AN OPERATIONAL DEFINITION OF EMERGENCY RESPONSE CAPABILITIES

Henrik Jönsson[1,2,3]
Marcus Abrahamsson[1,2]
Henrik Johansson[1,2]

Lund University

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Abstract

Well developed emergency response capabilities are crucial in order to keep the risk in a community at low levels. Analysing these capabilities before an emergency occurs is important since it can identify weaknesses and possibilities for improvements. To start off from an operational definition is a possible point of departure in such an analysis. In this paper, therefore, we develop an operational definition of emergency response capabilities, which builds on systems theory and an operational definition of risk. The definition includes three essential elements; the task to which the capability is related, measures of how well that task can be performed and a description of the context affecting the performance of that particular task. The definition makes clear that the context might have large effects on how well a task can be performed and that there are uncertainties both regarding the context and how well a task can be performed given a context. Furthermore, we argue that it should be possible to make judgements about any statements that are made in the analysis regarding their validity and therefore the tasks and performance measures must be defined accordingly. The conclusion is that the operational definition provides an analytic structure which can help actors to gain knowledge about their emergency response capabilities and limits thereof.

Introduction

In the ideal world all hazards facing a community can be prevented and kept from materialising. Preventive risk reductions are indeed often effective in mitigating hazards; unfortunately perfect prevention is virtually impossible. Actually, it might be counter-effective to excessively focus on preventive measures since this often leads to an increased level of community vulnerability (McEntire, 2001), which is also known as the vulnerability paradox (Boin, 2004). In addition, many hazards are beyond the human ability to prevent (Gundel, 2005; McEntire, 2005) or beyond the authority of specific organisations to influence. Furthermore, prevention and mitigation measures might be known but impracticable because they are associated with too high costs, require technology that has not yet been developed or are otherwise not feasible. Another issue is that some hazards are extremely hard to predict and therefore impossible to prevent (Gundel, 2005). Because of these inherent insufficiencies of preventive strategies, it is sensible to complement preventive measures with mitigation and preparation efforts in order to increase

[1] Department of Fire Safety Engineering, Lund University, P.O. Box 118, SE-221 00 Lund, Sweden.
[2] Lund University Centre of Risk Analysis and Management (LUCRAM).
[3] Corresponding author, henrik.jonsson@brand.lth.se.

response capabilities and reduce vulnerabilities in communities, so that the consequences are kept at low levels once a hazard materialises. Achieving a balance between prevention and resilience (developing a capacity to absorb, respond to and recover from events) is thus a rational strategy in managing the risk in a community.

When a hazard materialises it exposes people, organisations and infrastructure in the community to strains and stresses of various magnitude, which put demands on their capabilities to resist, cope with and recover from the potentially harmful events. In such situations needs arise because fundamental values, such as human values, are threatened. These needs have to be met in a timely manner in order to minimise the negative consequences. However, in crises and emergencies, affected persons and groups may lack the capabilities (such as lacking the resources, knowledge or skills) that are required for meeting some of these needs, thus causing needs for external assistance to emerge. Meeting these needs then become the task for emergency management organisations (Fire and Emergency Services, NGOs etc.), which thus put demands on their emergency response capabilities. An important step in order to attain good emergency response capabilities is to work proactively with emergency planning and preparedness (Coles and Buckle, 2004). In the proactive work it is important to analyse and evaluate the existing emergency response capabilities in the organisation in order to highlight weaknesses and possibilities for improvements. Furthermore, conducting regular assessments are crucial since organisations and the environment in which they operate, constantly undergo change, which means that organisations have to adjust and adapt their current activities and strategies to even maintain their existing emergency response capability.

Suggestions of methods and frameworks for assessing capabilities have been made previously in the research literature and in various guidelines, e.g. Anderson and Woodrow (1991), UNDP (1998), IFRC (1999), Kuban and MacKenzie-Carey (2001). Some of these methods focus on organisational capabilities while other focus on the capabilities of the affected population to self-protect. An issue in applying these methods, however, is that there is no general consensus of how the relevant concepts are to be interpreted (Buckle and Mars, 2000; Weichelsgartner, 2001), which is exacerbated by the general lack of operational definitions. Furthermore, these frameworks generally provide a limited guidance of how to analyse capabilities in order to ensure the validity of the analysis. The aim of this paper is therefore to operationally define emergency response capability and the intention is that the operational definition should provide a framework for analysis as well. Here, an operational definition of emergency response capability is considered to be a definition that provides an operation or procedure, which can be used to determine what is required to comply with the definition. The definition builds on systems theory and an existing operational definition of risk. Therefore, we first review the definition of risk and also extend it to include the concept of vulnerability, which is tightly coupled to capability.

Risk framework

The concept of risk is used across many scientific disciplines and is also extensively used in practice. However, there is no general consensus regarding the definition of risk (Fischhoff, Watson et al, 1984). According to Renn all definitions of risk have in common that they make a distinction between reality and possibility and he proposes to define risk as "the possibility that human actions or events lead to consequences that affect aspects of what human values" (Renn, 1998). According to the standpoint on risk that is adopted in this paper, the risk in a system depends on two essential components; the likelihood of harmful events and the consequences of them. However, this view is by no means accepted universally. In some disciplinary areas related to emergency management, risk is given a different meaning, which is also pointed out by Dilley and Boudreau (2001) who argues that risk is sometimes used only referring to external events and hazards, not the consequences for the system in question. Cutter and colleagues, for example, relate risk only to the external hazard agent, where it is seen as "an objective measure of the likelihood of a hazard event" (Cutter, Boruff et al, 2003). References to the consequences of the hazards are thus not made in this definition. McEntire argues that "risk is a result of proximity or exposure to triggering agents, which increase the probability of disaster"(McEntire, 2001). This definition clearly expands on the one proposed by Cutter and colleagues. In our view proximity to triggering agents contributes to the risk; however it is not the only factor that determines which consequences that arise. The approach to risk chosen in this paper leads to the conclusion that the purpose of all emergency management efforts, whether it is in the form of prevention, preparedness, response or recovery, is to reduce the risks, by reducing the likelihood of harmful event, the consequences of them or a combination of both.

A quantitative, operational definition of risk is proposed by Kaplan and colleagues (Kaplan and Garrick, 1981; Kaplan, 1997; Kaplan, Haimes et al, 2001) and is used extensively in risk research. The definition is based on systems theory and it is assumed that one has defined a system for which the risk is to be estimated. A system is perceived as a collection of state variables that can be used to describe the world. It is important to note that the system and the real world is not the same thing. Since "…every material object contains no less than an infinity of variables and therefore of possible systems" (Ashby, 1957) one has to define the system with the objective to achieve a good enough, for the purpose of the analysis, representation of the real world. The state variables can be lumped together into elements that consist of one or a collection of such variables and constitute some kind of meaningful unit in the context of interest. Here, for example, an element can be the Fire and Emergency Services which can be described by several state variables of which one could be the number of fire fighters that are engaged in an emergency response operation. One could employ a more detailed system definition, for example using individual fire fighters as elements in the system, but in the present context it is sufficient to use emergency response organisations as the elements of interest.

The assessment of emergency response organisations' capabilities has similarities with the problem of risk assessment. Both types of assessments are concerned with potential events that can happen in the future and therefore the development of an operational definition of emergency response capabilities can benefit from using the definition of risk as a point of departure. Of central importance in the definition of risk referred to above is the notion of scenarios, which is defined as "a trajectory in the state space of the system" (Kaplan, 1997). A scenario can thus be seen as the progression of the system over time. In determining the risk in a system one has to identify all (at least the most important ones) scenarios that deviate from the "success scenario", S_0. S_0 denotes a scenario where everything in the system behaves as intended and scenarios that deviate from S_0 are called risk scenarios. After estimating the probability and consequence of each scenario, one ends up with a set of risk scenarios (S_i) and their corresponding probabilities (L_i) and consequences (X_i). This set, called the "set of triplets", *is* the risk in the system. Therefore, when determining the risk in a system one really has to find the answer to the three questions: "What can go wrong?", "How likely is it?", "What are the consequences?" (Kaplan, 1997). Based on the set of triplets several risk metrics and measures can be expressed in order to facilitate risk presentations and decision making.

Obviously, an important issue resides in deciding which negative consequences to include in the definition of risk. Ashby uses the term essential variable to refer to a state variable that is related to a consequence dimension, i.e. the variables that are important to protect (Ashby, 1957). Consequences can be said to arise when these essential variables take on values outside some predefined range. However, there is no general answer to which state variables that should be seen as essential, since the consequences of interest depend on the values that the analysis is based on. The consequences to consider are thus contingent on the context of the particular analysis, such as its purpose. In addition, at which point in time the consequences should be estimated is also contingent on the particular context. Traditional application of the quantitative definition of risk, in what is frequently called "technical risk analyses", has been claimed to be too narrow in only focusing on a single consequence dimension (Renn, 1998), and only focusing on immediate impacts after a hazardous event (Einarsson and Rausand, 1998). However, we argue that there are no preconditions of which consequence dimensions to use when employing the quantitative definition of risk. The criticism thus addresses the traditional *application* of risk analysis, not the *definition* of risk per se. Therefore, we believe that the quantitative definition of risk provides a suitable platform in an emergency management context as well.

Incorporating vulnerability into the risk framework

Research over the last couple of decades has recognised the limitations of the previously predominant view, in which the hazards where seen as the main concern for emergency and risk management. Since then there has been a shift in focus to a view that also account for the vulnerability of the exposed systems, e.g. persons, groups, organisations, communities (Weischelsgartner, 2001; Wisner, Blaikie et al, 2004). However, there is no general consensus as to how vulnerability is to be conceptualised, and some definitions are even contradictory (Cutter, Mitchell et al, 2000; Dilley and Boudreau, 2001; Haimes, 2006).

According to the view adopted in this paper the overall risk in a system is a result of the interactions between the characteristics of the various hazardous events that might affect the system and a range of "vulnerability inducing" factors (e.g. physical, economical, institutional and societal) that characterises the system (Salter, 1997; Dilley and Boudreau, 2001; Sarewitz, Pielke Jr. et al, 2003). These factors either aggravate or alleviate the effects of various hazardous events, but those "factors that make a system vulnerable to a hazard will depend on the nature of the system and the type of hazard in question" (Brooks, Adger et al, 2005). Therefore, vulnerability is context-dependent and has to be related to a specific hazardous event to be meaningful (Dilley and Boudreau, 2001). A corollary of this is that a system that is vulnerable to a certain hazardous events is not necessarily vulnerable to other, although there often exist generic factors that altersthe system's vulnerability to many hazards (Brooks, Adger et al, 2005). In this paper we use vulnerability to represent an emergent system property[4] that determines the effect a specific hazardous event has on the essential variables of the system.

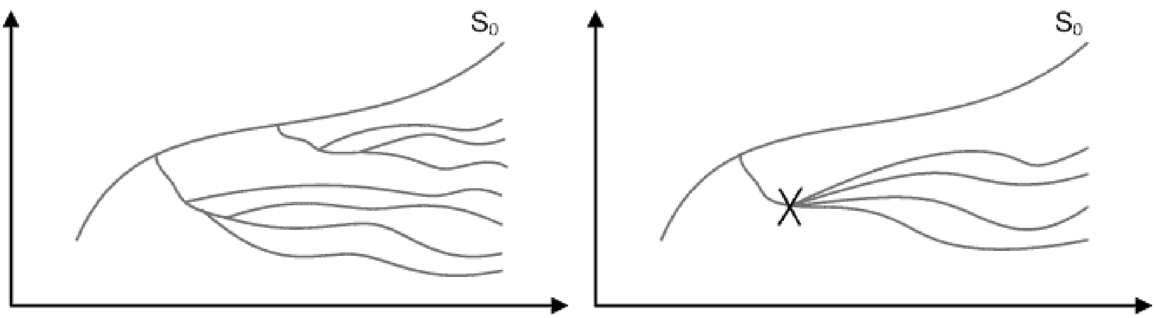
The framework provided by the quantitative definition of risk, referred to above, can also be utilized to define vulnerability in that the vulnerability of a system can be expressed as a "set of triplets". An imperative difference from the definition of risk, however, follows from the fact that vulnerability must be related to a specific hazardous event. The risk scenarios, i.e. the trajectories in the state space, described by the set of triplets are thus contingent on that the specific hazard has materialised and exposed the system. Thus, the vulnerability in a system is the answer to the three questions; "What can happen?", "How likely is it?" and "What are the consequences", where the answers are contingent upon that a specific hazardous event affects the system. In Figure 1 the difference between the definition of risk and vulnerability is illustrated using a state space representation.

To illustrate the use of the triplet assume that a community's vulnerability to a release of chlorine gas due to train derailment close to the city is to be analysed. The purpose of the analysis, such as whether the physical consequences (e.g. death and injuries), the consequences to the community's future prosperity, both these factors, or other factors are of interest, can have large effects on which the relevant scenarios are and which consequence dimensions to consider. Assume that we in this example are interested in the direct physical consequences. Next, one has to identify what can happen given that there is a chlorine gas release. One factor that affects the consequences of the gas release is the wind direction. If it blows away from the city negative consequences do not arise. If it blows towards the city the extent to which populated areas are exposed to the gas depends on for example wind speed, atmospheric stability class, and land exploitation proximate to the railway track. Furthermore, the extent to which the population in the affected areas are

[4] A closely related definition of vulnerability does not regard vulnerability as a system property, e.g. a "property of the whole". Instead vulnerability refers to the system's states or the conditions that "can be exploited to adversely affect (cause harm or damage to) that system" (Haimes 2006). Furtermore, Einarsson and Rausand suggest that vulnerability should be used to describe the *properties* of a system that "may weaken its ability to survive and perform its mission in the presence of threats" (Einarsson and Rausand 1998).

exposed to toxic gas concentrations for example depend on whether warning systems are in function and alert the community inhabitants, whether the ventilation can be shut down, either automatically or manually etc. From these varying conditions a number of scenarios can be defined and consequences and probabilities of each scenario can be estimated. The resulting set of triplets then represents the vulnerability of the community to the specified hazardous event.

Figure 1. The difference between risk and vulnerability using state space representations.*



* The definition of risk is illustrated to the left and the definition of vulnerability is illustrated to the right. The main difference can be seen in the right part of the figure where the scenarios in the definition of vulnerability are contingent on that a particular hazardous event has occurred and affected the system. This event is marked by a cross in the right figure. In a risk analysis, on the other hand, one is interested in all scenarios that deviate from the "success scenario", S_0.

It is important to note that the specification of the hazardous event and the purpose of the analysis can have large effects on the description and analysis of vulnerability. Assume for example that in addition to the specification of the hazardous event made above, the wind blows towards the city. The community is clearly more vulnerable to this event since the possibility of the wind blowing in a ”harmless” direction is dismissed. However, no characteristics of the community has been altered, only the specification of the hazardous event. Therefore, we argue that it is important to clearly state the event that the vulnerability is related to. Regarding the purpose of the analysis, assume that instead of analysing the vulnerability of the community we are interested in the vulnerability of the responsible railway company to a chlorine gas release. The consequence dimensions of interest will be different than above, since the interest resides in how the company is affected. Damages to goodwill and costs due to damage liabilities are examples of consequence dimensions of interest. The physical consequences to the population certainly might have an effect on how the railway company is affected, but it is not necessarily in the central interest of the analysis. This example shows that changing the purpose of the analysis might also lead to a change in system definition. Thus, when analysing vulnerability it is important to clearly state the purpose of the analysis along with system definition and system boundaries.

Emergency response capabilities

The use of the term vulnerability has suffered some criticism since its main focus is on the negative characteristics of systems, i.e. their inabilities. The criticism has especially addressed those instances when vulnerability is applied to individuals or social groups since it might lead to a view that "treat them as passive victims" (Cannon, Twigg et al, 2003). Instead, the argument goes, one should focus on the capabilities of systems to resist, cope with and recover from hazardous events. In this paper we are interested in applying the concepts to emergency response organisations. However, this focus is not to be interpreted that we are depreciating the importance of the capabilities of the affected population. Both these types of capabilities are crucial for the overall vulnerability of a community. We agree with Coles and Buckle who state that "governments are rarely able to meet all needs of affected people" (Coles and Buckle, 2004), therefore it is important that the affected population are empowered and encouraged to take proper actions.

As described in the introduction, emergencies and crises are often characterised by the fact that the affected population is not self-sufficient. Thus, needs of external assistance emerge, which if unmet will lead to negative consequences. The extent and character of the assistance needs is determined by factors such as the nature of the hazardous events, its severity and the capabilities of the affected to resist, respond to, and recover from the events. Relieving these needs and preventing additional needs to arise becomes the overarching goal for the emergency response organisations in a community, e.g. Fire and Emergency Services, NGOs etc. Perry and Lindell argues that it is important that emergency planning aims at identifying "the demands that a disaster would impose upon emergency response organisations and the resources (personnel, facilities, equipment and materials) that are needed by those organisations to meet the emergency demands" (Perry and Lindell, 2003). However, it is not only the demands directly imposed by the hazard agent upon the emergency response organisations that they have to deal with. Other demands arise due to the fact that a response is initiated. As such, two fundamentally different types of demands can be distinguished; *agent generated demands* – those stemming directly from the hazardous event, such as demand for meeting assistance needs and demands for hazard containment, and *response generated demands* – those emerging from the response to the emergency, such as information distribution and coordination (Dynes, 1994). What ultimately determines the success of an overall emergency response is to which extent the agent generated demands are met, since these are related to the essential variables of the system. The extent to which the response generated demands are met have an indirect effect in that it facilitates or impedes the possibilities to meet the agent generated demands.

An operational definition of emergency response capabilities

Whether emergency response organisations are able to meet the demands that are put on them in a crisis depends on their *emergency response capabilities*. The operational definition of emergency response capabilities that is proposed in this paper acknowledges that analysing capabilities and evaluating them are distinct processes. Evaluating capabilities, i.e. deciding whether a capability is acceptable or not, is a process that is intrinsically value-laden and subjective. The proposed definition aims at facilitating an *analysis* of capabilities and does not address issues of evaluation. The definition includes three essential elements: the *task* to which the capability is related, *measures* of how well that task can be performed and a description of the *context* affecting the performance of that particular task. However, given a specific context there might still be uncertainties about how well the task can be performed, which can be expressed as a set of scenarios similar to the quantitative definition of risk. In the following sections these elements are explored further.

A capability should be related to the performance of a specific task or function when being analysed, i.e. capability to do what?, not just capability in general. For instance, in the case of train derailment mentioned above examples of tasks for the actor Fire and Emergency Service might be "to stop the release" and "to issue warnings". In being specific about the particular task, capabilities are related to the actual course of events, which enables the analyst to be concrete about whether that particular task can be performed or not and providing support for or against it. We argue that in an analysis of capabilities one should strive towards defining tasks such that it is possible to determine if they can be performed or not (or to which degree they can be performed).

It is important to be clear about how to measure how well a task can be performed. Performance measures might vary for different tasks but important dimensions often include effectiveness (the extent to which the response actually satisfy the need that correspond to the demand) and efficiency (whether the task can be performed in a timely manner and within reasonable resource limits). Some performance measures might be directly related to the essential variables of the system as a whole while others might have a more indirect relation, depending on the nature of the task. Since the performance measures determine how well a specific task can be performed they need to be possible to derive, given a specific scenario. This means that they cannot be, for example, of the type "how good the release was managed", unless a clear definition of "good" is provided. Returning to the example above a suitable performance measure related to the task "to stop the release" might be "time from alarm until the release is stopped".

Variation in context, such as conditions in the environment and effects of the hazardous event, will have an affect on how well the tasks can be performed in an emergency situation. Emergency response capabilities are thus context dependent and this must be accounted for in an analysis. In the example above, a description of the context may include, for instance, whether the scene of the accident is accessible by road and whether the actor has access to certain resources. The capabilities that organisations possess during "optimal" conditions might thus be reduced if the context is different.

Given a specific context there might be uncertainties regarding how well a task can be performed. The emergency response capability can thus be seen as a set of triplets, similar to the quantitative definition of risk, corresponding to the three questions:

- "What can happen when an actor is performing a specific task, given a specific context?"
- "How likely is it?"
- "What are the consequences, for the performance measures defined for that particular task?"

An actor can in this case be seen as a part of an organisation, an organisation, or several organisations, thus the definition is flexible regarding the scope. From the scenarios it is possible to extract measures and metrics very much similar to what is done in a quantitative risk analysis, for example curves equivalent to risk curves or expected values. However, the details of how to do this in practice are outside the scope of this paper.

The relation between the definition of emergency response capabilities and the definition of vulnerability, proposed in a previous section is quite straightforward. In a system, for example a geographic region, there might be several actors that possess different emergency response capabilities. The actors and their capabilities will affect the unfolding of the scenarios, i.e. the trajectories in the state space of the system, given that the system is affected by a hazardous event. Thus, the emergency response capabilities will affect the vulnerability of the system as a whole. Some capabilities will certainly have a larger influence on the overall system vulnerability than others, which is important to consider in a comprehensive vulnerability analysis.

Discussion

The use of the definition of emergency response capabilities might be perceived as being demanding, in the sense that it can be time-consuming to carry out a comprehensive analysis. However, the definition should be seen as an ideal operationalisation and be used as a guidance for how a systematic analysis can be structured. The definition acknowledges that there are uncertainties about future events, both regarding the context in which the task are to be performed and regarding how well the task can be performed given a specific context. Furthermore, it should be possible to make judgements about the validity of any statements that are made about capabilities.

We argue that the main purpose of adopting the definition to analyse emergency response capabilities is to introduce a proactive mode of thinking into emergency response organisations. The definition provides an analytic structure that can encourage actors to be systematic when anticipating future events, the demands that are put on them in these events and whether these demands can be met. In the analysis it is possible to identify weaknesses in the emergency response capabilities of actors and alternatives regarding improvements can be suggested. In addition, such an analysis might have the potential of creating a mental awareness of the actors' capabilities and the limits thereof. The limits of the capabilities can then be communicated to other organisations and people and thereby increasing the awareness of the society as a whole. Furthermore, in analysing capabilities the organisations are forced to be concrete about how well the tasks can be performed and to express the capability in measurable quantities.

If the analysis is carried out as a coordinated exercise between many emergency response organisations, there might be additional benefits of analysing emergency response capabilities. First, there is a possibility that adoption of a common perspective on emergencies and a common language can be encouraged. This would for example facilitate communication and cooperation during an emergency and thereby improve the emergency response. By making an analysis of emergency response capabilities into a coordinated exercise between many organisations in a community it is also easier to gain knowledge about the emergency response capabilities of the community as a whole.

In the proposed definition, capabilities are analysed in a concrete manner where tasks are directly related to the actual course of events in the emergency. Another approach could be to analyse higher level abstractions, such as flexibility or capacity to improvise. However, since these are hard to relate to the actual course of events in an emergency it is hard to gain knowledge about the effect these abstractions have on the emergency response and evaluating the validity about statements addressing higher level abstractions might be difficult. In addition, these higher level abstractions are often effects of having a set of concrete capabilities. An example is flexibility, which is often an effect of the ability to perform tasks in different contexts and conditions, for example being able to perform a task even though the regular personnel are disabled. Higher level abstractions can thus often be extracted from the more concrete capabilities.

In analysing emergency response capabilities one will encounter the same problem as one does when applying the quantitative definition of risk, namely choosing an appropriate level of detail in the description of scenarios and context. In theory, there is an infinite set of scenarios and an infinite number of possible contexts, since a description always can be made more detailed. However, very detailed descriptions are often unpractical in real world applications since there is a trade-off between for example the level of detail and the time required to complete the analysis. An important task when analysing emergency response capabilities is therefore to choose an appropriate level of detail. Choosing a too fine level of detail will lead to that too much effort is committed to details that will not affect, or have very limited effect on, the overall analysis. Choosing a too coarse level of detail, on the other hand, could result in that important aspects are overlooked. An example is how to define a task. At the most general level regarding the example with the derailed train, the task might be "to manage the situation". This could be divided into a number of more detailed tasks, e.g. "stopping the release", "issue warning" etc., which in turn could be further divided into tasks of even higher level of detail. The level of detail will in turn affect the number and character of the performance measures that are used to capture what is to constitute a well performed task. The level of detail that is ultimately chosen need to depend on the aim of the specific analysis.

There are several areas for further research. Firstly, there is a need to apply the definition of emergency response capabilities in a comprehensive case study with the purpose of testing the applicability of the framework. Choosing an appropriate level of detail in the analysis is one issue that needs to be addressed. Secondly, the problem of synthesis should be addressed. Using the proposed definition capabilities are *analysed*, i.e. the overall emergency response is broken down into separate tasks, but it is sometimes not straightforward how to synthesise these capabilities into an overall assessment of the capabilities of for example a community.

Conclusions

In this paper we have proposed an operational definition of emergency response capabilities that includes three essential elements. The task to which the capability is related, measures of how well that task can be performed and a description of the context affecting the performance of that particular task. The definition makes clear that there are uncertainties about how well a particular task can be performed given a specific context and that this must be taken into account in an analysis. We conclude that the definition provides a framework for analysing emergency response capabilities which can help actors to gain knowledge about their capabilities and limits thereof. Such an analysis can also serve as a basis for a subsequent evaluation and suggestions for capability improvements.

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Author Biographies

Henrik Jönsson is a PhD student at the Department of Fire Safety Engineering and has a M.Sc. in Risk Management and Safety Engineering and a B.Sc. in Fire Safety Engineering. His main research area is risk and vulnerability analysis of complex social and technical systems.

Marcus Abrahamsson is a PhD student at the Department of Fire Safety Engineering at Lund University and holds a Licentiate degree in Fire Safety Engineering. His main research areas are risk and vulnerability analysis of social and technical systems and treatment of uncertainties in quantitative risk analysis.

Henrik Johansson is an assistant professor at the Department of Fire Safety Engineering at Lund University and has a Ph.D. in Fire Safety Engineering and a M.Sc. in Civil Engineering. His main research areas are vulnerability analysis of social and technical systems and decision analysis concerning investments in risk reducing measures.