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Jelle Groenendaal*, Ira Helsloot and Astrid Scholtens

A Critical Examination of the Assumptions Regarding Centralized Coordination in Large-Scale Emergency Situations

Abstract: Scientists have extensively debated the effectiveness of different emergency response management models, with a particular focus on the "command and control" versus "coordination" models. This debate, which focuses on centralized coordination at the tactical and strategic levels, assumes that the activity of frontline units within and between response organizations must be aligned and that it is possible to exercise control over frontline units. In this article, we discuss these assumptions and argue that researchers overestimate the degree to which frontline units can and should be centrally coordinated during the acute phase of emergency situations. Instead, we provide a mechanism in which coordination naturally emerges from the task at hand when frontline units follow a few simple decision rules. In addition, two managerial intervention strategies are presented that only may work in specific situations when frontline units are likely to misinterpret the environment in which they operate.

Keywords: command and control; coordination; distributed decision making; emergency response management; recognition primed decision making; stigmergy.

***Corresponding author: Jelle Groenendaal,** Faculty of Management Sciences, Department of Public Administration, Radboud University Nijmegen, Thomas van Aquinostraat 3, 6525 GD Nijmegen, the Netherlands, e-mail: j.groenendaal@fm.ru.nl
Ira Helsloot: Faculty of Management Sciences, Department of Public Administration, Radboud University Nijmegen, Thomas van Aquinostraat 3, 6525 GD Nijmegen, the Netherlands
Astrid Scholtens: Crisislab, Dashorsterweg 1, 3927CN Renswoude, the Netherlands

1 Introduction

For many years, researchers have debated how governments and emergency services (e.g., police, fire departments and medical services) should organize the response to large-scale emergencies, which can be defined as unforeseen, wide-scope and complex incidents that irregularly occur and necessitate immediate action under high levels of uncertainty and time-pressure (cf. Perry and Lindell 2006). Some scholars have argued for a command and control model with a hierarchical chain of command that is supposed to ensure an effective inter- and intraorganizational

response by temporarily centralizing the authority to direct members of multiple independent organizations (Bigley and Roberts 2001; Buck et al. 2006; Moynihan 2009). Others have argued for a coordination model that decentralizes decision making and places a premium on cooperation, flexibility and initiative among responders of governments, emergency services, relief agencies and emergent voluntary organizations at the frontline (Dynes 1994; Drabek 2003; Comfort 2007). In the coordination model, effective cooperation between emergency organizations is secured by coordination, which is often considered to be a key function of designated operational, tactical and strategic commanders from the various organizations involved (Dynes 1994; Drabek 2003). Although the "command and control" and "coordination" models exhibit major differences (see e.g., Moynihan 2009), they share two underlying assumptions. First, both models presume that activities must be centrally coordinated to achieve good collaboration, e.g., prevent conflicts between tasks executed by different emergency response organizations at the scene of the event (Drabek 2003; Buck et al. 2006). Second, because coordination is commonly viewed as a managerial function, both models presume that commanders at different hierarchical levels are able to exercise control over the responding frontline units, such as fire fighters, search and rescue teams or law enforcement personnel, in the first hours of large-scale emergencies.

In this article, we compare the "command and control" and "coordination" models and present the conflicting evidence regarding these two assumptions, which is rarely considered in the current debate. Inspiration for this article stems from, on the one hand, consequences of Naturalistic Decision Making (NDM) theories on individual decision making, and on the other hand, narratives from practitioners about command and control in the first phase of large-scale emergencies. The NDM body of knowledge is based on retrospective accounts and participatory analyses of operational decision makers such as fire ground commanders (Klein and Calderwood 1988) and has identified significant limitations in the extent to which the tasks of frontline responders can be centrally coordinated and directed in the first phase of large-scale emergencies. Narratives from experienced tactical and strategic commanders of the Amsterdam-Amstelland Fire Service (AAF)[1] in the Netherlands have indicated that the task alignment of frontline units is almost impossible during the first few hours of large-scale emergency situations. AAF commanders have reported that they have little control over their frontline units in the first hours of large-scale emergencies, despite their hierarchical position in the incident command system. When asked whether this affected the cooperation between responding units at the scene of the event, they could not provide first-hand examples in which the lack of control created problems.

1 One of the authors was also working as a strategic commander at the AAF.

We therefore seek to extend the current debate by focusing on the relation between the operational or emergency response level, on the one hand, and the tactical and strategic command levels, on the other hand. This article has two goals. The *first* aim is to discuss two assumptions shared by the two predominant emergency management models: (a) the assumption that the tasks of frontline units within and between emergency organizations must be centrally coordinated and (b) the assumption that higher-echelon decision makers are able to "steer" frontline units from a distance. This discussion is centered on the first life-saving phase of the emergency response, in which complex work has to be carried out under high levels of time pressure and uncertainty. The *second* aim is to present (a) an alternative approach to centralized coordination in which task-adjustment naturally emerges from the task at hand when frontline units follow a few simple rules, and (b) two managerial intervention strategies which only may work in specific situations when frontline units are likely to misinterpret the environment in which they operate.

2 The Scholarly Debate

2.1 The Command and Control Model

The command and control model originated in the USA after World War II (Dynes 1990). In the absence of knowledge about emergency management and in close association with civil defense, military doctrines were used to develop the command and control model for emergency response management. Command and control is defined as "*the exercise of authority and direction by a properly designated commander over assigned and attached forces in the accomplishment of the mission*" (Alberts and Hayes 2006, p. 32). The command and control model can be regarded as a prototypical example of classical management thinking (Buck et al. 2006), which was the dominant view of management at the time (Stacey 2000; Mcmillan 2004). In the command and control model, decision making is temporarily centralized and functionally specialized to ensure that resources and tasks are allocated and put to good use in the most efficient and effective way (Alexander 2008). The command and control model envisages a strict division between those who decide and control (management) and those who act and execute (frontline responders). In the command and control model, the management role is to collect information from the field, plan, forecast, coordinate and control (Drabek and McEntire 2003), while frontline units provide operational information to higher echelon decision makers and simply follow orders from above.

2.2 The Coordination Model

In the 1960s and 1970s, based on research on the appropriateness of organizational structure and the resource dependency model, some emergency management researchers argued that command and control models were inappropriate for large-scale emergency situations (Dynes and Quarantelli 1969). Dynes and Quarantelli (1969) claimed that these events were highly dynamic and complex that required flexibility and initiative among the organizations involved. Quarantelli (1988, p. 377) stated that *"too often disaster planners and managers assume that centralized control has to be imposed, from the top down, on emergency activities. However, research has consistently shown that this is not a good model for disasters and makes the wrong assumptions about what is likely to be happening and what is needed. But coordination, not control, is what is required and what is partly achievable."* In opposition to the command and control model, Quarantelli (1988) and Dynes (1994) proposed the coordination model, in which no artificial authority structure was created apart from the structure of the "pre-emergency authority". Dynes (1994, p. 150) argued that *"using the structure of the pre-emergency community as a base, there are a number of mechanisms which can develop coordination. Coordination can be enhanced through common planning and rehearsal activities, the establishment of personal contacts, the development of liaison activities and the establishment of shared facilities for emergency operations, such as the development of emergency operating centers. In effect, the core of emergency planning should be directed toward mechanisms, techniques and facilities which promote inter-organizational coordination and common decision making, rather than in hypothetically establishing the "proper" authority relationships."* The coordination model thus recognizes that interdependence within and between emergency organizations should not be based on authority and hierarchical position but on the need to bring together organizational units *"as a mean to pool resources, authority, knowledge and technology"* (O'Toole et al. 2003; Morris et al. 2007, p. 95).

2.3 Defining Centralized Coordination

The emergency management literature does not provide a universally accepted definition of coordination (Helsloot 2008). Sometimes coordination is defined in terms of its *results*. For instance, Dynes and Aguirre (1979) defined coordination as *"the degree to which there are adequate linkages among organizational parts"*. Coordination can also be defined as an *attempt* to integrate and align the tasks

to be performed in the response network. Comfort (2007) defined coordination as *"aligning one's actions with those of other relevant actors and organizations to achieve a shared goal"*, which reflects the notion that task-alignment can be achieved from the bottom-up (by self-organization at the front line) or top-down (by emergency managers). A widely accepted definition of top down coordination proposed by Malone and Crowston (1990) defines it as "managing interdependencies between activities performed to achieve a goal". This definition, in which coordination is imposed by one or more designated incident commanders, seems to predominate in the emergency management literature (for instance, see Drabek 2003; Comfort 2007; Moynihan 2009). We refer to this top-down form of coordination as "centralized coordination". Centralized coordination can take place between actors of different organizations (inter-organizational) and/or between actors within the same organization (intra-organizational). An important characteristic of centralized inter-organizational coordination is its voluntary nature since emergency managers only have the formal authority over their own organizational resources. Comfort (2007) stressed that *"the term assumes that the participatory actors align their activities voluntarily. If this does not occur, managers are left with only two options. They can either coerce the recalcitrant actors into changing their performance (at which point the process can no longer be called coordination), or they can ignore the fact that some actors are not participating fully and essentially become 'free riders'."* Centralized coordination thus assumes the need for and possibility of intra-organizational control by managers of their frontline units.

Table 1 summarizes the differences between "command and control", "centralized coordination" and "coordination" regarding how task-alignment is organized.

Different mechanisms are proposed in the literature to align frontline activities (for a review see Roberts 2011).

Table 1 Three Forms of Alignment of Activities at the Scene of the Event.

	Inter-organizational	**Intra-organizational**
Command and control	Hierarchical alignment of activities by a designated commander	Hierarchical alignment of activities by a designated commander
Centralized coordination	Voluntary alignment of activities by commanders of different organizations	Hierarchical alignment of activities by a designated commander (=command and control)
Coordination	Voluntary alignment of activities by two or more actors of different organizations	Voluntary alignment of activities by two or more actors of the same organization

3 Centralized Coordination in Incident Command Systems (ICS)

3.1 Centralized Coordination in Policy

This section briefly discusses the incident command systems (ICS) in the UK, the Netherlands and the USA, which are the systems most commonly analyzed in the literature. These systems all assume that centralized coordination is required and that emergency managers are able to direct the activities of their organizations performed at the frontline in the first phase of large-scale emergencies.

In the United Kingdom, the incident command system consists of three coordination levels – termed bronze, silver and gold – that may operate during a large-scale incident (HM Government 2008). The tasks performed by individuals or crews at the scene are directed and controlled by sector (*Bronze*) commanders to achieve the operational objectives determined by incident (*Silver*) commanders, who centrally coordinate and provide overview of operations on the ground. Strategic decision making at the Gold level of command is exercised only in the most serious situations (Arbuthnot 2008). Depending on the nature of the incident, the police or fire service is ultimately in charge of the incident (ibid).

The Netherlands follows a similar emergency response management model that incorporates many principles of the command and control model and centralized coordination (Scholtens 2008). In the Netherlands – in contrast to the UK incident command system – decision making at the tactical level does not occur at the scene of the event but is located near the strategic level command, and no single emergency organization is in charge of overall emergency operations. The mayor of the municipality or safety region in which the incident occurs is primarily responsible for emergency operations (Scholtens 2008). The mayor designates an operational leader who under his or hers authority leads the operations.

The design of the USA Incident Command System also reflects elements of the command and control model and centralized coordination (Moynihan 2009). Buck et al. (2006, p. 1) describe several types of ICS, which all include the following program elements: standardized job descriptions with a training program for those positions; common terms for equipment and supplies; a hierarchical chain of command from the specialist on the ground to the incident commander that emphasizes the unity of command, with each individual in the organization reporting to one supervisor; authority commensurate with responsibility; a span of control limited to the number of people that one person can effectively control; and division of labor to insure efficiency, effectiveness and safety. Finally, following a scalar principle, the size and complexity of the ICS depends on the size

and complexity of the disaster or emergency incident that it addresses. According to the Federal Emergency Management Agency (FEMA), *"ICS is a fundamental form of management established in a standard format, with the purpose of enabling incident managers to identify the key concerns associated with the incident – often under urgent conditions. ICS is used to organize on-scene operations for a broad spectrum of emergencies from small to complex incident, both natural and manmade. The field response level is where emergency management/response personnel, under the command of an appropriate authority, carry out tactical decisions and activities in direct response to an incident or threat"* (FEMA 2008, p. 46). Centralized coordination is mirrored in the concept of unified command, which means that incident command is shared by two or more individuals, each having authority in a different responding agency (FEMA 2008). But it is also reflected in the obligation to make an Incident Action Plan (IAP) as formulated in the National Incident Management System (NIMS). According to the NIMS (FEMA 2008, p. 47) *"centralized, coordinated incident action planning should guide all response activities. An IAP provides a concise, coherent means of capturing and communicating the overall incident priorities, objectives, strategies and tactics in the context of both operational and support activities. Every incident must have an action plan."*

3.2 Centralized Coordination in Practice

In general, researchers who have studied how an ICS operates have reported that, in practice, there are differences between the operations that are expected according plan and those that are observed (Dynes and Quarantelli 1976; Quarantelli 1986; Dynes 1990, 1994; Schneider 1992; Flin 1996; Drabek and McEntire 2003; Tierney and Trainor 2004; Helsloot 2005; Buck et al. 2006; Comfort and Kapucu 2006; Corbacioglu and Kapucu 2006; Comfort 2007; Arbuthnot 2008; Helsloot 2008; Kapucu 2008, 2009; Scholtens 2008; Helsloot et al. 2009; Moynihan 2009; Boin and 't Hart 2010; Leonard and Howitt 2010). Although incident command systems are presumed to unify authority, researchers have found that, in practice, authority is shared and decision making is decentralized. In a study of ICS operations in different large-scale incidents in the USA, Moynihan (2009) concluded that the ICS structure did not clearly identify who was in charge. According to the author, *"...the incident commander is not truly a commander. He can issue an order, but whether and how the order is obeyed depends upon the willingness of the network members to accept the legitimacy of his position and the specific task."* Moynihan therefore discussed the concepts of "shared authority" and "network governance" in large-scale emergency situations. Based on many field studies, Quarantelli (1988) and Dynes (1994) noted that tightening up the hierarchy to

exercise control over frontline responders is ineffective during the first hours of large-scale emergencies because of the time required for the higher hierarchical levels to acquire a sufficient understanding of what is going on, while large-scale emergencies typically demand immediate decision making (Quarantelli 1985; Dynes 1994; Flin 1996). These authors found that, in large-scale emergencies, most decisions of what to do and how to do it were made by individuals with ongoing direct access to the problem at hand rather than by emergency managers at a distance. Boin and 't Hart (2010, p. 362) arrived at a similar conclusion and stated that it was impossible to control the initial actions of frontline responders: *"The first phase of a crisis will inevitably be marked by a lack of information, communication and coordination, and at that time it is impossible to control each and every move of first responders."*

Despite the problems associated with incident command systems, researchers have positively assessed the incident command system structure for emergency management overall. Although Leonard and Howitt (2010) recognized the importance of decentralized decision making in large-scale emergencies, they noted that the ICS and unified command are widely used and have empirically been proven useful and flexible and robust in many situations. Therefore, they concluded that "*It probably makes more sense to harmonize on and practice making this system work than it would to redesign it significantly or adopt a completely new approach*" (Leonard and Howitt 2010, p. 383). Similarly, Moynihan (2009) stated that the *"continuing practitioner preference for the ICS suggests a functional value not acknowledged by its critics. Responders need a central coordinating mechanism to direct resources and resolve conflict in a timely fashion."* Boin and 't Hart (2010) argued that the often observed importance of the crisis management structure was overrated in the literature. According to these authors, the quality of communication, coordination and collaboration within, across and beyond emergency services rather than formal structures primarily influenced the quality of crisis responses. In this regard, the authors regard the ICS as an appropriate structure for providing order and helping emergency organizations to perform their tasks in a coordinated fashion (Boin and 't Hart 2010, p. 366).

4 A Closer Examination of the Literature: Three Observations

Although incident command systems may be sufficient to organize the emergency response after the initial, life-saving phase of large-scale emergency situations (which may explain the reported practitioner preferences for ICS), there seems to

be limited and even conflicting empirical evidence regarding some of its underlying assumptions. This section more closely examines the literature on emergency management and presents three observations. First, we note that many researchers focusing on incident command systems draw conclusions about effective ICS functioning often without examining the operations at the scene of the event. Second, we show that there are conflicting views regarding the assumption that tasks of frontline responders need to be centrally coordinated within and between response organizations. Finally, we observe that the emergency management literature overestimates the ability and need to exercise control over frontline responders in the first hours of large-scale emergency situations.

Observation 1: Research focuses on the higher hierarchical levels of incident command systems rather than the overall connection between these levels and the emergency operation at the frontline.

Researchers studying incident command systems have suggested that because the ICS structure has proven useful, flexible and robust in many situations, it is widely employed by practitioners (Moynihan 2009; Leonard and Howitt 2010). Leonard and Howitt (2010, p. 381) claimed that incident command systems *"work surprisingly well even in large, complex events."* However, only a few scientific studies, which primarily address the suppression and management of brushfires, have empirically supported the claim of effective ICS functioning (e.g., Leonard and Howitt 2010).

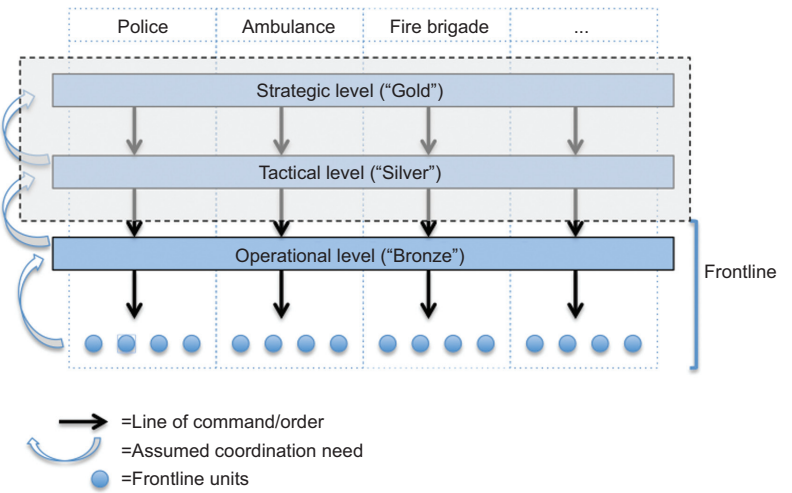

Figure 1 The Debate Focus Primarily on the Tactical (silver) and Strategic (gold) Coordination Levels (Gray box).

A large portion of the literature on emergency response management focuses on the higher hierarchical levels of incident command systems rather than the operational level or on the overall connection between the higher hierarchical levels and the actual frontline response (for notable exceptions, see Helsloot 2005; Berlin and Carlstrom 2008, 2011). These studies provide significant insight into the way emergency managers of different emergency organizations arrive to decisions and collaborate. However, they provide little information regarding the effect of the functioning of unified command on the response at the operational level or the overall functioning of the incident command system. The public administration literature has found that the behaviors of frontline units, such as policemen and firefighters, are influenced not only by what managers want them to do but also by their own moral judgments, which are based on their personal knowledge and interactions with the social environment (Lipsky 1980; Considine and Lewis 2003; Maynard-Moody and Musheno 2003). These considerations indicate that the ICS must be studied in relation to the activities at the incident before conclusions about the effective functioning of ICS can be drawn. Three examples that clarify this issue are presented.

Chen et al. (2007) examined crisis coordination during the 2006 snowstorm in New York. He and his coauthors studied how the incident command system operated during the incident and identified several coordination deficiencies at the tactical and strategic levels but did not investigate how these deficiencies influenced actions at the operational level. Lutz and Lindell (2008), who examined the degree to which the use of the ICS influenced the performance of 22 Texas Emergency Operations Centers (EOCs) during Hurricane Rita, found that the tasks each ICS section performed varied substantially from one EOC to another. Moreover – in contrast to the EOC's physical environment – the ICS experience and ICS implementation were not significantly correlated with the dependent variable of team climate. However, the researchers did not investigate how team climate influenced the actual response at the operational level. Finally, Moynihan's (2009) analysis of the functioning of the US incident command system during several large-scale emergency situations examined the ICS at the level of the incident commander but did not investigate the connection between the functioning of the incident commander and the decision making of emergency units in the field.

Observation 2: There are conflicting views regarding the need for centralized coordination within and between organizations in the initial phase of large-scale emergencies

The literature appears to adopt the more or less implicit assumption that tasks performed by frontline responders should be centrally coordinated to achieve

an effective response during large-scale emergencies (Waugh and Streib 2006; Moynihan 2008, 2009; McGuire and Silvia 2010; Leonard and Howitt 2010).

First, scholars studying coordination during large-scale emergencies typically hold the view that collaboration between frontline organizations is necessary to attain an effective emergency response. Kapucu (2005, p. 46) for instance argued that an *"effective response and recovery operations require collaborations and trust between government agencies at all levels and between the public and nonprofit sectors."*

However, only a few studies have empirically examined the assumed need for collaboration during large-scale emergencies. Berlin and Carlstrom (2008), who studied cooperation by emergency services during operational exercises in Sweden, investigated the collaboration between police, fire department and ambulance services from the arrival of the first units through establishment of an accident organization until the mission was completed. The authors found that relatively little frontline collaboration occurred. On the contrary, the emergency services basically worked in tandem and only performed tasks within their own responsibility. The aim of the response organizations was to establish stability by preferring repeated and well-known behavior. The authors found no evidence that increased or closer collaboration would improve the effectiveness of the emergency response because there were few interdependencies between the responding organizations involved (Berlin and Carlstrom 2008). In another study, Berlin and Carlstrom (2011) investigated three types of interagency collaboration –

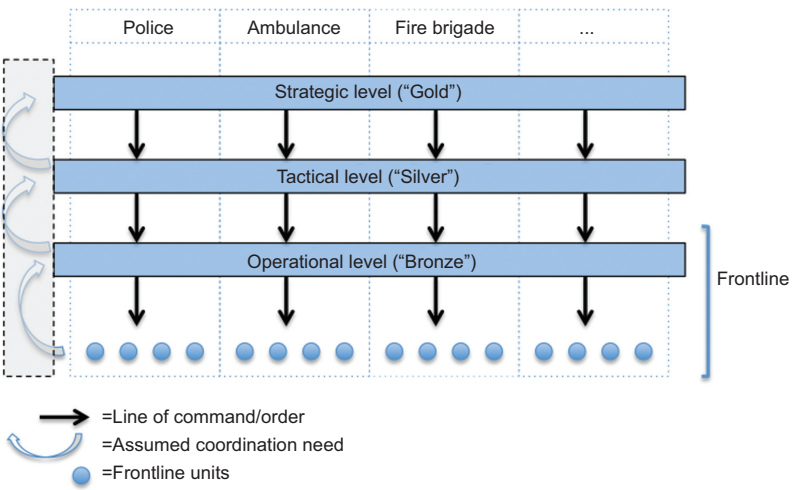

Figure 2 The Assumed Need to Centrally Coordinate the Tasks of Frontline Responders (Gray box).

sequential, parallel and synchronous – during emergency work. The authors found that organizations at an accident scene avoided collaboration both because this would lead to uncertainty and due to the lack of incentives for collaboration. Berlin and Carlstrom (2011, p. 169) noted that *"the commands did not have incentives to develop cooperation between the organizations... the commanding officers met for a short time at the management location, but their attention was concentrated on their own staff and operational activities at the accident site."* The authors concluded that increased or improved collaboration would not produce a more effective or efficient emergency response.

Second, the coordination literature commonly presumes that centralized coordination is needed to achieve good collaboration. Leonard and Howitt (2010, p. 379) for instance put forward that (centralized) coordination is needed to resolve conflicts that may arise when the actions of two or more independent units interfere with each other's operations.

Based on evaluations of large-scale emergencies in the Netherlands, Scholtens (2008) rejected the assumption that centralized coordination is necessary in order to achieve or maintain sufficient task-adjustment at the front line. She reported that *"it seems that emergency services actually work reasonably well together in the field, in spite of the reigning chaos in the level above them and of the failure of the coordination mechanism that is supposed to operate in such situations."* Similarly, Helsloot (2008) challenged the view that central coordination of frontline responders is required to attain good collaboration by arguing that frontline responders of different organizations may work successfully side-by-side without central coordination. Helsloot discussed the work of Donahue (2006), who described the debris recovery operations for the space shuttle Colombia and the remains of its crew. Donahue reported that these operations were successful because of good collaboration based on the explicit articulation of a common vision, a focus on problem solving rather than rule following, shared values and joint planning. However, Donahue (2006, p. 141) stressed that initial response to the crash was chaotic and poorly managed. She stated: *"Dozens of communities immediately activated their emergency plans and operations centers. Police, firefighters, the National Guard, the American Red Cross, the Salvation Army and scores of other agencies and volunteers poured to help. Most of these organizations had never worked together before, and many involved had little formal knowledge of incident command and management procedures."* Helsloot (2008) concluded therefore that a closer examination of the recovery operation indicated that this operation was best described as "working together apart", in which each organization performed its own operations effectively without centralized coordination.

Third, centralized coordination is often perceived to be necessary in the coordination literature to obtain the "big picture" of overall operations to ensure that

critical dimensions of the situation are correctly identified and to periodically revise the overall response strategy. Again, this assumption can be challenged. Researchers have noted that in complex network settings, such as the response network in the case of a large-scale emergency, no "detached" observer is able to oversee the response network (Kickert et al. 1997; Wheatley 2006; Scholtens 2008; Stacey 2010). Distributed Decision Making (DDM) provides a useful approach for understanding the difficulties of centralized coordination in large-scale emergency situations (Rasmussen et al. 1991; Brehmer 2000; Scholtens 2008). DDM assumes that that it is impossible to understand and control all of the different and complex aspects of dynamic organizations through a centralized decision-making process (Schneeweiss 2003). Because a single individual unit can only affect a restricted area and process a limited amount of information, DDM proposes that complex problems should be divided into smaller components and that the size of these components be matched to the individual's information processing abilities. Because individuals may attempt to resolve a larger problem in different ways, it becomes almost impossible to identify a global pattern or to forecast how an intervention by one actor will affect the decision making of other individual response units in the field (Rasmussen et al. 1991; Scholtens 2008). DDM proposes that each individual unit should make its own decisions as independently as possible within the main outlines of the overall goal (Rasmussen et al. 1991).

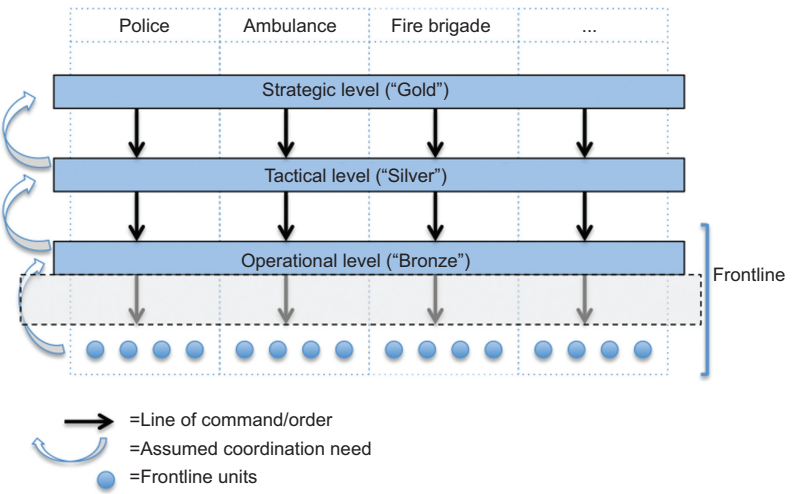

Figure 3 The Assumed Ability and Need to Exercise Control over Frontline Responders (gray box).

Observation 3: Both the literature and practitioners overestimate the ability and need to exercise control over frontline responders during the initial phase of large-scale emergencies

Researchers as well as practitioners tend to overestimate the ability and need to exercise control over frontline responders during the initial phase of emergencies. However, the limited ability to exercise control is rarely addressed in the literature on emergency response management.

The literature provides little empirical evidence to support the assumption that frontline responders can be hierarchically controlled during the first phase of large-scale emergencies. On the contrary, the literature identifies many examples that reveal problems in directing emergency responders in the initial phase of large-scale emergency situations. For example, Smith and Dowell (2000) investigated coordination during the 1995 Ais Gill railway accident in the UK with a focus on the coordination activities of emergency managers. At the onset of the incident, the first emergency managers of the fire departments, medical services and police at the scene discussed three options for transporting the casualties to the nearest hospitals because the transport was made difficult by the remoteness and inaccessibility of the location. Although one option was chosen, none of the incident commanders were able to carry out this decision, and the three options for casualty transport were pursued in parallel. The authors claim that their study reveals the difficulty of shared meaning-making and interagency coordination in emergencies. However, we would argue that this study indicates that the commanders were unable to implement the chosen course of action and had little control on what occurred inside and outside the accident site. The Oklahoma City bombing, in which the ICS functioning was generally perceived as successful (Moynihan 2009), provides another example. The evaluation report provides several instances in which emergency responders followed their own intuition rather than orders from supervisors. For example, the report stated that *"while police officers were given assignments on perimeters and in positions limiting access to the scene, some officers and supervisors left their posts to participate in the rescue operations. Some officers appeared to become emotionally involved and had difficulty following instructions"* (Oklahoma City Bombing inquiry 1996, p. 35). In addition, the evaluation report stated that *"throughout the incident, there was a constant concern as to the number of officers on-site, their locations and duties. Field personnel frequently utilized the personnel without on-site command post personnel being advised"* (ibid).

Naturalistic Decision Making (NDM) provides a useful approach for understanding the limited ability to exercise control in emergency situations (Zsambok and Klein 1997). NDM describes how experienced decision makers make decisions

in naturalistic settings, which exhibit time pressures, ambiguous information, high stakes and uncertainty. Zsambok and Klein (1997, p. 5) defined NDM as "*how experienced people, working as individuals or groups in dynamic, uncertain and often fast paced environments, identify and assess their situation, make decisions and take actions whose consequences are meaningful to them and to the larger organization in which they operate.*" The recognition-primed decision-making model (RPD) can be considered a prototypical NDM model (Lipshitz et al. 2001).

The RPD model is a prominent example of an NDM model that was originally based on the observations and retrospective accounts of fire ground commanders (Klein et al. 1989). Klein et al. (1989) investigated how fire ground commanders handled time pressure and uncertainty and found that, in most cases, experienced fire ground commanders did not analyze options when choosing a course of action but instead performed the first action that came to mind. The authors found that when experienced decision makers operated under conditions of time pressure and uncertainty, they quickly recognized cue patterns signaling a particular type of problem, and this fast recognition triggered the retrieval of responses previously associated with a similar cue pattern, which led to successful problem resolution. Consequently, experienced decision makers made workable – but not always optimal – decisions almost instantaneously. In large-scale emergency situations, therefore, frontline units decided in a split second to what they would do based on preceding incidents and easily communicated procedures. Regardless of the scale of the incident, firefighters arriving at a scene attempt to put out the first fires they come across and rescue the first people they see, medical personnel concentrate on treating victims and the police focus on restoring order (Scholtens 2008).

NDM has significant implications for those seeking to direct frontline decisions. Because decision makers facing time pressure and uncertainty operate as they would in similar conditions, it is very hard to control these decisions, particularly if emergency responders are instructed to do something that conflicts with typical practice. An illustrative example is provided by the wildfire near Storm King Mountain in which several firefighters failed to drop their tools to escape the danger (Weick 2001, p. 322–323). Weick (2001) stated that "*On July 6 1994, near Glenwood Springs, Colorado, a mixed crew of smokejumpers and hotshots were constructing a fire line downhill on the east slope of a valley near Storm King Mountain. The fire they were trying to stop circled around them on the south and started up the west slope of the valley. Portions of it spotted across to the east slope underneath them and overran them with flame heights of 150 feet while they were retreating up to the ridge to upon the east slope. A group of firefighters already on the ridge top yelled at them to speed up and drop their tools, but they did not. The firefighters died with their tools at hand.*" In this example, which is consistent with NDM, the smokejumpers were unable to drop their tools, although colleagues and

commanders ordered them to do so, because it was contrary to what they had learned. Therefore, Weick (2001, p. 325) stated that, *"People who have been trained to carry out whatever equipment they carry in to a fire or whatever is dropped to them, people who hear repeatedly how much equipment costs, and people who practice carrying heavier and heavier loads, faster for longer periods, on sleeper slopes, might be at disadvantage when, without any prior experience of what it feels like or how to do it, they are told to drop their tools and their packs."*

NDM also provides a plausible explanation for the assumption that operational commanders, such as battalion chiefs, are "in control" of their organizational members in the initial phase of emergencies. Based on NDM, orders consistent with everyday practices are likely to be carried out by frontline responders because these practices are obvious to the responders. If we assume that most orders given in emergency situations are consistent with day-to-day practices, there is little need for operational commanders to really direct the activities of emergency responders in the initial stage of emergencies.

NDM fits in the observation by Dynes and Aguirre (1979) who have suggested that emergency response organizations are basically coordinated through planning and feedback. Coordination through planning is based on pre-established schedules and programs directing and standardizing the functioning of organizations, and coordination through feedback is centered in the transmission of new information so as to facilitate the mutual adjustment of parts.

5 An Alternative to Centralized Coordination: Facilitating Self-Organization at the Frontline

This section presents an alternative approach to centralized coordination in which task-adjustment naturally emerges from the task at hand when frontline units follow a few simple rules. In addition, two managerial intervention strategies already used in practice are described. These strategies only may work in specific situations when frontline units are likely to misinterpret the environment in which they operate.

5.1 Task-Adjustment Through Stigmergy

Stigmergy is a form of self-organizing, bottom-up coordination in which activities are neither centrally controlled nor locally supervised; it is generated by placing signs and modifying the environment (Bonabeau and Meyer 2001). Grassé (1959),

a French zoologist who studied animal sociology, first introduced the concept of stigmergy to explicate the mechanisms underlying the emergence, regulation and control of social insects. Grasse discovered that the activities of social insects were coordinated and regulated through indirect communication mediated by modifications of the environment, which was termed stigmergy (Marsh and Onof 2008). Theraulaz and Bonabeau (1999, p. 111) described the basic principle of stigmergy more simply as *"Traces left and modifications made by individuals in their environment and may feed back on them."*

Stigmergy in social insects is illustrated by the food foraging of ants (Valckenears et al. 2006). In the absence of environmental signals, ants randomly search for food. When an ant discovers a food source, it deposits an odorant pheromone as it returns to the nest with some of the food, generating a pheromone trail between the nest and the food source that will evaporate if no other ants deposit fresh pheromones. When another ant senses a pheromone trail, its instincts will lead it to follow the trail to the food source. When it locates the food source, it deposits more pheromone to maintain and strengthen the pheromone trail. When the food source is exhausted, the ants return to a randomized search for food, and the trail evaporates (Valckenaers et al. 2006).

Valckenaers et al. (2006) identified three distinguishing characteristics of stigmergy. First, patterns of self-organization are generated without the need for direct communication between organizational members, which is significant because poor communication between frontline responders is almost inevitable in emergency situations. Second, the environment shields the decision maker from the complexity of the environment because global information is locally available and a complete operational "picture" is not required before units can perform a task. Finally, the information is accurate because its lifetime is limited and refreshed only as long as it remains valid, which allows the recognition-primed decision-making behavior of emergency responders to be efficient and effective.

A practical example of stigmergy is illustrated by the 2011 Fireworks disaster in the Netherlands. After the explosion, which destroyed more than 1000 residential buildings, firefighters and other rescue workers searched the buildings for possible casualties. The emergency responders agreed to place colored signs on the doors of buildings that had previously been searched for victims. By using a simple rule (*"when a sign is painted on the door, I will take the next one"*), emergency responders were able to search buildings effectively and efficiently without any central supervision (Oosting Committee 2001). In this example, coordination followed from the task itself rather than from emergency managers' coordination activities. Interestingly, although this procedure has been adopted by Urban Search and Rescue Teams (USAR), the firefighters devised this procedure

independently in the Fireworks disaster (Oosting Committee 2001). Berlin and Carlstrom (2008) provided another example of stigmergy by describing how various "signals" initially placed in the environment influenced the decisions made by frontline responders: *"The choice of points of entry, command centre location, and vehicle positions in relation to the object of the accident became precedent during the rest of work"* (Berlin and Carlstrom 2008, p. 180).

5.2 Two Managerial Intervention Strategies

Stigmergy is based on the recognition of locally available information, which may occasionally lead to poor decision outcomes (Leonard and Howitt 2010). Based on NDM, two specific situations can be described. *First*, experienced decision makers operating under time pressure base their decisions on the rapid recognition of local environmental cues, which might lead to decisions that are optimal at the micro level but suboptimal at a macro level. For instance, different firefighting teams who use locally available information to suppress a fire might approach a fire from opposite sides of a building without knowing about each other, which may increase the flames on the opposite side and harm one of the teams. This occurred during the response to the 2008 fatal fire in De Punt in the Netherlands (Helsloot et al. 2009). *Second*, decisions made on a day-to-day basis may be inappropriate in certain situations and require alternative interventions. For instance, in the wildfire situation described in Weick (2001), it would have been better to violate the standard operating procedure of carrying equipment at all times by dropping the equipment and fleeing from the fire.

For these two specific situations, direct and indirect managerial intervention strategies that draw on NDM may be more broadly applied in practice. However, these strategies cannot be applied often or in every situation. The first strategy provides direct control through a simple decision rule taught to emergency responders prior to an event requiring immediate evacuation, with a simple outcome for the decision rule. For instance, a specific whistle signal can be associated with immediate danger and a complete drawback of all field units. This is the current practice in US fire departments, where a whistle is currently used to order the evacuation of firefighters inside a burning building. Although everyone in the response network would be able to use this signal, it should rarely be used due to its extended range and because its effectiveness would be diminished if it were applied too often or incorrectly.

The second managerial intervention strategy is based on indirect control by influencing the behavior of organizational units by making subtle changes in their environment based on an accurate prediction about how emergency responders

will behave in a given situation. This strategy is more difficult to apply because it requires an extensive understanding of how emergency responders typically operate in similar conditions. The strategy was successfully applied by the incident commander at the 1998 Eschede train collision, which led to 101 deaths and 103 injuries (Hüls and Oestern 1999). On June 3, 1998, a high-speed train traveling at 200 kilometers per hour collided with a bridge and caused it to collapse. As a result, the train broke into two pieces. An emergency manager, who arrived at the scene and observed the initial response from a hill at a distance, noticed that the train wreckage was separated into two large areas, one near the bridge and one far from the bridge. However, following the usual operating procedures, all the arriving units proceeded to the first visible accident site because they were unaware of the other disaster site. Due to nonfunctional communication systems, the incident commander was unable to inform the arriving units about the two accident sites (Köbl 1999; Lange 1999). However, based on the expectation that the first responders would drive directly to the first wreckage site they came across, the incident commander directed a fire engine to block the main road to detour arriving units. Because these units had to take a different road, they were effectively directed to the second accident site (Köbl 1999).

6 Conclusion

In this article, we have demonstrated that the debate on emergency response management would benefit from a deeper understanding of the response that occurs at the scene of the event during the first phase of large-scale emergency situations. Based on the preceding analysis, we conclude that for large-scale emergencies, centralized coordination is initially difficult to achieve because supervisors at this stage often do not possess the required and reliable information. In addition, in the acute phase of the emergency response we argue that emergency managers have no possibility to exercise control to align activities at the scene of the event. More fundamentally, the analysis raises the issue of the extent to which centralized coordination is necessary in the first hours of large-scale emergencies, which is a question that certainly demands further research.

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