*. Harper.

Teddlie, C., A. Tashakkori. 2009. *Foundations of mixed methods research: Integrating quantitative and qualitative approaches in the social and behavioral sciences*. Sage Publications, California.

Thompson, J. D. 1967. *Organizations in action: Social science bases of administration*. McGraw Hill, Chicago.

Tierney, K. J. 1985. Emergency medical preparedness and response in disasters: The need for inter-organizational coordination. *Public Administration Review*, **45**(S1) 77-84.

Tierney, K .J., M. K. Lindell, R. W. Perry 2001. *Facing the unexpected. Disaster preparedness and response in the United States*, Joseph Henry Press, Washington, United States.

Tierney, K. J., C. Bevc, E. Kuligowski. 2006. Metaphor matters: Disaster myths, media frames, and their consequences in hurricane Katrina, *The ANNALS of the American Academy of Political and Social Science*, **604**(1) 57-81.

Topper, C. M., K. M. Carley (1999) A structural perspective on the emergence of network organizations. *Journal of Mathematical Sociology*, **24**(1) 67-96.

Trompette, P., D. Vinck. 2009. Revisiting the notion of boundary object. *Revue d'anthropologie des connaissances*, **3**(1) 3-25.

Tsoukas, H., R. Chia. 2002. On organizational becoming: Rethinking organizational change. *Organization Science*, **13**(5), 567-582.

Uddin, S., L. Hossain. 2011. Disaster coordination preparedness of soft target organizations. *Disasters*, **35**(3) 623-638.

Uhr, C., H. Johansson. 2007. Mapping an emergency management network. *International Journal of Emergency Management*, **4**(1) 104-118.

Uhr, C., H. Johansson, L. Fredholm. 2008. Analysing emergency response systems. *Journal of Contingencies and Crisis Management*, **16**(2) 80-90.

Van De Ven, A. H., A. L. Delbecq, R. Koenig. 1976. Determinants of coordination modes within organizations, *American Sociological Review*, **41**(2), 322-338.

Van de Walle, B., T. Comes. 2015. *A Journey into the information typhoon. Typhoon Haiyan DRL Field Report Findings and Research Insights December 2013, Part 2 The Role of Information*. Disaster Resilience Lab, Tilburg, The Netherlands.

Vasavada, T. 2013. Managing disaster networks in India. A study of structure and effectiveness. *Public Management Review*, **15**(3) 363-382.

Vaughan, D. 1999. The role of organization in the production of techno-scientific knowledge. *Social Studies of Science*, **29**(6) 913-943.

Walle, B., M. Turoff. 2008. Decision support for emergency situations. *Handbook on Decision Support Systems*, **2** 39-63.

Watson-Manheim, M. B., K. M. Chudoba, K. Crowston. 2012. Perceived discontinuities and constructed continuities in virtual work. *Information Systems Journal*, **22**(1) 29-52.

Wassermann, S., K. Faust. 1994. *Social network analysis: Methods and applications*. New York: Cambridge University Press.

Waugh, W. L., G. Streib. 2006. Collaboration and leadership for effective emergency management. *Public Administration Review*, **66**(s1) 131-140.

Weber, K., M. A. Glynn. 2006. Making sense with institutions: Context, thought and action in Karl Weick's theory. *Organization Studies*, **27**(11) 1639-1660.

Weick, K. E. 1977. Organization design: Organizations as self-designing systems. *Organizational Dynamics*, **6**(2) 31-46.

Weick, K. E. 1990. The vulnerable system: An analysis of the Tenerife air disaster. *Journal of Management*, **16**(3) 571-593.

Weick, K. E. 1993. The collapse of sensemaking in organizations: The Mann Gulch disaster. *Administrative Science Quarterly*, **38**(4) 628-652.

Weick, K. E., K. H. Roberts. 1993. Collective mind in organizations: Heedful interrelating on flight decks. *Administrative Science Quarterly*, **38**(3) 357-381.

Weick, K. E. 1995. *Sensemaking in Organizations*, Sage Publications Incorporated, Thousand Oaks, CA.

Weick, K. E., K. M. Sutcliffe, D. Obstfeld. 1999. Organizing for high reliability: processes of collective mindfulness. *Research in Organizational Behavior*, **1** 81-123.

Weick, K. E., K. M. Sutcliffe, D. Obstfeld. 2005. Organizing and the process of sensemaking. *Organization Science*, **16**(4) 409-421.

Weick, K. E., K. M. Sutcliffe. 2011. *Managing the unexpected: Resilient performance in an age of uncertainty* (Vol. 8). John Wiley & Sons, San Francisco, United States.

Wenger, E. 2000. Communities of practice and social learning systems. *Organization,* **7**(2) 225-246.

Wolbers, J., K. Boersma, J. de Heer. 2012. *Netcentrisch werken in ontwikkeling*. De Swart, Den Haag.

Wolbers, J., K. Boersma. 2013. The Common Operational Picture as collective sensemaking, *Journal of Contingencies and Crisis Management*, **21**(4) 186-199.

Yakura, E. K. 2002. Chartering time: Timelines as temporal boundary objects. *The Academy of Management Journal,* **45**(5) 956-970.

Yanow, D. 1997. Passionate humility in interpretive policy and administrative analysis. *Administrative Theory and Praxis*, 19(2) 171-177.

Yanow, D., P. Schwartz-Shea. 2006. *Interpretation and method: Empirical research methods and the interpretive turn*. ME Sharpe Inc., New York, NY.

Ybema, S., D. Yanow, H. Wels, and F. H. Kamsteeg (Eds.). 2009. *Organizational ethnography: Studying the complexity of everyday life*. Sage, London.

Zeiss, R., P. Groenewegen. 2009. Engaging boundary objects in OMS and STS? Exploring the subtleties of layered engagement. *Organization,* **16**(1) 81-100.

Summary

When disaster strikes the common perception is that *chaos* arises and emergency response organizations need to put the situation under *control* by employing a centralized *command* structure. 'Command and Control' is the dominant paradigm for many disaster theories and for the response organizations themselves. However, current studies in disaster sociology have proven this idea of control to be unrealistic. Disasters generally do not end up in chaos. Instead the capabilities of societal and organizational structures remain in place, whilst being put under pressure. The relief effort thus requires *coordination* and *cooperation* with different stakeholders in a network of responding organizations. Therefore the following question is central in this PhD dissertation: *how do emergency responders coordinate the response operation across the boundaries of their organizations in fast paced environments?*

The results of this research indicate that while in the preparation phase for emergencies organizational designs are created, plans and protocols are administrated, and centralized command structures are instated, a different coordination approach appears during the response operation itself. In four empirical chapters I build up an account which illustrates that cross-boundary coordination during emergency response is based upon emergent adaptation, deference to expertise, and spontaneous networking across the boundaries of organizations in response to changing interdependencies. Crisis managers require these practices to deal with unexpected situations and unknown threats they encounter in emergency response operations.

On a theoretical level this offers counter intuitive evidence to conceptualize coordination processes in fast-paced environments. The dominant coordination approach articulates that coordination is achieved through integration based on three conditions: accountability, predictability and common understanding. In contrast, my results indicate that crisis managers cope with the fast paced environment by engaging in coordination processes that are rooted in conditions of *fragmentation*. Fragmentation often has a negative connotation of disconnectedness and failure. Yet, in this dissertation I show that fragmentation is not necessarily negative, and matches much closer to the reality experienced by crisis managers on the disaster scene. This is the case as crisis managers are inclined to reinforce the functional, knowledge, and normative boundaries they encounter, instead of bridging them. This allows them to demarcate their responsibilities, engage in continuous adaptation, and employ their expertise, to keep sufficient speed

and flexibility in the response operation.

Fragmentation is not only identified in the crisis managers' work practice, but it also appears during a second study focusing on the drawing of maps of the disaster scene. Maps of the disaster scene are commonly used in command centers to develop situational awareness. The professional term for these maps is a *common operational picture*. The common operational picture can be regarded as a boundary object, because it allows crisis managers to bridge the boundaries between them by engaging with the object. By looking into the language crisis managers use to discuss their interdependencies whilst drawing maps, four different coordination strategies were identified: *selecting tasks*, *phasing action*, *standardizing information*, and *transforming understanding*. A process analysis of these strategies revealed that crisis managers employ different coordination strategies. The dominant coordination strategy is based upon segmentation, hinting to a fragmentation logic.

Similar coordination issues become visible when zooming in on sensemaking processes during the construction of the common operational picture in a third study. In crisis management the common operational picture is increasingly incorporated into more advanced information systems. This development is rooted in an information warehousing logic. It holds that information can be collected, sorted, and exchanged in an accessible and univocal form. In practice, however, professionals interpret similar information differently as they make sense of the information based on their different professional backgrounds. The analysis of three crisis situations indicates that different ways of sensemaking trigger a negotiation process. Negotiation is an important process in crisis management, because it allows crisis managers to clarify their position and specify their needs, without depending on shared ideas, interest, and norms. This is difficult to accomplish in fast-paced environments. As a result of negotiations different narratives are constructed, each with their own value. However, dominant narratives can only be negotiated if sufficient time is taken to reflect during command meetings. If crisis managers neglect this process and forget to address all interests, coordination problems and misunderstandings are likely to resurface in later phases of the incident.

Finally, fragmentation also becomes visible in the fourth study at the level of networks. This study focuses on the analysis of the response operation to a fire in the Schiphol train tunnel. The network analysis shows that the network segments on multiple occasions during the response operation. Although many network study are based on a accumulation of network interaction across a certain time period, this study shows that

a response network undergoes major changes during much shorter time periods. This stresses the necessity to incorporate time dynamics in network studies of emergency response operations. In addition, the segmentation of the network again illustrates the role of fragmentation during coordination processes, this time at the level of network collaboration.

Combined, these four empirical studies challenge the dominant role of integration as condition for coordination in crisis management. In this dissertation I show that not only integration, but especially fragmentation is an alternative approach for coordination under time pressure. Hereby, this research expands current organizational knowledge on coordination and disaster management. Designing structures and developing technological solutions does not offer a way out for coordination under pressure, but their efficacy depends for a large extend on their configuration in action. Still, it is also important not to dismiss integration, as it features so dominantly in the preparation phase and in the logic of command doctrines. Integration and fragmentation can be regarded as two different coordination approaches that have a paradoxical relation. The paradox is that while integration is often the way emergency management organizations prepare for response operations, in practice crisis managers based their coordination on a fragmentation approach that allows them to employ their expertise, and increase speed and flexibility during the operation.

This also has important implications for practice. An analysis of after-action incident reports reveals that recommendations are often based upon an integration approach. Improvements of structures, protocols and procedures are regularly advised, while the research findings in this dissertation indicate that a different coordination logic is used on the disaster scene. Plans and protocols are required to activate the emergent crisis response structure, but cross-boundary coordination also requires a fragmentation approach to harness the expertise driven, flexible mode of operations that is practiced by crisis managers.

Samenvatting

Als de samenleving wordt geconfronteerd met een ramp is een gebruikelijke aanname dat rampenbestrijdingsorganisaties de *chaos* van de ramp onder *controle* moeten brengen door daadkrachtige *commandovoering*. 'Chaos, Command & Control' is dan ook het dominante paradigma in onderzoek naar rampenbestrijding en vormt daarnaast de basis voor de sturing binnen veel hulpverleningsorganisaties. Echter, recentelijk sociologisch onderzoek toont aan dat dit idee van beheersing tijdens rampen onrealistisch is. Rampen ontaarden over het algemeen niet in chaos. De capaciteiten van getroffen organisaties en maatschappelijke actoren blijven juist vaak in tact, hoewel ze onder druk komen te staan. Rampenbestrijding vergt dan ook veel meer *samenwerking* en *coördinatie* in een complex, snel veranderend netwerk van partijen. Daarom staat de volgende vraag centraal in dit proefschrift: *hoe coördineren crisis managers hulpverleningsoperaties over de grenzen van hun organisatie in snel veranderende omgevingen*?

De resultaten van dit onderzoek suggereren dat waar er in de preparatie fase veel aandacht uitgaat naar het ontwerpen van organisatiestructuren, het vastleggen van plannen en protocollen, en het bekrachtigen van gecentraliseerde commando structuren, er tijdens de hulpverleningsoperatie zelf een andere benadering van coördinatie ontstaat. In vier empirische hoofdstukken bouw ik een gelaagde analyse op die laat zien dat coördinatie op de rampplek zelf gebaseerd is op een proces van emergente adaptie, het voegen naar elkaars expertise en spontane netwerksamenwerking in reactie op steeds veranderende afhankelijkheden. Crisis managers hebben deze praktijken nodig om in te spelen op onverwachte situaties en onbekende dreigingen die zich voordoen tijdens hulpverleningsoperaties.

Op een theoretisch niveau levert deze analyse contra-intuïtief bewijs op om coördinatie processen in snel veranderende omgevingen anders te conceptualiseren. De dominante benaderingswijze van coördinatie is gebaseerd op integratie, waarbij coördinatie mogelijk wordt geacht onder drie condities: verantwoording, voorspelbaarheid, en wederzijds begrip. De resultaten uit mijn onderzoek laten echter een contrasterend beeld zien, waarin crisis managers omgaan met een snel veranderende omgeving door coördinatie processen te hanteren die gebaseerd zijn op condities van fragmentatie. Fragmentatie heeft vaak een negatieve connotatie die doet denken aan elementen die uit elkaar vallen en mislukken. Echter, beargumenteer ik in dit proefschrift dat coördineren op basis van fragmentatie niet per se negatief is, en veel beter past bij de realiteit die crisis managers op de rampplek ervaren. Dit komt omdat crisis managers geneigd zijn om de functionele,

kennis en normatieve grenzen die zij tijdens de coördinatie met anderen ervaren, te versterken in plaats van te overbruggen. Dat stelt ze in staat om verantwoordelijkheden af te bakenen, zich continue aan de situatie aan te passen, en hun expertise in te zetten, zodat ze voldoende snelheid en flexibiliteit in de operatie kunnen houden.

Fragmentatie doet zich niet alleen voor in de werkpraktijk van crisis managers, maar komt ook naar voren tijdens een tweede studie die zich richt op het tekenen van kaarten van de rampplek. Kaarten van de rampplek worden veel gebruikt in crisis centra om een situationeel overzicht te ontwikkelen. In vakjargon staat dit bekend als een *'common operational picture'*, of een gemeenschappelijk operationeel beeld. Conceptueel gezien vormt het common operational picture een *'boundary object'*, omdat ze crisis managers in staat stellen om via interactie met het object grenzen tussen elkaar te overbruggen. Uit het taalgebruik waarmee crisis managers hun wederzijdse afhankelijkheden bediscussiëren tijdens het schetsen van de locatie van de rampsituatie kwamen vier coördinatie strategieën naar voren: *taken selecteren, actie faseren, informatie standaardiseren en begrip transformeren*. Een procesanalyse van deze strategieën laat zien dat crisis managers verschillende coördinatie strategieën hanteren. Hierbij is een sequentie van strategieën dominant die tot segmentatie leidt. Dit duidt wederom op een onderliggende fragmentatie logica.

Tijdens het inzoomen op betekenisgevingsprocessen tijdens het construeren van het gemeenschappelijk operationeel beeld in een derde studie deden zich vergelijkbare coördinatie problemen voor. In crisis management wordt het operationele beeld steeds meer geïncorporeerd in geavanceerde informatie systemen. Echter, deze ontwikkeling komt voort uit een magazijn logica. Dit houdt in dat de onderliggende overtuiging bestaat dat informatie kan worden verzameld, gesorteerd en uitgewisseld in een toegankelijke en uniforme vorm. In de praktijk, daarentegen, wordt informatie door verschillende actoren anders geïnterpreteerd als ze betekenis aan deze informatie geven op basis van hun professionele achtergrond. Uit de analyse van drie crisis situaties blijkt dat de verschillende manieren van betekenisgeving leiden tot onderhandelingen. Onderhandeling is een belangrijk proces in crisis situaties omdat hierdoor de positie en behoeften van verschillende actoren zichtbaar wordt, zonder dat men zich hoeft te beroepen op een gedeelde ideeën, belangen en normen. Dit is namelijk moeilijk te bewerkstelligen als er weinig tijd is. Het resultaat van onderhandelingen in crisis situaties is dat er verschillende narratieven ontstaan, elk met hun eigen waarde. Dominante narratieven kunnen alleen ter discussie gesteld worden als er voldoende tijd wordt genomen om te reflecteren. Als blijkt dat hieraan voorbij wordt gegaan en niet alle belangen van de crisispartners worden behartigd,

ontstaan er in een later fase van het incident coördinatie problemen en misverstanden.

Tot slot wordt fragmentatie in de vierde studie nogmaals zichtbaar op het gebied van netwerken. In deze studie staat de analyse van de hulpverleningsoperatie tijdens een brand in de Schipholtunnel centraal. De netwerkanalyse laat zien dat het netwerk over de tijd heen meerdere keren segmenteert. Ondanks dat veel netwerkstudies zich baseren op een cumulatie van netwerk interacties over een totale tijdsperiode, blijkt uit deze studie dat het netwerk in kortere tijdsperiodes grote veranderingen ondergaat. Dit laat de noodzaak zien om tijdsdynamiek mee te nemen in de analyse van crisis management netwerken. Daarnaast illustreert de segmentatie van het netwerk wederom de rol van fragmentatie in coördinatie processen, deze maal op het niveau van netwerksamenwerking.

Gecombineerd ontkrachten deze vier empirische studies de dominante rol van integratie als conditie voor coördinatie tijdens crisis management. In dit proefschrift laat ik zien dat niet alleen integratie, maar juist fragmentatie een alternatieve benadering is voor coördinatie onder tijdsdruk. Hiermee verruimt dit onderzoek de kennis over coördinatie en management van crisis situaties. Het ontwerpen van organisatiestructuren en het ontwikkelen van technologische oplossingen bieden geen directe uitweg voor het oplossen coördinatie dilemma's, maar de doelmatigheid van coördinatie hangt juist in grote mate af van de configuratie van structuren in actie. Toch is het ook belangrijk om integratie niet af te doen als onnodig, omdat het nog steeds zo'n dominante rol heeft in het preparatieproces en in commandovoering doctrines. Integratie en fragmentatie kunnen beschouwd worden als twee verschillende coördinatie benaderingen die een paradoxale relatie hebben. De paradox is dat waar hulpverleningsorganisaties zich vaak voorbereiden op rampenbestrijding middels integratie, in de praktijk de crisis managers coördinatie baseren op een fragmentatie benadering die hen in staat stelt om hun expertise te benutten en snelheid en flexibiliteit te waarborgen gedurende de operatie.

Dit heeft ook belangrijke praktische implicaties. De analyse van evaluatie rapporten van incidenten laat zien dat aanbevelingen over het algemeen gebaseerd zijn op een integratie benadering. Verbetering van structuren, protocollen en procedures worden met regelmaat geadviseerd, terwijl de onderzoeksbevindingen in deze dissertatie juist laten zien dat op de rampplek zelf een andere coördinatie logica wordt gehanteerd. Plannen en protocollen zijn nodig om de rampenbestrijdingsstructuur goed te kunnen activeren, maar coördinatie over de grenzen van de betrokken hulpverleningsinstanties heeft een fragmentatie benadering nodig om de flexibele en expertise gestuurde modus van opereren te ondersteunen die gehanteerd wordt door crisis managers.

Acknowledgements

Every now and then you get the question we as academics are all familiar with: *what do you do at the university*? The world of academia is hard to grasp for outsiders and full of curiosities. The image that friends shared with me on several occasions was that I always seemed to be reading or writing something, and travelling to conferences around the world. It's true that this line of work can really get a hold of you. It is a privilege as a social scientist to take the freedom to discover how society functions, and how people organize themselves. In particular at times of disaster, when society comes under great pressure, the challenge mounts to uncover the social processes that underlie our resilience. It is at these times of great distress when I get to discover how emergency responders perform at the best of their ability to rescue the lives of citizens in anxiety.

That gets me into a lot of special places with extremely committed and motivated professionals. Interviewing the emergency responder communities is a great experience. Once they start to talk and get enthusiastic, they won't stop. I am very glad to the emergency response community that collaborated in my research efforts, and would like to thank them for their extraordinary efforts and the ability to share their feelings and thoughts with me. The hospitality of closely observing their actions, having a drink at the bar in the evening after the exercises, and the tours around their operations centers were a real treat and gave me a wonderful image of their work. I would like to thank all the responders and emergency managers that helped to make this research project a success. I hope that by writing several practitioner research reports I was able to give something back to you for reflecting on your work.

Another privilege was to work with some of the most motivated and committed colleagues I know. First, of all my co-supervisor, Kees. We first met in a meeting when I joined the department at the VU as a research assistant, still finalizing my master's degree. Your friendly gesture and appreciation of my work hinted me to your great character. In the years to come we would undertake amazing research efforts together, that ranged from witnessing the Turkish Airlines response operation in Haarlem, towards travelling deep into the mountains regions of Nepal after the earthquakes to study the relief operation. When working in such challenging environments you really get to know each other. Like you said to me once, a PhD trajectory can truly create a bond. Up to today, we still walk in each other's office on a daily basis to discuss upcoming events, reflect on the academic working environment, or joke around about the newest peculiar concept; what you like to

refer to as linguistic darwinism. We were so fortunate that one of our collaborative efforts really scored, which allows us to continue our collaboration in the Smart Governance NWO project for the coming years. It is a real pleasure to keep joining forces and learning from you.

Peter, our team would not be complete without your role as mentor. Thank you for the opportunity to develop my own research proposal as we first met in 2009. I still remember the job offer in your room when you said to me: you might want to consider staying with us and combine teaching with research for a while. I didn't have to think long. It was a unique opportunity. For me it all started there with your recognition of my scientific ability, and your capacity to create a new type of research position. You gave me the opportunity to begin and advance my career as a social scientist. During the PhD trajectory you offered abstract ideas that made me think and really only landed after a week or so, send me the cryptic emails with often no more than two or three words, gave me the freedom to pursuit my own ideas, travel abroad to colleagues, and to further develop my research ideas. You have a special capacity to support PhDs and give them the possibility to grow. Thank you for guiding me, and I will keep bothering you for the coming years, probably also after you continue working as emeritus professor.

Of course I am surrounded by more colleagues outside the supervisory team. Also my direct peers, the PhDs community, and the colleagues at the department of Organization Science were of real support: Julie, Frank, Bianca, Peter(s), Irma, Maria, Cathy, Martin, Dick, Iina, Frans, Sietze, Henk, Christine(s), Alfons, Therese, Carel, Ida, Ed, Marja, Yvette, Marcel, Ingrid, Harry, Sierk, Halleh, and of course Elles en Welmoed. My co-phds for being such wonderful peers, and who took the liberty to rigorously comment on my work in the PhD club: Marieke, Michiel, Greetje, Freek, Annemiek, Nicoletta, Eveline, Karen, Femke, Leonore, Sander, Ludo, Luzan, Thijs, Rianne, the two Willem(s), and John. And not in the last place my roomies: David, Sietske, Anne, Juliane, Arjen, Femke: thanks for all the fun moments and the small talk about the events in our lives, and our local work culture. Taking a break, having a good laugh and a cup of coffee really helped to keep my spirits up. Thanks!

Despite all the wonderful colleagues close by, the scientific community doesn't stop at the VU, but also bridges boundaries. I regularly visited the Information Systems for Crisis Response And Management (ISCRAM) community. This became my home conference where I feel really welcome. I was also inspired during the practice-based studies workshop in beautiful Venice, where I had extensive discussions with Dvora

Yanow and Davide Nicolini that really helped to advance my thoughts. In addition, I also took regular trips to the University of Illinois at Urbana-Champaign, to collaborate with Scott Poole, John Lammers and Brian Brauer as part of our joint research project at the Illinois Fire Service Institute. Thank you for the warm welcome at your university and the inspiring discussions and diners together. Go Illini! In a later stage I also had the opportunity to travel to Boston University, and New York University to discuss the revision of my submitted manuscripts. I would like to thank Paul Carlile and Nathalia Levina for taking the time to discuss the manuscript and offering crucial advice.

Finally, I own the deepest gratitude to the people closest to me that gave me the love, protection and freedom to develop my scientific spirit and ideas. My parents for giving me the opportunity to study at the university, and the moment when they let me go and said: go and explore. My wife, Michelle, thank you for all the patience and support when I seemed to be in the clouds with my head and you had to bring me down to reality. For your strength when I was away on fieldwork and you had to manage on your own. When I was under academic peer pressure to perform and looked for support at home. It is at times of great joy, but also of disappointment when I looked for your love and support. Thank you darling for being there and making my life complete. Let's share wonderful moments together with our newborn daughter Myrthe, whom we love so dearly.

We can only be said to be alive in those moments when our hearts
are conscious of our treasures

Thorton Wilder

About the author

Jeroen Wolbers was born on January 25, 1986, in Naarden, the Netherlands. In 2007, as part of his bachelor thesis in Public Administration, he conducted research into multidisciplinary collaboration in Emergency Response Centers. This study inspired him to further explore the field of Emergency Management. In 2009, Jeroen obtained his research master of Public Administration and Organizational Science based on a study of the Netcentric Operations in several safety regions in the Netherlands. With this research master he graduated from the School of Governance based at Utrecht University, Erasmus University Rotterdam and Tilburg University.

After completing his research master Jeroen was invited to develop his own PhD research proposal during his position as lecturer at the Department of Organization Science, Faculty of Social Sciences of the VU Amsterdam. In this position he taught several courses on Bachelor and Master level, on the topics of organization theory, communication theory, safety and crisis management, and virtual organization. He also supervised up to 30 master theses in the area of Crisis and Disaster Management. Based on his publications in leading crisis management journals Jeroen was invited to give a keynote at the Joint Research Center of the European Commission, and joined an expert panel on situational awareness at the ISCRAM conference.

At the end of his PhD research trajectory Jeroen co-authored a successful NWO Smart Disaster Governance research grant. Currently, he is working on this project as postdoctoral researcher at the same Department of Organization Science at the VU. As part of the postdoc he studied the disaster response operation after the earthquakes in Nepal together with Oxfam Novib and Cordaid. Jeroen is also involved on several national research projects about adaptive capacity and emergent coordination at the National Police, and the Red Cross.

In addition to his academic work Jeroen is a musician at the Band of the National Reserve of the Royal Dutch Army. He holds the position of solo/1st Flugelhorn and is deputy concertmaster. The Band of the National Reserve is one out of four professional orchestras of the Royal Dutch Army. As part of this military function he is also active as a soldier in the Dutch National Reserve.

How do emergency responders coordinate the response operation across the boundaries of their organizations in fast-paced environments? Coordination is a key aspect of emergency management that addresses how crisis managers from police, ambulance services and fire department align their mutual interdependencies in an environment that is prone to escalate. This challenges crisis managers to coordinate ad-hoc, under severe time pressure, with experts from different response organizations who have different skills and professional jargons.

In this dissertation, Jeroen Wolbers, explores how such cross-boundary coordination is practiced on the disaster scene based on detailed observations and reconstructions of exercises and real-life response operations. The results of this research indicate that the command and control doctrine emergency organizations employ is based on an *integration* logic, in which organizational *designs* are created, plans and protocols are *administrated*, and *centralized* command structures are instated. Yet, a different coordination logic appears during the response operation itself. In four empirical chapters Jeroen builds up a detailed account, which illustrates that cross-boundary coordination on the disaster scene is actually based upon a *fragmentation* logic. *Emergent* adaptations, the negotiation of the relevance of *expert* judgments, and the changing configuration of a multi-organizational response *network* are central aspects of this coordination logic. While fragmentation often has a negative connotation, results of this research indicate it is important not to dismiss it only as failure. Crisis managers utilize fragmentation to keep sufficient speed in managing unexpected situations and unknown threats. As such, fragmentation actually supports the very flexibility, sensitivity to operations, and improvisation that are claimed to be hallmarks of swift and effective crisis management.

ISBN: 978-94-92332-03-5

VU VRIJE UNIVERSITEIT AMSTERDAM
Faculty of Social Sciences