Improving capability assessments for disaster risk management

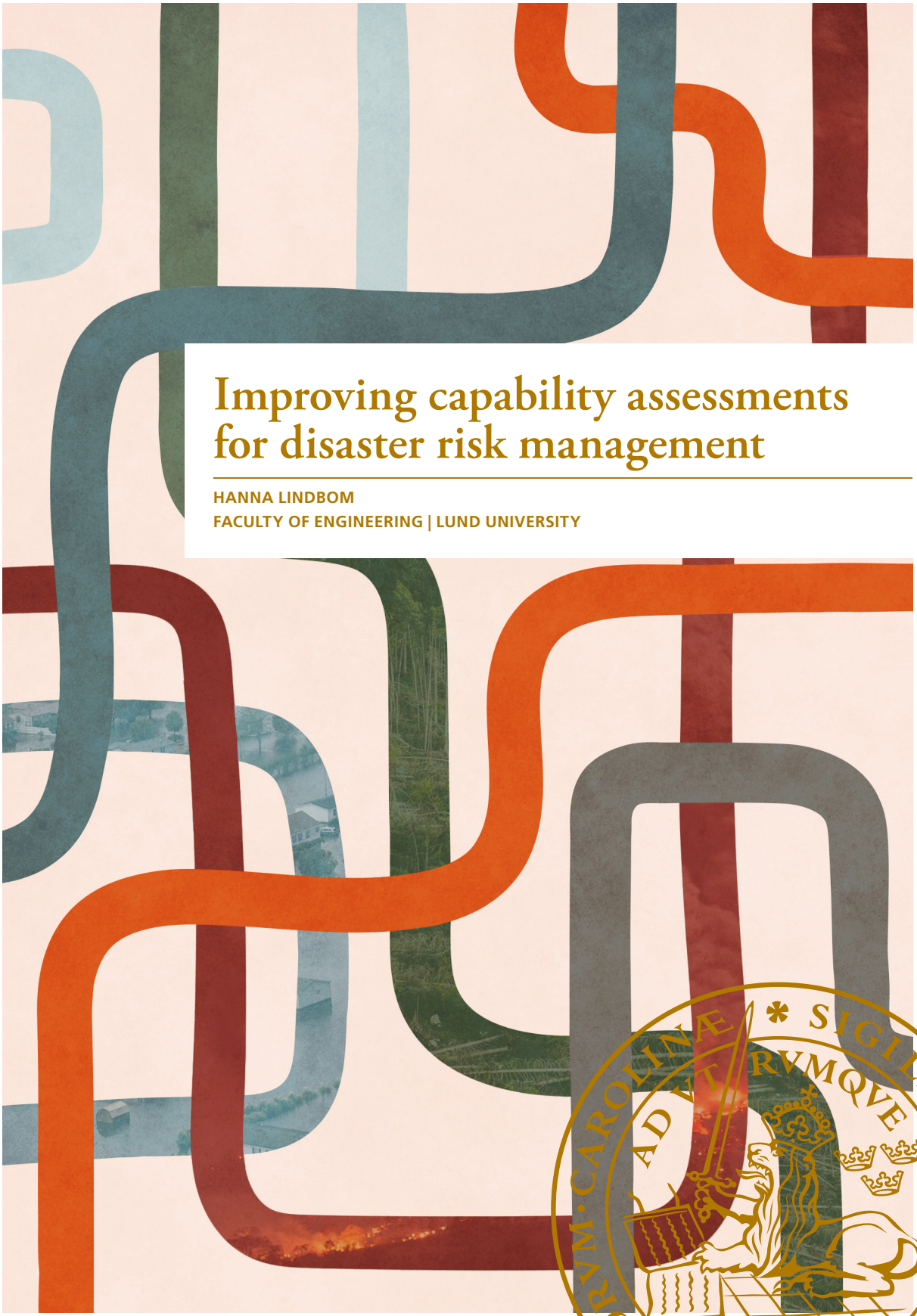
Lindbom, Hanna

2020

Document Version:
Publisher's PDF, also known as Version of record

Improving capability assessments for disaster risk management

HANNA LINDBOM
FACULTY OF ENGINEERING | LUND UNIVERSITY



Improving capability assessments for disaster risk management

Hanna Lindbom

LUND
UNIVERSITY

Doctoral dissertation to be publicly defended on Friday 31 January 2020 at 10:15 in lecture hall V:B (V-building), John Ericssons väg 1, Lund, by due permission of the Faculty of Engineering, Lund University.

The faculty opponent is Professor Lars Nyberg,
Karlstad University, Sweden.

Organisation	Document name
Lund University, Faculty of Engineering Division of Risk Management and Societal Safety	Doctoral dissertation
	Date of issue 31 January 2020
Author Hanna Lindbom	**Sponsoring organisation** The Swedish Civil Contingencies Agency

Title

Improving capability assessments for disaster risk management

Abstract

There is an urgent need for society to find more effective ways to reduce the impact of disastrous events. One way is to proactively increase actors' response capability. Capability assessments play an essential role in these disaster risk management efforts. Currently, capability is assessed using indicator and index methods that focus on available resources. Such methods may not provide the best guidance to decision-makers when selecting measures to increase capability. The reason for this is that they do not explicitly relate capability to the impact of disasters. Therefore, in an attempt to improve capability assessments, this research proposes a new definition and description of capability. The new definition is tested in several experimental studies, to investigate whether further work on the topic is warranted. The results suggest that the proposed approach provides better guidance to decision-makers who are seeking to proactively increase the response capability. These initial results suggest that additional research to extend this view of capability is warranted. Overall, this research provides a better understanding of the current use of capability assessments, and clarifies their potential role in disaster risk management. The proposed definition may be useful in this context, as current practice seems to encourage compliance and complacency among actors tasked with assessing capability. Such behaviour could hinder efforts that aim to reduce losses from disasters.

Keywords

disaster risk management (DRM), societal safety, capability assessment, response, decision-making, control

ISBN	Language
978-91-7895-290-8 (print) 978-91-7895-291-5 (pdf)	English

Improving capability assessments for disaster risk management

Hanna Lindbom

LUND
UNIVERSITY

Supervisor
Professor Henrik Tehler, Lund University

Co-supervisors
Associate Professor Christian Uhr, Lund University and the Swedish Civil Contingencies Agency
Associate Professor Henrik Hassel, Lund University
Doctor Kerstin Eriksson, RISE Research Institutes of Sweden

Faculty opponent
Professor Lars Nyberg, Karlstad University

Examining committee
Professor Marianne Jahre, Lund University
Professor Niklas Hallberg, Linköping University and the Swedish Defence Research Agency
Professor Patrick van Hees, Lund University
Professor Roger Flage, University of Stavanger

Sponsoring organisation
The Swedish Civil Contingencies Agency

Cover and illustrations
Cornelia Runehammar

ISBN 978-91-7895-290-8 (print)
ISBN 978-91-7895-291-5 (pdf)

Printed in Sweden by Media-Tryck, Lund University
Lund 2020

Media-Tryck is an environmentally certified and ISO 14001 certified provider of printed material. Read more about our environmental work at www.mediatryck.lu.se

Summary

Each year, over 30,000 people die from disasters, and the lives of over 100 million individuals are affected. All around the world, societies are striving to reduce these numbers by, for example, increasing the response capability. One example of this is when fire and rescue services invest in new equipment to increase their capability to pump water, or when flood protection levees are built. Capability assessments play an essential role in such efforts.

However, current assessments have significant weaknesses when it comes to providing decision-makers with guidance when selecting measures to increase capability. The reason for this is that they often only focus on available resources, rather than how these resources can reduce losses from unwanted events, such as floods and forest fires. It is typically the case that ten helicopters are considered to equal higher capability than five, irrespective of whether this actually reduces the impact of a forest fire. Similarly, a municipality that has a flood response plan is judged to have higher capability than one that does not have such a plan. Of course, this could be the case. But, the fact that the first municipality has a plan and the other has not, is insufficient evidence to draw such conclusions – it could well be the other way around.

This focus on resources, and the neglect of other factors, is problematic, as budgets are limited. It is clear that if additional investments do not contribute to reducing losses, the money could have been better used elsewhere. Therefore, in an attempt to improve capability assessments, this research suggests a new definition and description of capability. Specifically, capability is associated with an actor (e.g., a fire and rescue service) who carries out various tasks that seek to positively influence the outcome of an event (e.g., extinguishing a forest fire from both the ground and the air). Available resources remain, of course, essential. However, how resources are used and their effect on the outcome is also central. This conceptual perspective makes it possible to relate capability to other key concepts such as risk and vulnerability, and, importantly, to losses from disasters. This is particularly essential when capability assessments are integrated into proactive efforts to reduce losses from disasters.

Although the suggested approach seems better from a conceptual point of view, it is unclear whether it can provide decision-makers with better guidance than assessments that only focus on resources. Consequently, several experimental studies were developed to investigate the issue. Representatives from Swedish fire and rescue services and preparedness offices participated in investigations that focused on, for example, municipalities' capability to respond to forest fires and floods. The results suggest that the proposed approach provides better guidance to decision-makers who are seeking to proactively increase the response capability. These initial results suggest that additional research to extend this view of capability is warranted.

Sammanfattning

Varje år omkommer 30 000 människor i katastrofer, och fler än 100 miljoner drabbas. Över hela världen vill man minska dessa siffror, till exempel genom att öka förmågan att hantera händelserna. Ett exempel på detta är när räddningstjänsten investerar i ny utrustning för att öka sin förmåga att pumpa vatten och bygga fördämningar vid en översvämning. Förmågebedömningar spelar en viktig roll i detta arbete.

Men, dagens förmågebedömningar har svagheter när det kommer till att vägleda beslutsfattare om åtgärder för att öka förmågan. Anledningen är att bedömningarna ofta enbart fokuserar på tillgängliga resurser, istället för hur dessa kan användas för att minska konsekvenserna av händelser, exempelvis översvämningar och skogsbränder. Dagens fokus innebär, i princip, att tio helikoptrar motsvarar en bättre förmåga än fem, oavsett om de i större utsträckning faktiskt kan begränsa konsekvenserna av en skogsbrand. På samma sätt uppfattas en kommun som har en översvämningsplan ha högre förmåga än en som inte har en plan. Detta kan visserligen stämma. Men, bara det faktum att den första kommunen har en plan och inte den andra kan inte användas för att dra sådana slutsatser – det skulle även kunna vara precis tvärt om.

Att fokusera på enbart resurser är problematiskt eftersom samhällets resurser är begränsade. Om ytterligare investeringar i resurser inte bidrar till att minska konsekvenserna av olika händelser skulle pengarna ha kunnat användas till annat. I ett försök att förbättra förmågebedömningarna föreslår den här forskningen en ny definition av förmåga och ett nytt sätt att bedöma den. I den nya definitionen relateras förmåga till att en aktör, till exempel en räddningstjänst, utför olika uppgifter med syftet att positivt påverka utfallet av en händelse. Vilka resurser som finns är självklart en viktig aspekt av detta, men centralt är också hur dessa används och vilken effekt detta får på utfallet. Denna syn på förmåga gör det möjligt att konceptuellt relatera förmåga till andra viktiga begrepp såsom risk och sårbarhet, och inte minst till konsekvenserna av händelser. Detta är viktigt om förmågebedömningar ska kunna integreras i det proaktiva arbetet för att minska förluster från katastrofer.

Även om det föreslagna sättet att bedöma förmåga förefaller bättre rent konceptuellt, så är det inte säkert att det i praktiken ger beslutsfattarna bättre beslutsunderlag än förmågebedömningar som fokuserar enbart på resurser. För att undersöka detta har flera experimentella studier genomförts. Representanter från svensk räddningstjänst och kommunal och regional krisberedskap har deltagit i studierna, som bland annat har fokuserat på kommuners förmåga att hantera skogsbränder och översvämningar. Resultaten visar att det föreslagna synsättet verkar fungera bättre som beslutsunderlag i det proaktiva arbetet med att öka responsförmåga. Därmed kan ytterligare forskning på att utveckla denna syn på förmåga motiveras.

Acknowledgements

I am sincerely grateful for all the support I have received during the years working with this dissertation. I would like to thank the Swedish Civil Contingencies Agency for funding my dissertation project, and the professionals in the Swedish disaster risk management system for participating in my studies.

To my supervisor, Henrik Tehler: I admire your clear way of thinking and your calmness. You have provided guidance and support in so many ways and been such a source of inspiration. Through your feedback and reflections, you have guided me to grow, both as a scientist and as a person. You have my deepest gratitude.

To my co-supervisor, Christian Uhr: Thank you for helping me put things into perspective and interpreting things in different ways. Without your unconditional support, this journey would have been even rougher.

To my co-supervisors, Henrik Hassel and Kerstin Eriksson: Thank you for following me on my first conferences and for valuable discussions throughout the years.

In addition to my co-authoring supervisors, I would like to thank Professor Terje Aven for co-authoring one of the appended papers and contributing with expertise on the new risk perspective.

I would like to thank Professor Vicki Bier for the rewarding stay at the University of Wisconsin–Madison.

I am also thankful for the discussions, both academic and non-academic, with past and present colleagues at the Division of Risk Management and Societal Safety. I have met so many inspiring people during these years and I am proud to call you my colleagues.

Thank you, Cornelia Runehammar, for the great illustrations and for creatively interpreting my research.

Last, but certainly not least, thank you to my ever-supportive family and friends. To the love of my life, Johan: I don't have enough words to describe how grateful I am for all your love and support. To our adorable children Edvin and Stina: You are the biggest joy in my life, and you put a smile on my face every day. I love you!

Contents

Introduction

Adverse events threaten many of the things we care about – for example, lives, the functioning of society and the environment. Events range from traffic accidents and house fires, to those that affect entire regions or nations, like the Fukushima earthquake and tsunami in 2011. They can also be global, like the H1N1 flu pandemic of 2009.

Globalisation, urbanisation and technological advances are intensifying the consequences of large-scale disruptions on how society functions (Boin & Lagadec, 2003; CADRI, 2011; OECD, 2003, 2011; Perrow, 1999; UNISDR, 2017). The number of lives lost and assets destroyed due to disasters continues to grow (UNISDR, 2017): 108 million people were affected in 2015, while more than 30,000 died and economic losses reached over 70,000 billion USD (IFRC, 2016).

Finding effective ways to reduce their impacts has become urgent (World Economic Forum, 2017). Reacting is no longer sufficient, and proactive disaster risk management (DRM) is gaining ground, with the goal of reducing long-term losses (FAO, 2008; UNISDR, 2005, 2009, 2015). This can be achieved by, for example, increasing the response capability. However, such measures come at a cost, and resources are limited; consequently, societies must decide which measures to prioritise (Bier, Haphuriwat, Menoyo, Zimmerman, & Culpen, 2008; Caudle & de Spiegeleire, 2010; Ivgin, 2013; McConnell & Drennan, 2006; Mennen & van Tuyll, 2015; OECD, 2009; Petrenj, Lettieri, Trucco, & Milano, 2012). Is it, for example, worth to buy additional fire engines, or relocate the fire station in order to reach accidents faster? Should all critical infrastructure be supplied with auxiliary power units? Should more exercise drills be held, and should plans be revised to improve the response to a disaster?

For frequent events, such as traffic accidents and house fires, previous experience can be used to assess whether the response capability is sufficient to limit the severity of any consequences, and guide decisions to increase it if necessary. In the case of disasters, however, experience can rarely guide such decisions. As they are associated with considerable uncertainty, we cannot know for sure when one will strike, the subsequent losses, or the effect of an increased or decreased response capability.

In this context, risk, vulnerability and capability assessments are valuable analytical tools for managing uncertainty and guiding efforts to reduce long-term disaster losses (Alexander, 2005b; Perry & Lindell, 2003; Quarantelli, 1998; Rasmussen, 1997; Rasmussen & Svedung, 2000). However, significant challenges remain when it comes to

risks to societal safety, as there are often numerous interdependencies and potential spill-over effects between societal functions, geographical areas, and administrative levels, making them difficult to foresee and address (Ansell, Boin, & Keller, 2010; Boin & McConnell, 2007; Hills, 2005; Little, 2004; Olsen, Kruke, & Hovden, 2007). Increasing interdependencies have created complex systems of systems (Calvano & John, 2004; Cilliers, 2000; OECD, 2011), while risks themselves are becoming increasingly complex (OECD, 2003) and associated with uncertainty and ambiguity (Klinke & Renn, 2002; Renn, 2008; van Asselt & Renn, 2011). At the same time, society is becoming institutionally fragmented (Almklov & Antonsen, 2010; de Bruijne & van Eeten, 2007), meaning that one single actor cannot increase the collective response capability (OECD, 2010; Renn, 1998).

A precondition for effective action is to understand current capabilities (OECD, 2015). This research focuses on capability assessments carried out by, for example, municipalities, regions and nations, to both assess the current level of response capability and identify ways to increase it. Capability assessments are one element of proactive initiatives in several countries, including Canada, Estonia, Germany, Latvia, the Netherlands, New Zealand, Poland, Sweden, the United Kingdom and the United States (DHS, 2013b, 2013a; Friesen, Giroux, & Villeneuve, 2013; Karlsson, Olsson, & Riedel, 2016; Ministry of Civil Defense and Emergency Management, 2015). On a multinational level, the European Union has launched a programme that aims to assess the capability of all its member states (European Commission, 2015); the From gaps to caps project aims to develop methods to carry out joint national capability assessments in ten countries in northern Europe (Karlsson et al., 2016).

Although capability assessments are becoming increasingly popular world-wide, there is limited research on the topic of preparedness, in general (Reidar & Kruke, 2018), and the capability concept and capability assessment methods, in particular (Hemond & Robert, 2012). Taken together, these observations motivate more research to help professionals develop their practices. Therefore, this research addresses the issue of proactively increasing response capability in order to lessen the impact of events. More specifically, it focuses on rare events where prior experience is limited, and how capability assessments can facilitate the efforts to increase response capability.

Research aim

This research aims to increase knowledge about the concept of capability and capability assessments in the context of reducing losses from disasters. It describes current capability assessment practice and suggests improvements. To this end, this research focuses on four research questions that should be interpreted in the light of the conceptual framework presented in the next chapter. This framework limits the range of possible answers to the, otherwise broad, research questions.

Research questions and research process

The first question is exploratory, and relates to current capability assessment practice:

- How is capability defined and assessed? (Research question 1)

The answer to this question reveals that current definitions and assessment methods provide limited guidance for increasing response capability. In the light of the conceptual framework, it became clear from the answer to the first question that there was a need to define and describe capability in the context of DRM and DRM concepts. Hence, the second research question was formulated as:

- How should capability be defined and described? (Research question 2)

Taking the answer to the second research question, the first question was then revisited in order to explore to what extent capability is currently described according to the proposed new definition. Additionally, the answer to the second research question led to the formulation of two more questions. Although the answer to the second question provides a definition that relates the concepts of capability and capability descriptions to the goal of DRM and other DRM concepts and activities, it provides no evidence that capability assessments based on this definition can support DRM goals better than the methods identified through the first research question.

In practice, it is methodologically challenging to study the effect of various capability descriptions on the goal of DRM. Disasters are rare, which necessarily makes it difficult to study the effects of implementing different ways of describing capability. One way to address the problem from a research perspective is by taking a step back and studying the capability descriptions that the various methods generate. Therefore, the third research question was formulated to include the central aspects of capability (task and resource descriptions) derived from the answers to the first and second questions:

- To what extent do task and resource descriptions contribute to decision-makers' perceived usefulness of capability descriptions? (Research question 3)

The latter question assumes that a useful description will, ultimately, lead to increased capability and ultimately less losses (which is the goal of DRM). However, this assumption needs further scrutiny. Therefore, the final research question was formulated to focus on the relationship between capability descriptions and the actual behaviour of the decision-maker. More specifically, it focuses on whether different ways of describing capability affect resource allocation for investments in capability. Consequently, the fourth research question was formulated as:

- Do capability descriptions affect decisions concerning the allocation of resources intended to increase capability? (Research question 4)

The research process and how the five papers that make up this dissertation contribute to answering the research questions is illustrated in Figure 1.

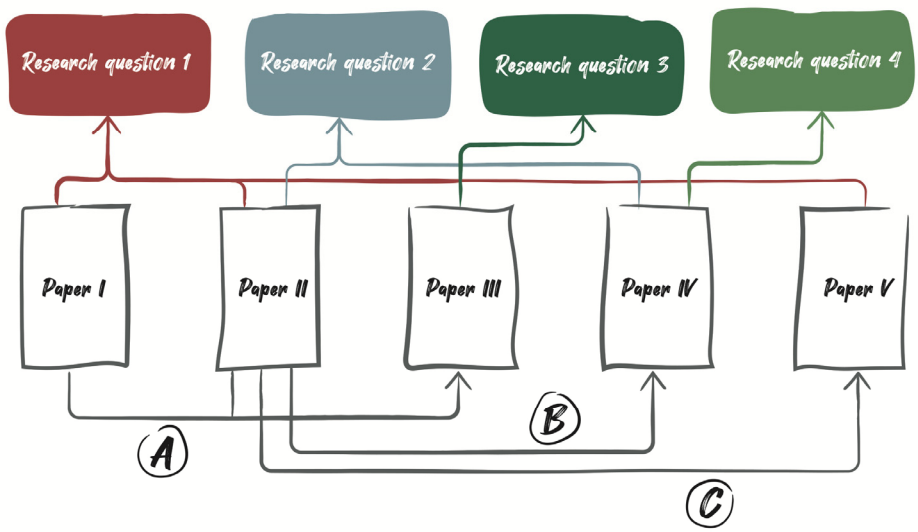


Figure 1. The research process.
The schematic outline of the research process shows how the five papers contribute to answer the four research questions and how the output from earlier papers was used as input to later papers. Although each study is independent, they inspire each other and are closely related. For example, Papers I and II identified and suggested different ways of describing capability (A), and these ways were further studied in Paper III. Similarly, the way of describing capability suggested in Paper II was further explored in Papers IV and V (B and C).

Publications

Appended papers

I. **Palmqvist** [1], **H.**, Tehler, H. & Shoaib, W. (2014). How is capability assessment related to risk assessment? Evaluating existing research and current application from a design science perspective. In *Proceedings of the 12th Probabilistic Safety Assessment and Management Conference*, PSAM 2014, Honolulu, United States, 22–27 June 2014.

I designed the study, performed the scoping study and analysed all the empirical material. The authors jointly wrote the paper.

II. **Lindbom H.**, Tehler, H., Eriksson, K. & Aven, T. (2015). The capability concept – On how to define and describe capability in relation to risk, vulnerability and resilience. *Reliability Engineering and System Safety*, *135*, 45–54.

The authors jointly developed the theoretical argument and wrote the paper. I collected and analysed the empirical material.

III. **Lindbom, H.**, Hassel, H., Tehler, H. & Uhr, C. (2018). Capability assessments – How to make them useful for decision-making. *International Journal of Disaster Risk Reduction*, *31*, 251–259.

The authors jointly designed the study and collected the empirical material for the first experiment. I collected the material for the second and third experiments, analysed the empirical material for all experiments and played a major role in writing the paper.

IV. **Lindbom, H.** & Tehler, H. (2019). Striking a balance between the costs and benefits of increasing response capability: A microworld study of the effect of capability assessments. *International Journal of Disaster Risk Reduction*, *41*, 101297.

The authors jointly designed the study and wrote the paper. I collected and analysed the empirical material.

V. **Lindbom, H.** (submitted). The missing link – The importance of the capability concept for relating risk assessments and plans. Submitted to an international peer-reviewed journal.

[1] My former surname was Palmqvist

Related publications

Palmqvist, H., Bergström, J. & Henriqson, E. (2012). How to assess team performance in terms of control: A protocol based on cognitive systems engineering. *Cognition, Technology and Work*, *14*(4), 337–353.

Palmqvist, H., Tehler, H., Hassel, H., Svegrup, L. & Petersen, K. (2012). *Utveckling av förmågebedömningar* [Development of capability assessments]. Report 1022. Lund: LUCRAM.

Palmqvist, H. & Eriksson, K. (2013). Understanding capability – how the concept is used in emergency management. Paper presented at Amsterdam risk conference, Risk and uncertainty: ontology and methods, Amsterdam, the Netherlands, 23–25 January 2013.

Lindbom, H. (2015). Förmågebedömning i ett komplext samhälle [Capability assessment in a complex society]. In *Slutrapport från ramforskningsprogrammet PRIVAD* [Final report from framework program for research PRIVAD]. Report 3003. Lund: LUCRAM.

Lindbom, H., Tehler, H., Frykmer, T. & Uhr, C. (2015). How can the usefulness of capability assessments be improved? In *Safety and reliability of complex engineered systems*, Proceedings of the 25th European Safety and Reliability Conference, ESREL 2015, Zürich, Switzerland, 7–10 September 2015.

Hanson, M., Severinsen, S. & **Lindbom, H.** (2016). How well do capability assessments reflect actual capability? – An experimental study of capability assessments with multi-actor dependencies. In *Risk, reliability and safety: Innovating theory and practice*, Proceedings of the 26th European Safety and Reliability Conference, ESREL 2016, Glasgow, Scotland, 25–29 September 2016.

Lindbom, H., Tehler, H. & Hassel, H. (2017). *Hur används riskanalyser för att dimensionera hanteringsförmåga?* [How are risk analyses used to design response capability?] Report 1024. Lund: LUCRAM.

Tehler, H., Lindström, J. & **Lindbom, H.** (2018). Using microworlds to study critical infrastructure protection – The effect of incentives on risk management. In *Safety and reliability: Safe societies in a changing world*, Proceedings of the 28th European Safety and Reliability Conference, ESREL 2018, Trondheim, Norway, 17–21 June 2018.

Terminology

Definitions of the terms accident, catastrophe, crisis, emergency and disaster have been the subject of much debate (cf. Alexander, 2002; Alexander, 2005a; Boin & Hart, 2007; Quarantelli, 2000). In this research, the term disaster denotes relatively rare events with, at least, fairly severe consequences. Decision-makers have limited experience of such events and their losses and little information to rely on when deciding whether to invest in increasing capability. In this case, capability assessments play a key role. Accidents here refers to frequently-occurring events, such as traffic accidents and house fires. In this case, responding organisations and decision-makers have ample experience to draw upon. In line with Alexander (2005b), the term emergency, used in Paper II, is a broader concept that includes both accidents and disasters. In Paper IV, the concept adverse event is used for the same purpose.

This research is concerned with the proactive assessment of response capability. DRM is commonly divided into four phases: mitigation, preparedness, response and recovery (McEntire, 2007). They are closely related and sometimes difficult to distinguish. The common goal of all of the phases is to reduce long-term losses from disasters (UNISDR, 2009), either by reducing the likelihood of disasters through mitigation, or by reducing their impact through preparedness, response and recovery. Capability assessments are, in this research, seen as a DRM activity that is carried out in the preparedness phase and are intended to increase the response capability.

Delineations

The concept of capability is used, and capability is assessed in various contexts. These applications are briefly introduced below, with explanations of how they differ from the focus of this research.

Capabilities-based planning

Capabilities-based planning is used in, for example, the Netherlands, Singapore, the United Kingdom and the United States, to guide investments with respect to the full range of risks, from forest fires to terrorist attacks. It is loosely based on investment portfolio theory and improves an organisation's ability to set specific preparedness goals and priorities, compare the costs and benefits of investment choices, and evaluate preparedness results. Risk assessments form the basis for capabilities-based planning by describing a broad range of possible future scenarios for which capabilities should be either developed or maintained. Instead of focusing on resources, capabilities-based planning focuses on what the organisation needs to accomplish; resources are only of

value when used (Filinkov & Dortmans, 2014; OECD, 2009; Webb, Richter, & Bonsper, 2010).

Capabilities-based planning is an ambitious attempt to optimise investments designed to close capability gaps and identify capabilities that address multiple or all scenarios. However, there is confusion regarding its meaning (Webb et al., 2010). Thus, a prerequisite to developing capability assessment practices associated with the approach is to develop a fundamental understanding of the concepts of capability and capability assessments. That is the focus of the research presented in this dissertation.

Military capability assessments

It is difficult to assess capability in the military domain, and current knowledge is "dreadfully limited" (Yue & Henshaw, 2009, p. 64). There is no precise, agreed-upon definition of capability (Oxenham, 2010), and typically it is assessed by counting resources, such as the number of personnel or the number of weapons of a given type. However, counting resources fails to account for the complexity of warfare, and is insufficient to diagnose weaknesses and prescribe remedies. Another approach is to look at per-capita military spending. However, this is also a poor measure; while the military budget may be generous, a country might fail to transform these resources into war-fighting capabilities.

A more meaningful measure is how resources can be used to counter threats (Biddle, 2004; Friedberg, 1987; Marshall, 1966; Tellis, Bially, Layne, & McPherson, 2000; Wood, 2019). In the early 2000s, a discussion emerged regarding the complex relation between equipment and what can be accomplished with it (de Spiegeleire, 2011; Oxenham, 2010); consequently, capabilities-based planning has become the gold standard (de Spiegeleire, 2011). However, sophisticated, complex and realistic models are difficult to construct, hard to test and inevitably inexact in their results, and remain in danger of being displaced by misleading resource counting (Friedberg, 1987). Moreover, the output of capabilities-based planning could be improved, given the potential benefits (de Spiegeleire, 2011).

The research presented in this dissertation focuses on capability assessments in civil contexts, and differs from military assessments, where capability is always relative to the capability of an enemy.

The capability-based approach

Other applications of the concept of capability are found in development economics, policy and ethics (cf. Sen & Nussbaum, 1993). From this perspective, the focus is on the capability of individuals, which is, in turn, a function of alternative combinations of functioning that they could realistically achieve. Murphy and Gardoni (2006, 2007,

2008, 2010, 2012) and Gardoni and Murphy (2008, 2009, 2010) have applied these ideas in a risk analysis context, and suggest that estimates of societal impact should be based on likely changes in individuals' capabilities, which is a function of their resources and what they are able to do with these resources. This, in turn, depends on not only these individuals' resources (such as talents and skills) but also the environment, for example, legislation, norms and physical infrastructure. The following example illustrates this view of capability:

> [Consider an individual who before a hazard has] the capability of being mobile. A, B and C could represent alternative ways that are available for an individual to go to work (e.g., alternative routes or transportation methods). Due to the impact of a hazard, option C might not be available at least for a period of time. While an individual might still choose route A, as he or she did before the hazard, traffic will likely increase, given the reduction in other available routes. This will impact the level of mobility the individual is free to achieve. On the other hand, if as part of the recovery reinvestment or mitigation strategy a new route opens, then even if he or she chooses A the traffic will likely be less than before the hazard, thereby enhancing mobility (Murphy & Gardoni, 2010, p. 142).

There are clear similarities between the capability-based approach and the definition of capability proposed in Paper II. Both focus on available resources and what can be achieved with them. However, while the capability-based approach focuses on the capability of individuals from the perspective of justice, the focus of the research presented in this dissertation is on the assessment of various stakeholders' abilities to respond to disaster.

Capacity development and assessment

The concept of capacity is not unlike the concept of capability. Capacity development for DRM is concerned with strengthening the capabilities of individuals, organisations and societies so that they can, over time, achieve their development objectives (Hagelsteen & Becker, 2013). More affluent countries and international organisations assist developing countries in developing their DRM capacities, and capacity assessment is a vital tool for effective capacity development (Becker, 2012). Capacity assessments focus specifically on describing, for example, current legislation and policies, institutional arrangements, financial resources and competencies that have been put in place to reduce disaster risk (CADRI, 2013).

In this dissertation, capacity assessments differ from capability assessments. Capability assessments focus on assessing the response capability. Capacity assessments, on the other hand, assess the overall DRM structures and processes.

The conceptual framework

The new risk perspective

Risk is a concept that is used in disciplines such as technology, economics, psychology and sociology (Renn, 1998). Consequently, there are several definitions and its interpretation remains ambiguous (Aven & Renn, 2009; Aven, Renn, & Rosa, 2011; Haimes, 2009; van Asselt & Renn, 2011). Central to many definitions, however, is the idea of an uncertain future in which something might happen that leads to unwanted consequences for something of value (ISO, 2009; SRA, 2018; UNISDR, 2009).

This research builds on the new risk perspective (Aven & Ylönen, 2018), which is a view of risk that contrasts with the traditional risk perspective. The latter focuses specifically on the use of probabilities to express uncertainty, and assumes that the system of interest can be modelled using probabilities to rationally calculate and control the level of risk. The traditional perspective's narrow focus on probabilities has been heavily criticised. Uncertainty is the core component of the new perspective, and probability is only one tool among many to express it. Moreover, the background knowledge and assumptions that underlie uncertainty estimates are central to the result of a risk assessment. Characterising the strength of knowledge, and presenting the arguments that underlie uncertainty estimates, improve decisions about resource allocation (Askeland, Flage, & Aven, 2017; Aven, 2017; Aven & Renn, 2019; Aven & Ylönen, 2018 & Hadorn, 2018).

In this work, risk refers to "uncertainty about and severity of the consequences (or outcomes) of an activity with respect to something that humans value" (Aven & Renn, 2009, p. 6). It is consistent with Aven's (2010) argument that events, consequences and uncertainty are the cornerstones of the concept. The new risk perspective also includes definitions of, for example, vulnerability and resilience (Aven, 2011). Moreover, it distinguishes the concept from its description, for example, the concept of risk and the results of a risk assessment (Aven, 2010, 2012). This position is in line with the critical realism paradigm that guides this research (cf. the next chapter). More specifically, the risk description includes a description of consequences, the measure of uncertainty, and the background knowledge that the uncertainty measure is based on (Aven, 2012). The distinction is highly relevant to this research, as it investigates capability descriptions, and not actual capability. Moreover, this perspective does not necessarily limit the research to any specific type of event or value.

Risk management as a control problem

We tend to become concerned when something that might happen in the future may have consequences for something we value. In this situation, managing risk to reduce potential consequences becomes a priority. There are several definitions of risk management (cf. ISO, 2009; SRA, 2018; UNISDR, 2009) that stress that risk management is about doing something (e.g., mitigate or prepare), in order to achieve something (limit the severity of the consequences). This allows viewing risk management as a control problem (Brehmer, 1992; Rasmussen, 1997).

Control can be based on either an open-loop or closed-loop strategy (Rasmussen, 1997). In the former, actions are independent of the outcome that is produced. From a risk management perspective (and the DRM goal of reducing the severity of consequences), this could mean that decision-makers continuously invest a specific sum in increasing capability, or in a predetermined measure – irrespective of what is currently needed to reduce the severity of consequences or whether the investment has any effect.

On the other hand, closed-loop control implies that the decision-maker takes feedback from the system into account. This feedback could be experience (e.g., actual losses from events that have occurred), which indicates whether a decision reduced the severity of consequences or not. From this, the decision-maker can adjust measures taken to reduce losses, for example by increasing investments in response capability.

However, events may be rare. Here, decisions have to be made without any feedback from experience. Assessments of, for example, capability are ways to compensate for this lack of experience. They provide the decision-maker with estimated feedback regarding whether the previous decision resulted in increased response capability, or not, allowing them to proactively adjust the measures that are taken.

Decision-making in risk management

What does current decision-making theory tell us about how decisions are made in risk management situations? The classical way of describing decision-making under uncertainty, which is the case for risk management decisions, is as a gamble (Keeney, 1982; von Neumann & Morgenstern, 1944). The focus is on decision-makers' judgements, and how decisions should be made. In such studies, individuals face the hypothetical problem of accepting either a very positive or a very negative outcome (or not). Moreover, the outcomes' probabilities are varied to see how the individual's judgements change. The benefit of the gamble analogy is that it studies decision-making under uncertainty, which is a central characteristic of reality. However, the classical view of

decision-making is normative and focuses on the fact that people should make decisions based on expected outcomes, rather than describing how decisions are actually made.

Prospect theory is a descriptive model of decision-making that developed from gambling scenarios (Kahneman, 2003; Kahneman & Tversky, 1979). It suggests that actual decision-making does not follow the rules of optimal decision-making, as suggested by normative decision-making models. Instead, decisions are guided by various heuristics and biases (Tversky & Kahneman, 1974). Prospect theory predicts, among other things, that low probabilities are given more weight than high probabilities when making decisions. This would, for example, mean that decision-makers are more concerned with reducing losses from rare, potential disasters than classical decision theory predicts, and vice versa for frequent events such as accidents.

Thus, the literature on heuristics and biases shows that actual decision-making deviates from normative rational choice theories. However, the conclusions from this body of research are mainly based on experimental situations in which participants are presented with hypothetical questions, and have been criticised for not reflecting how people make decisions in reality. To this end, the naturalistic decision-making paradigm (NDM) attempts to study less-structured decision problems and decision-making under time pressure, as well as how decision-makers use their experience when making decisions under uncertainty (Lipshitz, Klein, Orasanu, & Salas, 2001). One naturalistic decision-making model is recognition-primed decision-making, in which recognition of similar or relevant situations that have been experienced guide decision-making. Naturalistic decision-making typically uses field-based methods such as observations, interviews and verbal protocols. These approaches make it possible to study decision-making in a real-world setting. The downside of this is that the richness of the collected material, and the lack of control over the studied environment make it difficult to make causal claims.

Another paradigm is dynamic decision-making (DDM). Microworlds are traditionally used in this context, as they capture more of the dynamics and complexity of reality than traditional experiments, while retaining control over the variables under study. Dynamic decision-making is particularly relevant when seeing risk management as a control problem. According to dynamic decision-making, decision-makers act and receive feedback on their actions. Decision-making is not an end in itself, but rather a means to reach a goal (Brehmer, 1992). From this perspective, the decision-problem is characterised by dynamics, and the state of the system depends both on the system itself (factors beyond the decision-maker's control) and on the decision-maker's decision. This means that even if the decision-maker does not make a decision, the system will change. Furthermore, decisions are dependent, in the sense that earlier decisions may constrain later decisions, and mistakes in earlier decisions can be corrected in later decisions. The decision-problem itself is characterised by complexity; the system's interactions are complex, and its behaviour is difficult to understand or predict. There

can be several, conflicting goals and several action possibilities at any given time. The decisions that are made can have side-effects, apart from steering the system towards one or many desired goals. Finally, the decision-problem is characterised by opaqueness – some aspects of the system are not known to the decision-maker who, consequently, is forced to form and test hypotheses about its state and characteristics (Brehmer, 1992). While dynamic decision-making has traditionally focused on making quick decisions under time pressure (as when responding to disasters), the characteristics of the decision-problem are also highly relevant in the context of this research.

The new risk perspective, vieweing risk management as a control problem and dynamic decision-making make up the conceptual framework of this dissertation (Figure 2). When risk management is seen as a closed-loop control problem, the decision-maker is provided with information about the state of the system, for example, from capability descriptions. A fundamental assumption in this research is that different description formats are not equally useful in guiding decisions regarding investments and adjustments. How the description is communicated to decision-makers is important, and small variations in the presentation can change their decisions (Abt, Rodricks, Levy, Zeise, & Burke, 2010; Dilla & Stone, 1997; Johansen & Rausand, 2012; Johansen & Rausand, 2014; Kühberger, 1995; Scurich & John, 2011). However, there is limited previous research on how differences in descriptions actually affect the decision-maker (Bier, 2001; Thompson & Bloom, 2000), and studies focus on the format of risk descriptions rather than capability descriptions (see, e.g., Arvai, 2007; Bier, 2001; Dieckmann, Slovic, & Peters, 2009; Kristensen, Aven, & Ford, 2006; Lin, Nilsson, Sjölin, Abrahamsson, & Tehler, 2015; Lin, Rivera, Abrahamsson, & Tehler, 2017; Månsson, Abrahamsson, & Tehler, 2017).

Figure 2. The conceptual framework.
The core of the conceptual framework is in the intersection of the new risk perspective, viewing risk management as a control problem and decision-making theory (specifically, dynamic decision-making). The focus of this research is on how capability assessments provide the decision-makers with feedback about the state of the system.

Methodology

Philosophical positioning

This research is guided by the critical realism paradigm, which is characterised by ontological realism (there is a reality beyond the observer), epistemological relativism (knowledge is changeable) and assessment rationality (it is possible to assess the validity of knowledge) (Archer et al., 2016; Bhaskar, 2008; Brandén, 2016).

From the ontological perspective of critical realism, reality consists of three domains: the real, the actual and the empirical. These three layers distinguish it from realism. In the latter, observers are assumed to have direct access to reality through their senses, while in critical realism, empirical reality (what is observed) is only the top of the iceberg. However, according to critical realism, even if something can be observed, it is not necessarily real. For something to be real, it has to be able to cause something actual. In this respect, critical realism differs from the positivistic paradigm. In critical realism, it is considered too superficial to establish causes and effects without explaining why causes created effects. The question of what makes something possible is fundamental.

On the other hand, from a purely idealistic ontological viewpoint (as found in the social constructivist paradigm), there is no objective reality, and different explanations of why something happens are equally valid. Critical realism, however, acknowledges that our understanding of the world depends on our experiences; consequently, different individuals can understand a phenomenon in various ways. At the same time, some explanations of why something happened are accepted as more plausible than others.

Design science

In line with critical realism, this research is also guided by a design science approach. Design science originates from the work on the sciences of the artificial (Simon, 1996), and is a pragmatic paradigm driven by problems found in the environment. It focuses on producing prescriptive knowledge that can solve these problems, rather than describing different phenomena found in the field, which is the goal of traditional

descriptive research (Denyer, Tranfield, & van Aken, 2008; Hevner, March, Park, & Ram, 2004; van Aken, 2005a, 2005b).

Artefacts are a central concept in design science. An artefact is, in the broad sense, any product that was created intentionally by a human being to achieve some purpose or goal (Simon, 1996). It could be something concrete, like a car or a chair, or something more abstract, like a definition or a method. In the present work, artefacts are the concepts of capability, capability descriptions and the methods used to produce them.

Despite the common origin in Simon's sciences of the artificial and the focus on artefacts, design science has evolved and become an inhomogeneous research area consisting of several disciplines focusing on, for example, design cycles (Hevner et al., 2004; March & Smith, 1995), design theory (Gregor & Jones, 2007), design propositions (Denyer et al., 2008; Romme, 2003; van Aken, 2004; van Aken, 2005a, 2005b) and the abstraction hierarchy (Brehmer, 2007; Rasmussen, 1985). The latter two are especially relevant to the present work.

Design propositions are the research product of design science, and support professionals in the process of designing solutions to problems found in the field. They suggest general knowledge that provides input to solutions. Such general knowledge can be formulated as: "if you want to achieve Y in situation Z, then something like action X will help" (van Aken, 2004, p. 227). Professionals can use this general information and translate it into solutions to their specific problem, rather than starting from the beginning every time they want to solve a problem.

The question of why is central to both design science and critical realism. In design science, it is operationalised by grounding and field testing design propositions. Grounding means using descriptive theories from, for example, the natural and social sciences, to explain why the intervention produces the outcome in the situation of interest. Field testing means that the design proposition has been tested in multiple case studies to verify that the intervention produces the desired outcome (van Aken, 2004; van Aken, 2005a, 2005b). The idea of design propositions guided the work presented in Papers II, III, IV and V.

The abstraction hierarchy can be used to describe, design and evaluate artefacts from three perspectives: purpose, function and form (Brehmer, 2007). These perspectives correspond to answers to the questions: why does the artefact exist? (purpose), what does the artefact do to fulfil its purpose? (function), and how does it do it? (form). The three questions indicate that the perspectives are interrelated; the form of the artefact should fulfil its purpose through the functions. However, the purpose can be fulfilled in several ways by various functions, and various forms can, in turn, fulfil functions. This is illustrated for capability descriptions in Figure 3.

The abstraction hierarchy was used in Paper I to trace connections between purpose, function and form with respect to capability assessment methods. Moreover, the ab-

straction hierarchy guides the research in general. For example, Papers III and IV focus on the idea that the purpose of assessing capability is to increase response capability. To do this, decisions have to be made (function), and this can be supported by various forms of capability descriptions. Consequently, various forms (capability descriptions) are evaluated based on how well they support decision-making (function) to increase response capability (purpose).

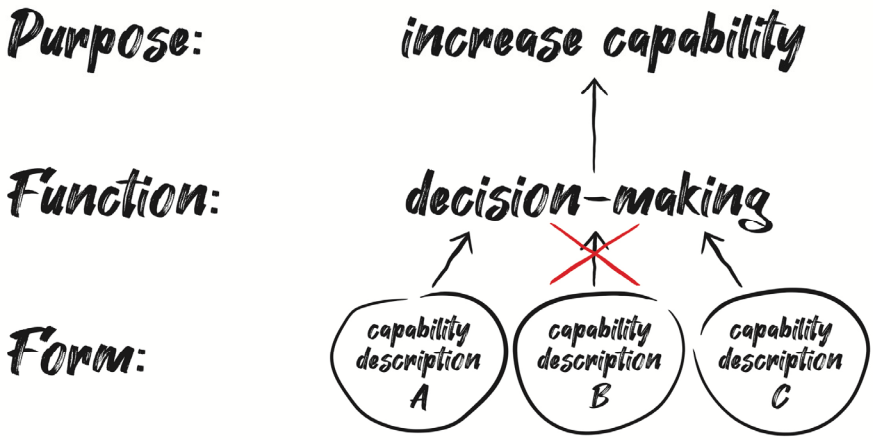


Figure 3. The abstraction hierarchy.
Several ways of describing capability (form) may guide decision-making (function) and contribute to increased capability (purpose). However, some capability descriptions provide better guidance than others to decision-makers who are seeking to proactively increase the response capability.

Geographical focus

Capability assessments are used world-wide in the DRM context. However, this research focuses on the Swedish DRM system in an initial attempt to understand current capability assessment practice and explore opportunities for improving it.

The Swedish DRM system consists of three administrative levels of governance: local (municipalities), regional (county administrative boards and county councils) and national (government agencies). Some of the studies that make up this dissertation have focused on specific regions (cf. Document analysis and Interviews) and these regions' geographical locations are illustrated in Figure 4.

At national level, the Swedish DRM system is coordinated by the Swedish Civil Contingencies Agency, which is responsible for issues concerning civil protection, public

safety, emergency management and civil defence. One of the Swedish Civil Contingencies Agency's principal tasks is to enhance Swedish society's DRM, by providing support and guidance to relevant stakeholders' DRM activities.

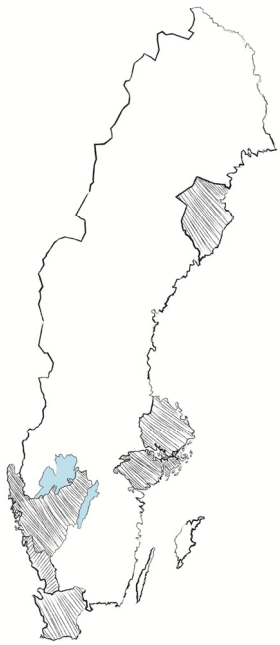


Figure 4. Geographical focus.
The geographical focus of the studies presented in Papers I, II and V has been on six counties in Sweden. The map illustrates their geographical locations and different sizes; three counties are located in southern Sweden, two in central Sweden and one in the north.

One of the most critical activities in Sweden's DRM system is risk and vulnerability assessments. Mandatory under Swedish law (SFS 2006:637; SFS 2015:1052), local, regional and national actors began to conduct such assessments on a regular basis in the early 2000s. The primary purpose of conducting these assessments is to raise the awareness and increase the knowledge and preparedness of those responsible for making decisions concerning risks and vulnerabilities, together with society in general, and to provide a basis for planning the implementation of measures that reduce risks and vulnerabilities (SOU 2004:134). More precisely, risk and vulnerability assessments are expected to form the basis for many DRM activities, for example, proactive planning, response preparations and DRM-related exercise drills (SFS 2006:637; SFS 2015:1052).

Until 2015, the risk and vulnerability assessment was required to assess the capability to withstand and respond to adverse events, according to a four-level ordinal scale: 1) good capability, 2) reasonably good capability, 3) some capability, but inadequate, and 4) no or very inadequate capability (MSB, 2013). To facilitate the assessment,

statutory guidelines (MSBFS 2010:6; MSBFS 2010:7) listed indicators related to, for example, command and control, auxiliary power, and material and personnel resources. Although the intention was that capability assessments should be integrated into risk and vulnerability assessments, they were often run in parallel (MSB, 2013).

The statutory guidelines were updated in 2015 and 2016 (MSBFS 2015:3; MSBFS 2015:4; MSBFS 2015:5; MSBFS 2016:7). Currently, capability assessments are no longer required, as the indicator method was perceived as problematic (MSB, 2013, 2014a, 2014b). Thus, the studies that make up this dissertation were conducted both when there was a requirement to assess capability (Papers I and II) and afterwards (Papers III, IV and V).

Methods and materials

This section presents an overview the methods and materials used (summarised in Table 1). More detailed descriptions can be found in the respective appended papers. All studies were documented to ensure transparency, reliability and replicability.

Table 1. Methods and materials.
The various research methods used in each of the appended papers have served different, but complementary purposes. For example, interviews and document analyses were used for descriptive purposes, but were of limited use in exploring possible improvements. In the latter case, experiments were used instead.

Paper	Method	Material
I	Scoping study	Scanning of 4544 titles from articles in databases, manual search of all titles in 15 scientific journals, and references in relevant papers
	Interviews	25 respondents from municipalities, county administrative boards and government agencies in Sweden
II	Conceptual research	
	Document analysis	Risk, vulnerability and capability assessments from 25 municipalities, county administrative boards and government agencies in Sweden
III	Experiments	230 participants from municipalities' fire and rescue services and preparedness offices in Sweden
	Interviews	4 respondents from municipalities' fire and rescue services in Sweden
IV	Microworld experiments	49 participants from municipalities' fire and rescue services and municipalities' and county administrative boards' preparedness offices in Sweden
V	Conceptual research	
	Document analysis	Risk and vulnerability assessments and plans from 25 municipalities in Sweden
	Interviews	9 respondents from municipalities in Sweden

Scoping study

A scoping study is an explorative approach for systematically mapping literature on a specific topic, examining the nature of a research area or identifying gaps in the research. It may be particularly relevant to topics that have not yet been extensively reviewed (Arksey & O'Malley, 2005; Colquhoun et al., 2014; Davis, Drey, & Gould, 2009; Levac, Colquhoun, & O'Brien, 2010; O'Brien et al., 2016; Pham et al., 2014).

The scoping study presented in Paper I aimed to identify capability definitions and capability assessment methods. The broad search strategy included two bibliographic databases, a manual search of the titles of all articles published in 15 DRM journals and the reference lists of the identified relevant documents. The database search resulted in the screening of 4544 unique titles. Papers that did not seem relevant based on the title were excluded, resulting in 62 possibly relevant papers. The references that were manually searched for added another 11 relevant papers based on the title. After reading their abstracts, 54 papers were still judged to be relevant. Ten of these could not be found in full-length, which resulted in that 44 full-length papers were read. In total, 36 papers describing capability assessment methods were identified.

Document analysis

The 25 municipalities, county administrative boards and government agencies included in the document analysis for Paper II were selected in a previous study (cf. Abrahamsson, Eriksson, Hassel, Petersen, & Tehler, 2011). These bodies were selected to reflect a broad range of sizes and geography. Two counties in southern Sweden, two in central Sweden, and one in the north were included. Within each county, a large, medium and small municipality were identified. The five government agencies were chosen to represent various functions of society.

Paper V focuses on municipalities in the county of Scania. The decision was motivated by the desire to have a sample of administrations that encompassed a range of characteristics: from inland to coastal, small and large, with different political and organisational orientations, and different DRM practices. This diversity contributes to the research validity.

Most of the documents that were reviewed are available on the internet or publicly through Swedish authorities. This also contributes to improving reliability, as other researchers can access the same information and confirm the results.

Interviews

Interviews were used in Papers I and V to capture aspects that could not be studied through the document analysis. They also complemented the experiments that are reported in Paper III. Semi-structured interviews were used as they have some structure, but allow respondents to answer in more detail if they want, and can reveal how respondents understand and frame issues of interest (Bryman, 2008, p. 438). To increase validity, interviews were iterative and included follow-up questions.

Respondent bias is a threat to validity in interview studies, since respondents might not be willing to share everything with the researcher, or try to answer questions in a way they think the researcher wants (Robson, 2002). To counter this, the goal was to establish trust early in the sessions and avoid unnecessary use of scientific concepts. Moreover, questions were distributed in advance, and the interviews' purpose was clearly described. All interviews followed a guide and the interviews that are the subject of Papers I and V were recorded, transcribed and their content was analysed (cf. Content analysis). This ensured transparency and makes it possible to revisit the contents.

For Paper I, interviews were conducted with representatives of 25 municipalities, county administrative boards and government agencies. The aim was to gain an insight into their understanding of the concept of capability and their capability assessment efforts. In addition to the stakeholders that were the subject of the document analysis in Paper II, representatives also came from the Swedish Civil Contingencies Agency's team working on the Swedish national risk and capability assessment. These interviews were conducted at respondents' workplaces and lasted approximately 60 minutes.

The semi-structured interviews described in Paper V were carried out after the document analysis, and supplemented it. They provided a more in-depth understanding of the aims of the study and, thus, increased validity. The nine respondents were professionals working with risk and vulnerability analyses and plans in nine municipalities in Scania. These municipalities were selected to capture a range of views in areas of different size and with different geography. These key informants were assumed to have most experience regarding matters of interest, and most were involved in both executing, and reporting the results, of their work.

The interviews that are described in Paper III were telephone interviews held soon after the respondent had participated in the experimental study. The aim of these was to gain a deeper insight into the perceived usefulness of the various capability descriptions (cf. Experiments). Although these interviews were not recorded, detailed notes were taken. Four respondents (out of the 20 participants in the experimental study) were randomly chosen. Each interview lasted approximately 30 minutes.

Content analysis

Content analysis is a way to reduce a large amount of text into smaller categories. It uses categories that have been specified in advance, while coding is both transparent and systematic (Bryman, 2008, p. 274; Weber, 1990). The method was used to analyse the content of risk, vulnerability and capability assessments, plans, transcribed interviews and documents identified in the scoping study. Coding schemes were used to specify categories relevant to the respective studies' aims and to facilitate tracking of the research. The use of coding schemes increases reliability, for example through inter-rater reliability testing, or by asking a previously-uninformed person to conduct the analysis on some of the documents. Coding stability was confirmed by coding the same texts several times. Working with co-authors and holding discussions also contributed to developing a more reliable interpretation of the empirical material.

Conceptual research

There is a distinction between research that focuses on generating risk knowledge related to real-world activities, and knowledge generation that is related to the concepts used to analyse risk. The latter is referred to as conceptual research, and is used to develop new concepts or reinterpret existing ones; it is normative and provides guidance on how to best research the former. This approach was adopted in Paper II, which proposes a definition of capability, and in Paper V, which suggests how risk assessments and plans can be linked using the concept of capability.

Conceptual research is essential for the development of knowledge, and consists of various activities. For example, identifying new concepts or revising existing ones (envisioning), differentiating and integrating (relating) various concepts, or arguing for and against different concepts (debating). These activities can be extended to a specific theoretical concept (a construct), or to, for example, theories and procedures. Although a conceptual paper can contribute in any number of ways, all of them move the field forwards by setting an agenda for further research (MacInnis, 2011). There is no correct, or best, way to perform conceptual research. Instead, the challenge is to develop the argumentation that supports a specific concept (Aven, 2018; Kothari, 2004).

The conceptual research presented here is primarily concerned with constructs, relationships and procedures. It seeks to revise existing definitions of capability, and relate a new, proposed definition to other concepts (risk, vulnerability and resilience) and activities (risk assessments and plans). This dissertation and, notably, the five appended papers, presents an argument for a new definition of capability and a way to describe it, and against the commonly-used indicator and index methods.

Paper II focuses on the concept of capability. It is an essential contribution to both research on capability assessment and capability assessment practice. Concepts play a

critical role in knowledge representation and sharing (MacInnis, 2011). As few words typically only have one meaning in a language, if a concept is not explicitly defined, users will apply their own definition, which may be quite different from that intended (Tähtinen & Havila, 2018). Moreover, abstract concepts need to be defined in a sufficiently precise manner to be operationalised or measured (MacInnis, 2011; Tähtinen & Havila, 2018). The definition of capability proposed in Paper II provides the conceptual foundation for the work that follows.

Experiments

Unlike the descriptive approaches presented above, experiments offer the opportunity to control conditions and study cause-effect relationships (Cunningham & Wallraven, 2011). They can therefore provide arguments regarding how capability descriptions can be improved. Both static and dynamic microworld experiments are part of this research, although they were used in an exploratory fashion rather than to test existing theories.

Static experiments were used in the three studies presented in Paper III. The first two adopted a between-subjects design. Each of the 210 participants was exposed to only one of the four experimental conditions. In the third experiment, a within-subjects design was used, and here each of the 20 participants was exposed to all four conditions. In order to counter any learning effects and increase validity, the order in which participants were exposed to conditions was randomised.

Participants in the first study, presented in Paper III, were recruited from Swedish municipal fire and rescue services through a snowball sampling approach. We contacted key individuals in the fire and rescue services and asked them to participate – and to forward the invitation to their colleagues. In the second study, we contacted preparedness officers in all of Sweden's municipalities via e-mail, asking them to participate. For the third study, a purposive sampling approach was used. This strategic sampling method is based on identifying participants who are relevant to the research questions (Bryman, 2008, p. 458). Here, we contacted persons that we knew were currently working, or who had previously worked, for Swedish municipal fire and rescue services.

These static experiments investigated how useful participants perceived various capability descriptions. We assumed that a capability description that was perceived as more useful by a decision-maker would lead to increased capability. However, the validity of this assumption proved to be difficult to investigate. For the experiments described in Paper IV we therefore used a dynamic microworld approach to study how participants balanced the costs and benefits of increasing capability. The microworld approach makes it possible to control the variables under study. At the same time, conditions are more realistic in terms of task complexity, as participants interact with a computer simulation and receive continuous feedback on the effects of their actions.

A within-subjects design was used in both experiments presented in Paper IV; participants were exposed to all experimental conditions. Participants in the first study were recruited through random sampling. Municipalities were randomly selected and invitations were sent out to the respective chiefs of fire and rescue services and preparedness officers. This was repeated until approximately 20 participants had participated. Purposive sampling was used in the second study.

Participants in the studies reported in Papers III and IV were preparedness officers and representatives from the fire and rescue services, and the sample consisted of all Swedish municipalities. The studies presented in Paper III investigated perceived usefulness for two kinds of events (forest fire and flood). This dual approach increased validity.

Detailed findings

Paper I

How is capability assessment related to risk assessment? Evaluating existing research and current application from a design science perspective

This paper presents the results of a scoping study that identified capability assessment methods published in international journals and conference proceedings. It also presents the results of interviews with representatives from 25 Swedish municipalities, county administrative boards and government agencies in order to gain a deeper understanding of how the Swedish capability assessment method was used in practice.

The scoping study identified 36 papers describing capability assessment methods, intended to be used at various administrative levels. Seventeen articles state the purpose of the assessment. Typically, this is to provide support to decision-makers, improve capability or identify weaknesses. Five of the described methods analyse response processes and their failures, based on table-top exercises or a military planning framework. The remaining 31 are indicator and index methods. Such methods make use of indicators of capability, and often assign each indicator a numerical value and derives a final score that reflects the capability. Examples of indicators include resources, management and plans. These broad indicators are usually sub-divided into more specific indicators, such as technological capabilities, staff quality, organisational structure and flexibility.

The study of the Swedish indicator method shows that there are four purposes of the capability assessment, one of which is to provide a basis for decisions. The method consists of a list of indicators and an assessment scale. However, it lacks guidance on how to translate these indicators into an assessment (e.g., through a weighting system). The interviews revealed that a majority of respondents found it difficult to assess capability and understand how the indicators related to it; at the same time, they noted that both indicators and the scale enhanced their understanding of how legislators wanted them to assess capability.

Paper II

The capability concept – On how to define and describe capability in relation to risk, vulnerability and resilience

This study aimed to extend the scientific foundations of the risk domain to include the concept of capability, by defining and operationalising it. The paper presents a review of capability definitions, and identifies five trends in the legislation, guidelines and scientific literature: 1) capability equals resources, 2) resources are an important aspect of capability, 3) capability is the ability to do something, 4) capability is capacity, and 5) capability is a factor affecting an outcome or goal.

A new definition of capability, which relates to the concepts of risk, vulnerability and resilience is proposed. The definition, in essence, associates capability with an agent's ability to perform a task (T) for a specific purpose, while consequences reflect the effect of performing the task (C_T). Specifically, capability refers to the uncertainty about and the severity of the consequences of the activity given the occurrence of the initiating event and the performed task. Apart from T and C_T, uncertainty (U) and event (A) are the cornerstones of the definition. This is presented in the following form: capability (definition) = (C_T, U | A, T).

As we clearly distinguish between actual capability and the description of capability, a description of capability based on this definition includes descriptions of the initiating event (A), the performed task (T), the consequences associated with the performed task (C'_T), the uncertainty concerning these consequences (Q) and the background knowledge (K), which form the basis for these descriptions. A description of capability can thus be expressed as: capability (description) = (C'_T, Q, K | A, T).

The paper also presents an analysis of existing capability assessments prepared by 25 Swedish actors. The results show that assessments lack some important elements, notably: uncertainty, tasks and their estimated effect on the severity of consequences. This makes them unsuited to guiding efforts to increase capability.

Paper III

Capability assessments – How to make them useful for decision-making

This paper presents three experimental studies that investigate the importance of including information on resources and tasks in capability assessments, in order for them to be perceived as useful in decision-making. Four versions of a capability assessment were studied, which included the following information related to a fictional municipality's ability to respond to a forest fire and a flood, respectively:

1) An overarching conclusion related to capability.
2) Information about the available resources, in the form of a list.
3) Information about which tasks were expected to be performed, and with what effect on the severity of consequences.
4) Information about both available resources and which tasks were expected to be performed, and with what effect on the severity of consequences (i.e. a combination of 2 and 3).

The first study used a fictional forest fire scenario. In this case, 112 participants from Swedish municipal fire and rescue services were randomly assigned to one of the four capability assessments (a between-subjects design) and asked to judge its usefulness for making decisions about measures to increase response capability. The second study used a fictional flood scenario. Here, 107 Swedish municipal preparedness officers participated. These studies showed that the first version was perceived as the least useful, but it was impossible to draw any clear conclusions about how the other versions related to each other.

Therefore, a third study was conducted with the forest fire scenario. Twenty new participants from Swedish municipal fire and rescue services were shown all four versions in a random order (a within-subjects design), in order to make a more detailed comparison. This study found that both descriptions of available resources and tasks that are expected to be performed contributed to the perceived usefulness of capability assessments, but that combining them was perceived as most useful.

Paper IV

Striking a balance between the costs and benefits of increasing response capability: a microworld study of the effect of capability assessments

This paper presents two experimental studies that investigated how effective various ways of describing capability are in reducing long-term losses, when dealing with accidents and disasters. These studies investigated how much decision-makers invest in increasing response capability, and how good they are at striking a balance between investing too much and too little under various conditions. These conditions differed with respect to the decision-maker's experience of events, and the presence and format of the capability description.

Forty-nine participants from Swedish municipal fire and rescue services, and preparedness officers from municipal authorities and county administrative boards played four games in which they assumed the role of municipal decision-makers. The order in which the games were played was randomised to minimise learning effects. In each game, they were asked to divide resources between investments to increase response capability and investments in public services and goods. In each turn there could be an adverse event that affected the municipality. The ultimate goal for participants was to maximise resources spent on public services and goods, taking account of resources lost due to accidents and disasters. Losses were determined by the level of capability, which participants could influence by investing more or less in; the more they spent on increaseing response capability, the fewer the losses – but, at the same time, fewer resources were available for public services and goods.

The results showed that it was more difficult to successfully trade-off the cost of investments in capability against losses due to disasters, compared to accidents. Therefore it appears that capability assessments are more important when proactively dealing with disasters than accidents. Assessments are useful for decision-makers, as they can contribute to deciding how much is spent on investments in capability, and how to successfully balance the cost of investments with a reduction in losses.

Paper V

The missing link – The importance of the capability concept for relating risk assessments and plans

International agreements and legislation highlight that risk assessments should inform planning. This paper proposes a conceptual relation between risk assessments and plans based on the capability of the responding organisation, and its effect on the severity of the consequences of events. It adopts the new risk perspective and the capability definition proposed in Paper II. The paper argues that the inclusion of capability descriptions in risk assessments and plans increases their strength of knowledge, which, in turn, makes it easier to use the output from one document as input to another.

From an empirical perspective, the paper presents an analysis of how capability is described in the risk and vulnerability assessments and plans prepared by 25 municipalities in Scania. The results show that capability descriptions, as defined in Paper II, are not part of the studied documents. Although 24 of the 25 pairs of documents (risk assessments and plans) explicitly state that the risk and vulnerability assessment forms the basis for the plan, in practice, it is unclear how the documents relate to each other.

To complement the study of the documentation, interviews with representatives from nine of the municipalities were carried out to explore the issue further. These confirmed a weak link between risk and vulnerability assessments and plans. Rather than drawing up specific plans for the various risks the municipalities face, they most often make use of standard plans and, sometimes, develop specific plans reactively (as opposed to proactively) based on recent events. A lack of resources was one reason put forward to explain why planning is not based on the risk and vulnerability assessment, another is a poor understanding of DRM within municipalities, for example, regarding how DRM activities should inform each other.

Discussion

Addressing the research questions

Research question 1: How is capability defined and assessed?

The first research question is addressed in Papers I, II and V. Capability is often used in relation to preparedness and response, but is rarely defined. Paper II presents thirteen definitions of capability identified in the scientific literature, legislation and guidelines. Five trends emerge from these definitions: 1) capability equals resources, 2) resources are an important aspect of capability, 3) capability is the ability to do something, 4) capability is capacity, and 5) capability is a factor affecting an outcome or goal. Some definitions are characterized by only one of these trends, others by several.

The capability assessment methods identified in the scoping study (Paper I) make it clear that the most common purpose is to support decision-making and increase capability. Indicator and index methods are most popular. Such methods focus on the resources, plans and procedures put in place to respond to events. Thus, capability is operationalised as equal to resources, plans and procedures (i.e. the first and second trends identified in Paper II). While both indicator and index methods use indicators to describe the current state of the system, index methods specifically assign numerical values to indicators, which can then be weighed to arrive at a final numerical capability estimate (capability index). Figure 5 on the next page illustrates a fictive indicator and index method.

Until 2015, the Swedish capability assessment used an indicator method. While the majority of interviewees (Paper I) found it difficult to assess capability and understand how the indicators related to it, their use made it easier for them to comply with legislative requirements. Post-2015, when the capability assessment requirement was removed, they disappeared from risk and vulnerability assessments (Paper V).

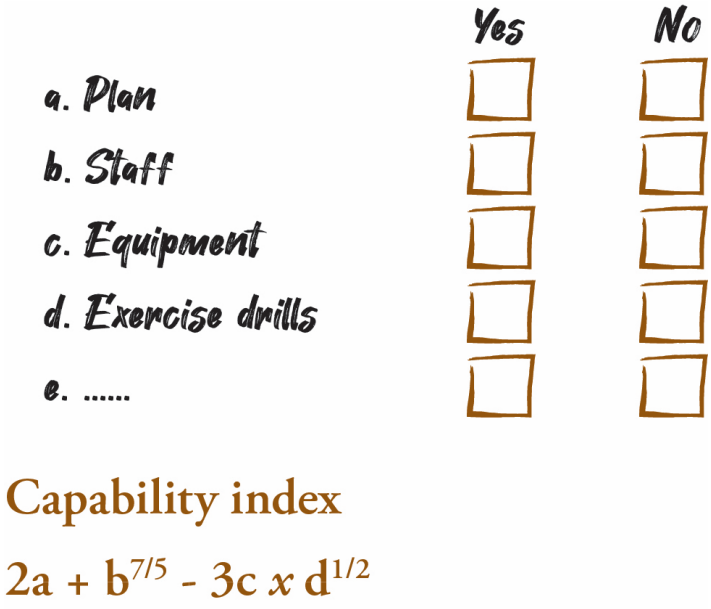


Figure 5. Indicator and index method.
These fictive indicator and index methods make use of a number of indicators of capability (plan, staff, equipment and exercise drills). For the indicator method, each indicator is assessed as available (yes) or unavailable (no). The resulting capability description is a list of the available and unavailable resources, procedures and plans. For the index method, each indicator is assigned a numerical value and a capability index is derived through a predetermined weighting system. The capability description produced by the index method takes the form of a numerical value.

Research question 2: How should capability be defined and described?

The point of departure for answering this research question was the ambition to define capability in relation to risk, vulnerability and resilience, in addition to the DRM goal of reducing long-term losses from disasters. The question is primarily addressed in Papers II and IV. In Paper IV, capability is defined as the ability to do something with the purpose of positively influencing the outcome of an adverse event, and the role of capability assessments in DRM is described.

A more detailed definition, which adopts the new risk perspective framework, is presented in Paper II. In this paper, capability is defined as the uncertainty about and the severity of the consequences of the activity given the occurrence of the initiating event and the performed task. This definition emphasises the role of uncertainty and the severity of events and consequences. There are, of course, alternative ways to define capability in the present context. For example, the review of definitions (Paper II) and methods (Paper I) identified a trend that defines and operationalises capability as resources. The implications of such definitions and methods are discussed when addressing the research aim. For now, the discussion is limited to whether the severity of events, consequences and uncertainty should be part of the capability definition.

Consequences are important in several risk definitions, and relate to something considered to be valuable (cf. Aven, 2011 for a review of definitions). The following risk definition reflects this idea: "[risk] refers to uncertainty about and severity of the events and consequences (or outcomes) of an activity with respect to something that humans value" (Aven & Renn, 2009, p. 6). Uncertainty and the severity of events and their consequences are thus important in this context.

The effect of increasing capability is a reduction in the severity of events and consequences. Hence, including the severity of events and consequences in a definition of capability is reasonable. Basically, if the severity of a disaster decreases due to the increased performance of an actor, then capability has increased. An important point to note is that severity depends on what is considered valuable. The same events and consequences might differ in severity depending on who is asked to judge it. Similarly, capability might be judged differently. However, the inclusion of the severity of events and consequences in the capability definition does not specify how to judge severity, only that there is a way to judge it. This assumption seems reasonable given the overall purpose of DRM, which is to lessen losses from disasters (UNISDR, 2009). Thus, for DRM to have meaning, events, consequences and their severity need to be specified.

While it seems intuitive to include the severity of events and their consequences in a capability definition, the reasons for including uncertainty are less obvious. This research focuses on proactively assessing capability, and (current) capability refers to an actor's ability to positively influence the outcome of a future event. The outcome of future events is always uncertain (cf. Aven et al., 2011), and, hence, defining capability without including uncertainty would be limiting. It is, for example, not only the actor in question that influences the severity of events and their consequences, but also other actors who contribute, more-or-less successfully, to the response.

An example is a hospital's ability to treat victims rescued from a burning building by fire and rescue services. The victims' condition when they arrive at the hospital depends on how quickly fire and rescue services were able to rescue them from the building, i.e. for how long they were exposed to heat and smoke. This creates uncertainty regarding the hospital's ability to treat them. Similarly, an actor's response may depend on the availability of the key individual or the functioning of a certain system or resource. Since the future is uncertain, it could well be that a key person is unavailable when disaster strikes, or that a system, say the communication system, is not working. These factors could influence both the actor's capability, and the severity of the event and its consequences. If uncertainty is not included in the capability definition, it becomes impossible to distinguish between these different potential futures.

In addition to the pragmatic argument that uncertainty and the severity of events and their consequences should be included, there are also conceptual arguments. Given the aim to integrate and delineate the concept of capability with respect to concepts such as risk, vulnerability and resilience, the choice of the new risk perspective framework

(and thus the focus on uncertainty and the severity of events and their consequences) seems warranted. The concepts of risk, vulnerability and resilience are already defined within this framework (Aven, 2010, 2011; Steen & Aven, 2011), and including capability supports the integration of the concepts. For example, there are similarities between the concepts of vulnerability and capability (see Paper II). First, both are conditional on some event. Thus, we cannot talk about vulnerability or capability without specifying an event. Moreover, both concepts include consequences and uncertainty. However, capability is also conditioned on tasks that are performed to influence the outcome of the event, unlike vulnerability. Subsequently, the consequences encompassed in the capability definition are narrower, and only refer to the consequences of performing tasks. This is unlike the definition of vulnerability, where all of the consequences related to the event are of interest.

Another benefit of using the new risk perspective framework, and defining capability as proposed in Paper II, is that it allows linking risk assessments and plans (Paper V). By including descriptions of capability in risk assessments and plans, their strength of knowledge increases. Consequently, using the output from one document as input to another is facilitated. Thus, the proposed definition provides a foundation for integrating not only concepts, but also various DRM activities.

Research question 3: To what extent do task and resource descriptions contribute to decision-makers' perceived usefulness of capability descriptions?

While capability descriptions are commonly based on a view that capability equals resources, the definition proposed in Paper II stresses the importance of including, among other things, tasks. Although there is clearly conceptual merit in using the proposed definition of capability, it is not clear that its use in assessments will help to reduce losses (the goal of DRM) any more than assessments where capability equals resources (such as in indicator or index methods). This question is addressed in the third research question and in Paper III.

Paper III describes three experiments that study the perceived usefulness of four versions of a capability description. Two versions use capability descriptions based on index and indicator methods (identified in Paper I), and two descriptions are based on the definition proposed in Paper II (Figure 6).

The results show that both information about available resources and the tasks that are expected to be performed contribute to perceived usefulness, while their combination is perceived as most useful. Consequently, a capability description that includes all of the components of the definition proposed in Paper II is perceived as the most useful (version 4), while the index method is least useful (version 1). Moreover, a description based on the indicator method (version 2) seems to be as useful as describing tasks, but not including the knowledge base of the assessment (version 3).

However, Paper III assumes that capability descriptions that decision-makers perceive as more useful lead to better risk management, i.e. fewer long-term losses. Paper IV, which answers the fourth research question, investigates the effects of capability descriptions on DRM goals more systematically. The static experimental design used in Paper III (participants answered questions about the usefulness of various capability descriptions) was changed to dynamic. In particular, capability descriptions informed participants' decisions in a microworld.

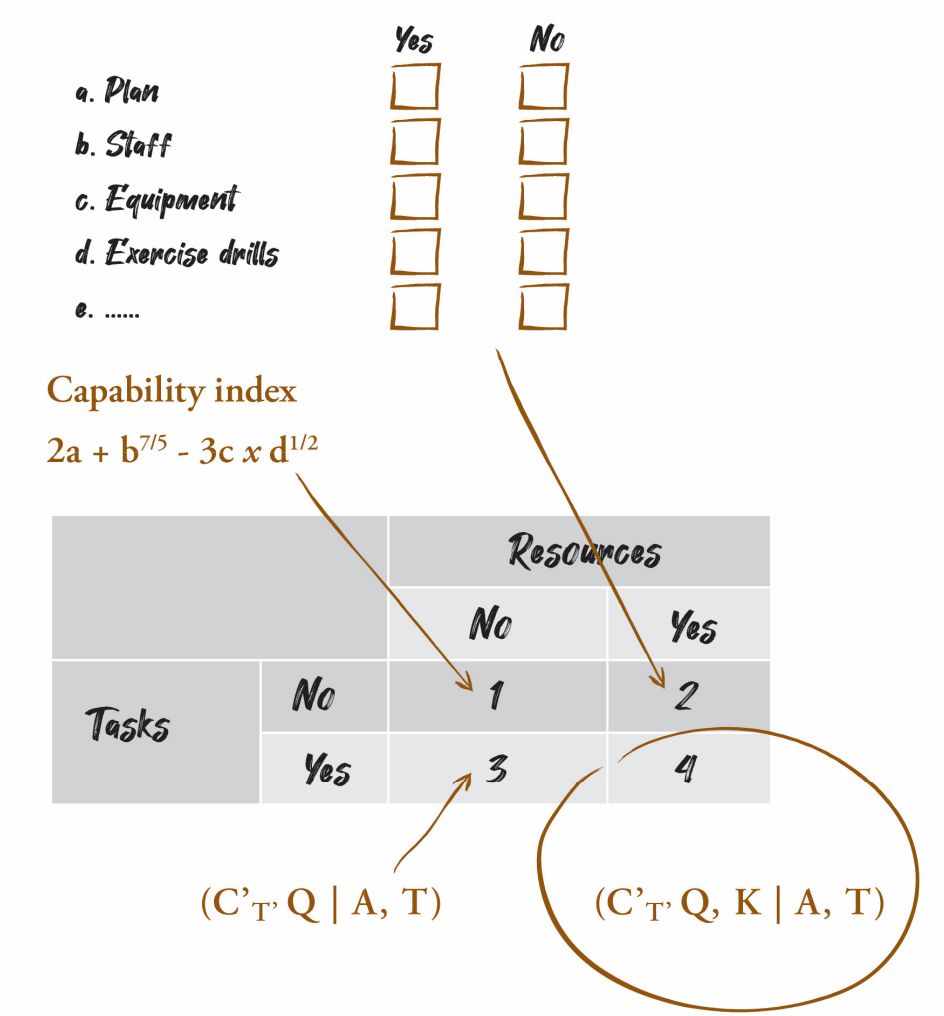


Figure 6. Versions of capability descriptions.
The four versions of capability descriptions included in the studies presented in Paper III differed in the information provided about tasks and resources. The versions relate to capability descriptions produced by index methods (version 1), indicator methods (version 2) and versions based on the definition proposed in Paper II (versions 3 and 4). Version 4 is perceived as the most useful for guiding decisions to increase capability.

Research question 4: Do capability descriptions affect decisions concerning the allocation of resources intended to increase capability?

The fourth research question is addressed in Paper IV. This paper extends the focus of the third research question and examines whether capability descriptions (based on the definition proposed in Paper II) contribute to reaching DRM goals, i.e. the reduction of long-term losses.

The results of the microworld studies showed that decision-makers tend to invest more in increasing capability when provided with a capability description that supports decision-making than if they are not provided with one. Furthermore, it seems to be more difficult to successfully reduce losses from disasters compared to accidents, while capability descriptions seem to help decision-makers to balance the costs and benefits of investments.

These results are valid in the microworld which is, however, a simplification of reality. Nevertheless, the microworld did represent reality to some extent by applying the characteristics of dynamic decision-making. Therefore, these results support further development and testing of the proposed approach to assessing capability.

Addressing the research aim

This research aims to increase knowledge about the concept of capability and capability assessments in the context of reducing losses from disasters. It describes current capability assessment practice and suggests improvements.

So, is there, in fact, a need to improve current capability assessment practice? The review of scientific and professional descriptions of capability assessment methods, and interviews with professionals found that the current use of capability assessments in DRM is fragmented. There are several definitions and methods; their role in DRM is unclear and their value is questioned. Thus, there appears to be a need to integrate and align capability assessments with other key DRM activities and concepts. The definitions proposed in Papers II and IV (research question 2) are an attempt to do exactly that. Nevertheless, these definitions do not directly address how capability assessments can be used, or their role in DRM. This lack of clarity clearly contributes to the opinions expressed by several of the interviewees, reported in Papers I and V: capability assessments are difficult to use for DRM and their purpose is unclear. It seems that many activities, such as assessing risk, vulnerability and capability, and planning, are motivated by the need to comply with legislation, rather than increasing capability and reducing losses. Thus, there is a need to clarify what role capability assessments could have in DRM.

The role of capability assessments in DRM

One way to address the above problem is to clarify the role of the capability assessment in achieving DRM goals. The model presented in Figure 7 is such an attempt. DRM has two overall goals: the reduction of adverse impacts, and the possibility of disasters (UNISDR, 2009). The response capability of an actor only affects the impact of disasters, and not their likelihood. Figure 7 illustrates this point in the arrows that run from actual capability to losses.

This model is an amalgamation of several important aspects included elsewhere in this dissertation, and the appended papers can be related to it. Paper I focuses on how actual capability is described in capability assessments. Paper II focuses on defining capability (actual capability) and describing capability (capability assessments). Paper III focuses on how capability assessments inform decisions. Paper IV focuses on all of the components shown in Figure 7. Finally, Paper V focuses on how actual capability is described in various forms of written assessments, and how assessments are used to inform decisions and investments.

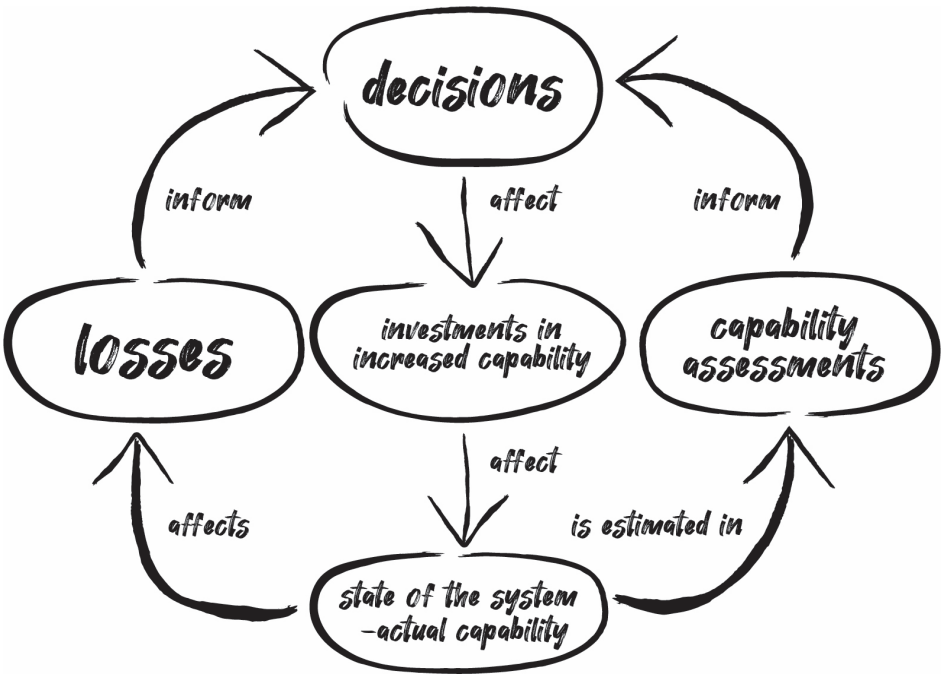


Figure 7. The role of capability assessments in DRM.
When viewing DRM as a closed-loop control problem, the decision-maker takes feedback from the system into account when deciding on investments in increased capability. This feedback could be experience (e.g., actual losses from events that have occurred) coming through the left-hand loop. In the right-hand loop, the decision-maker is provided with estimated feedback regarding whether the previous decision resulted in increased response capability, or not. If neither the left-hand loop nor the right-hand loop is informing decision-making, the control of the system is based on an open-loop strategy. This could mean that the decision-maker continuously invest a specific sum in increasing capability, or in a predetermined measure – irrespective of what is currently needed or whether the investment has any effect.

Feedback loop intervals

The model sees DRM as a control problem, and consists of two loops. These loops illustrate two kinds of feedback that inform decision-makers' decisions regarding investments in increasing capability. Feedback in the left-hand loop takes the form of actual losses, while right-loop feedback comes from capability assessments.

These two loops can provide feedback at different intervals. The left loop interval depends on how often events occur. For accidents, it is rather short. In a municipality, for example, there might be several car accidents each day that provide decision-makers with information regarding the current capability level. On the other hand, for disasters, the left loop rarely provides feedback. Instead, decision-makers have to rely on information provided through the right loop, in the form of capability assessments. These two loops can be related to Rasmussen's (1997) distinction between empirical and analytical risk management strategies. Obviously, the feedback interval of the right loop can also vary, notably as a function of how often capability assessments are performed. How often an assessment should be updated depends on how fast the system of interest changes. If it is changing quickly, it seems reasonable to assess capability more frequently, compared to if it rarely changes. If the system changes faster than capability is assessed, outdated information will guide decisions and subsequent investments. Thus, it is critical that the capability assessment reflects actual capability as well as is possible.

Weaknesses of indicator and index methods

Even if the analytical loop provides feedback at suitable intervals, it is important to design capability assessment methods based on what one wants to achieve. This means asking why capability should be assessed. Such thinking is in line with the design science approach adopted in this research. In this dissertation, and in line with the purpose of DRM stated by the UNISDR (2009), capability assessments are a means to reduce losses from disasters.

The design of the capability assessment method should also consider the characteristics of the system. For stable and not-too-complex systems, indicator and index methods might be suitable. In such systems, method designers have a good understanding of the behaviour of the system and can design effective indicators or indices by validating the method against what they want to achieve (in this case, a reduction of losses). One benefit of using indicator and index methods is that they make it relatively easy to measure changes in capability. Moreover, they are relatively fast and easy to use, do not require detailed knowledge of the system, and the descriptions that are generated are easy to present and explain.

However, as system complexity (cf. Jensen & Aven, 2018) and its rate of change increase, it becomes harder to design and validate indicators and indices. In such systems uncertainty is significant, but is not reflected in indicator or index methods. For example, the ability to respond to a forest fire will differ even though the resources are the same. In a rainy year a fire will not spread as much as in a dry year with extreme heat and high winds. Here, both the indicator and index method would suggest that capability is the same in both conditions, while it seems reasonable to expect more severe consequences from forest fires in the latter case, given the same resources.

In essence, indicator and index methods do not produce capability descriptions that reflect the severity of events and their consequences or uncertainty. Hence, such descriptions do not inform decision-makers about how current capability relates to the goals of DRM, and provide limited guidance when deciding trade-offs between the costs and benefits of investments in capability. Hence, from a DRM perspective, a capability assessment method that draws upon the definition proposed in this research seems more suitable than indicator and index methods. The lack of precision in capability descriptions produced by indicator and index methods is illustrated in Figure 8.

Compliance and complacency

The appended papers support a number of other observations. Firstly, it seems unclear how the concept of capability and current capability assessment methods relate to the long-term reduction of losses (Papers I and II). Secondly, practitioners question the purpose of assessments based on indicator methods and find it difficult to understand how these indicators relate to capability (Paper I). Finally, the analysis of risk, vulnerability and capability assessments, and plans (Papers II and V) shows that the link between assessments and plans is weak; in particular, it is unclear from reading the documents what the capability of the response organisation is, and how it is expected to contribute to reducing losses from disasters.

These observations suggest that capability assessments currently are of little use in DRM. Consequently, they may be considered to be outside the scope of DRM activities, or are primarily carried out to comply with legislation rather than to increase capability. The first trend has been observed in the Swedish DRM system; capability assessments used to be a requirement, but this was removed in 2015. As Paper V shows, capability descriptions are no longer found in statutory risk and vulnerability assessments.

Furthermore, the unclear role of capability assessments in DRM may lead to complacency, i.e. believing that capability is sufficient without any arguments to support this belief. This may be because methods such as the indicator and index methods can suggest that capability is sufficient (e.g., by demonstrating that all of the prescribed resources are available), when it is, in fact, insufficient to reduce losses from disasters.

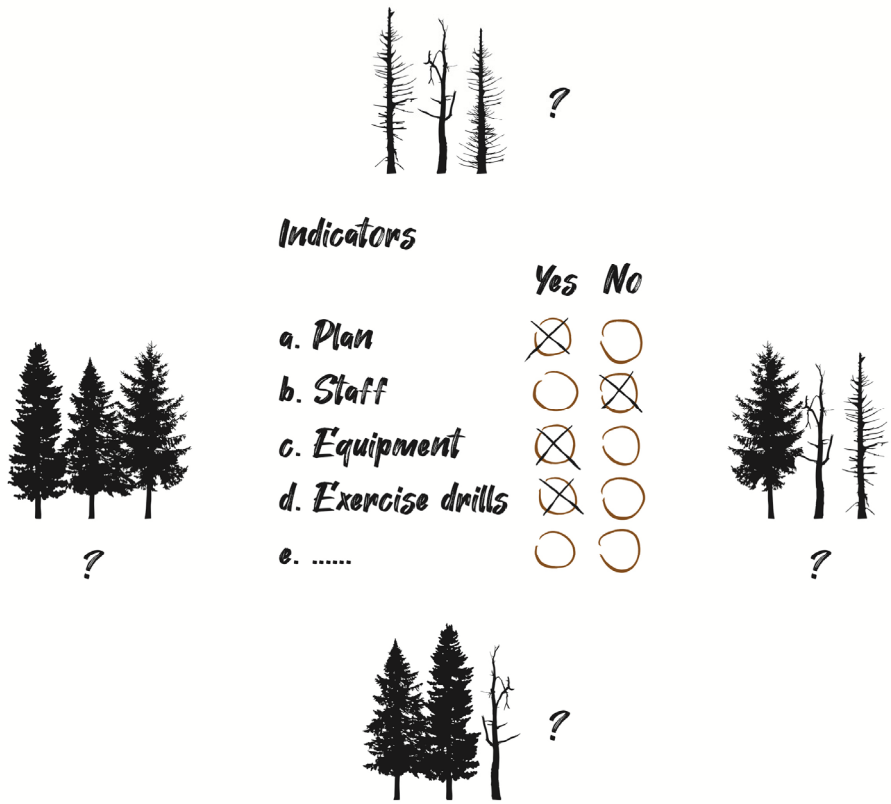


Figure 8. Weaknesses of indicator and index methods.
Indicator and index methods do not reflect the severity of events and their consequences or uncertainty. In this fictive example, the capability description produced by an indicator method informs the decision-maker that the fire and rescue service 1) has a forest fire response plan, 2) has equipment to extinguish a forest fire, 3) has engaged in forest fire exercise drills, and 4) does not have enough staff to handle a forest fire. This information, however, does not make it clear which of the four outcomes to expect if there were a forest fire, or what effect to expect on the severity if making sure that the number of staff is sufficient.

Improvements and future research

So, is there any reason to modify professional practice related to capability assessments? It is clear that the conceptual and experimental contexts that the results presented here are based on are very different to the context in real life. Hence, capability descriptions based on the definition proposed here will not necessarily help to reduce long-term losses from disasters any more than those generated by indicator and index methods.

However, the relevant question, based on this research, is not whether current practice instantly should be replaced by something completely new. Instead, it is more interesting to ask whether there are reasons to continue to develop and test the proposed approach to assessing capability. The findings presented here suggest that this is the case; current practice and its focus on indicator and index methods does not seem to contribute to reducing long-term losses from disasters and the findings from the experimental studies indicate that the proposed approach could be more suitable for the intended purpose.

One next step to continue develop and test the proposed approach could be to apply the ideas in, for example, a municipality. Such a study could focus on how stakeholders could describe capability according to the proposed definition in practice, and explore the strengths and weaknesses of the approach in the field.

The proposed way of defining and describing capability makes capability assessments more similar to risk and vulnerability assessments, and makes it possible to link risk assessments to plans, through a focus on describing the severity of events and their consequences from various angles. Therefore, future studies could focus on how, in practice, various assessments and plans could be integrated, and influence each other.

Apart from testing these ideas in practice, future research could also continue to study capability assessments in a microworld setting. The studies presented in Paper IV investigate some aspects of assessments, and how they contribute to balancing the costs and benefits of increasing capability. Future studies could, for example, explore how tasks and their associated effects could best be described in more detail.

Conclusion

This research aims to increase knowledge about the concept of capability and capability assessments in the context of reducing losses from disasters. It describes current capability assessment practice and suggests improvements. The answers to the research questions are summarised in the following:

How is capability defined and assessed? The capability concept is often used but rarely defined. Capability is commonly assessed by indicator and index methods focused on resources, procedures and plans. Such methods are easy and intuitive to use, which is positive. However, the capability descriptions that they generate are difficult to relate to the goal of DRM, and to, for example, risk assessments and plans.

How should capability be defined and described? The proposed capability definition relates to the ability to do something with the purpose of positively influencing the outcome of an adverse event. More specifically, capability refers to the uncertainty about and the severity of the consequences of the activity given the occurrence of the initiating event and the performed task.

To what extent do task and resource descriptions contribute to decision-makers' perceived usefulness of capability descriptions? Capability descriptions based on the proposed definition, including both task and resource descriptions, seem to be perceived as more useful by decision-makers than descriptions produced by indicator and index methods.

Do capability descriptions affect decisions concerning the allocation of resources intended to increase capability? Capability descriptions based on the proposed definition seem to make a positive contribution to balancing the more-or-less certain short-term cost of investment in increased capability with the more uncertain long-term benefits of reduced losses from disasters. They also seem to positively influence decision-makers' willingness to invest in increasing response capability.

This research makes several major contributions to improving the use of capability assessments in DRM. It provides a better understanding of the current use of capability assessments; it clarifies their potential role in DRM; and it suggests a new way to define and describe capability. The latter is worth further exploration in order to strengthen the role of capability assessments in DRM. Their ongoing neglect in the DRM context may foster compliance and complacency, which could hinder efforts aimed at reducing long-term losses from disasters.

References

Abrahamsson, M., Eriksson, K., Hassel, H., Petersen, K., & Tehler, H. (2011). *Kritiska beroenden, förmågebedömning och identifiering av samhällsviktig verksamhet* [Critical interdependencies, capability assessment and identification of critical infrastructure]. Report 1019. Lund: LUCRAM.

Abt, E., Rodricks, J. V, Levy, J. I., Zeise, L., & Burke, T. A. (2010). Science and decisions: Advancing risk assessment. *Risk Analysis*, *30*(7), 1028–1036. doi:10.1111/j.1539-6924.2010.01426.x

Alexander, D. (2005a). An interpretation of disaster in terms of changes in culture, society and international relations. In R. Perry & E. L. Quarantelli (Eds.), *What is a disaster?* (pp. 25–38). Philadelphia, PA: Xlibris.

Alexander, D. (2005b). Towards the development of a standard in emergency planning. *Disaster Prevention and Management*, *14*(2), 158–175. doi:10.1108/09653560510595164

Alexander, D. E. (2002). *Principles of Emergency Planning and Management*. Oxford: Oxford University Press.

Almklov, P. G., & Antonsen, S. (2010). The commoditization of societal safety. *Journal of Contingencies and Crisis Management*, *18*(3), 132–144. doi:10.1111/j.1468-5973.2010.00610.x

Ansell, C., Boin, A., & Keller, A. (2010). Managing transboundary crises: Identifying the building blocks of an effective response system. *Journal of Contingencies and Crisis Management*, *18*(4), 195–207. doi:10.1111/j.1468-5973.2010.00620.x

Archer, M., Decoteau, C., Gorski, P., Little, D., Porpora, D., Rutzou, T., … Vandenberghe, F. (2016). What is critical realism? Retrieved from http://www.asatheory.org/current-newsletter-online/what-is-critical-realism

Arksey, H., & O'Malley, L. (2005). Scoping studies: Towards a methodological framework. *International Journal of Social Research Methodology, 8*(1), 19–32. doi:10.1080/1364557032000119616

Arvai, J. L. (2007). Rethinking of risk communication: Lessons from the decision sciences. *Tree Genetics & Genomes*, *3*(2), 173–185. doi:10.1007/s11295-006-0068-7

Askeland, T., Flage, R., & Aven, T. (2017). Moving beyond probabilities – Strength of knowledge characterisations applied to security. *Reliability Engineering and System Safety*, *159*, 196–205. doi:10.1016/j.ress.2016.10.035

Aven, T. (2010). On how to define, understand and describe risk. *Reliability Engineering and System Safety*, *95*, 623–631. doi:10.1016/j.ress.2010.01.011

Aven, T. (2011). On some recent definitions and analysis frameworks for risk, vulnerability, and resilience. *Risk Analysis*, *31*(4), 515–522. doi:10.1111/j.1539-6924.2010.01528.x

Aven, T. (2012). On the link between risk and exposure. *Reliability Engineering and System Safety*, *106*, 191–199. doi:10.1016/j.ress.2012.06.004

Aven, T. (2017). Improving risk characterisations in practical situations by highlighting knowledge aspects, with applications to risk matrices. *Reliability Engineering and System Safety*, *167*, 42–48. doi:10.1016/j.ress.2017.05.006

Aven, T. (2018). Reflections on the use of conceptual research in risk analysis. *Risk Analysis*, *38*(11), 2415–2423. doi:10.1111/risa.13139

Aven, T., & Renn, O. (2009). On risk defined as an event where the outcome is uncertain. *Journal of Risk Research*, *12*(1), 1–11. doi:10.1080/13669870802488883

Aven, T., & Renn, O. (2019). Some foundational issues related to risk governance and different types of risks. *Journal of Risk Research*. doi:10.1080/13669877.2019.1569099

Aven, T., Renn, O., & Rosa, E. A. (2011). On the ontological status of the concept of risk. *Safety Science*, *49*(8–9), 1074–1079. doi:10.1016/j.ssci.2011.04.015

Aven, T., & Ylönen, M. (2018). A risk interpretation of sociotechnical safety perspectives. *Reliability Engineering and System Safety*, *175*, 13–18. doi:10.1016/j.ress.2018.03.004

Becker, P. (2012). The importance of integrating multiple administrative levels in capacity assessment for disaster risk reduction and climate change adaptation. *Disaster Prevention and Management*, *21*(2), 226–233. doi:10.1108/09653561211220016

Bhaskar, R. (2008). *A realistic theory of science*. London: Routledge.

Biddle, S. (2004). *Military power: Explaining victory and defeat in modern battle*. Princeton, NJ: Princeton University Press.

Bier, V. M. (2001). On the state of the art: Risk communication to decision-makers. *Reliability Engineering and System Safety*, *71*(2), 151–157. doi:10.1016/S0951-8320(00)00091-0

Bier, V. M., Haphuriwat, N., Menoyo, J., Zimmerman, R., & Culpen, A. M. (2008). Optimal resource allocation for defense of targets based on differing measures of attractiveness. *Risk Analysis*, *28*(3), 763–770. doi:10.1111/j.1539-6924.2008.01053.x

Boardman, J. T., & Sauser, B. (2008). *Systems thinking: Coping with 21st century problems*. Boca Raton, FL: CRC Press.

Boin, A., & Hart, P. (2007). The crisis approach. In H. Rodríguez, E. L. Quarantelli, & R. R. Dynes (Eds.), *Handbook of Disaster Research* (pp. 42–54). Boston, MA: Science+Business Media, LLC.

Boin, A., & Lagadec, P. (2003). Preparing for the future: Critical challenges in crisis management. *Journal of Contingencies and Crisis Management*, *8*(4), 185–191. doi:10.1111/1468-5973.00138

Boin, A., & McConnell, A. (2007). Preparing for critical infrastructure breakdowns: The limits of crisis management and the need for resilience. *Journal of Contingencies and Crisis Management*, *15*(1), 50–59. doi:10.1111/j.1468-5973.2007.00504.x

Brandén, H. (2016). *Kritisk realism* [Critical realism]. Linköping: Linköping University Electronic Press.

Brehmer, B. (1992). Dynamic decision making: Human control of complex systems. *Acta Psychologica*, *81*(3), 211–241. doi:10.1016/0001-6918(92)90019-A

Brehmer, B. (2007). Understanding the functions of C2 is the key to progress. *The International C2 Journal*, *1*(1), 211–232.

Bryman, A. (2008). *Social research methods*. Oxford: Oxford University Press.

CADRI (Capacity for Disaster Reduction Initiative). (2011). *Basics of Capacity Development for Disaster Risk Reduction*.

CADRI (Capacity for Disaster Reduction Initiative). (2013). *Disaster risk reduction capacity assessment tool*.

Calvano, C. N., & John, P. (2004). Systems engineering in an age of complexity. *Systems Engineering*, *7*(1), 25–34. doi:10.1002/sys.10054

Caudle, S. L., & de Spiegeleire, S. (2010). A new generation of national security strategies: Early findings from the Netherlands and the United Kingdom. *Journal Of Homeland Security And Emergency Management*, *7*(1), Article 35. doi:10.2202/1547-7355.1679

Cilliers, P. (2000). Rules and complex systems. *Emergence*, *2*(3), 40–50. doi:10.1207/S15327000EM0203_04

Colquhoun, H. L., Levac, D., O'Brien, K. K., Straus, S., Tricco, A. C., Perrier, L., … Moher, D. (2014). Scoping reviews: Time for clarity in definition, methods, and reporting. *Journal of Clinical Epidemiology, 67*(12), 1291–1294. doi:10.1016/j.jclinepi.2014.03.013

Cunningham, D. W., & Wallraven, C. (2011). *Experimental design: From user studies to psychophysics*. Hoboken, NJ: CRC Press.

Davis, K., Drey, N., & Gould, D. (2009). What are scoping studies? A review of the nursing literature. *International Journal of Nursing Studies, 46*(10), 1386–1400. doi:10.1016/j.ijnurstu.2009.02.010

de Bruijne, M., & van Eeten, M. (2007). Systems that should have failed: Critical infrastructure protection in an institutionally fragmented environment. *Journal of Contingencies and Crisis Management*, *15*(1), 18–29. doi:10.1111/j.1468-5973.2007.00501.x

de Spiegeleire, S. (2011). Ten trends in capability planning for defence and security. *RUSI Journal*, *156*(5), 20–28. doi:10.1080/03071847.2011.626270

Denyer, D., Tranfield, D., & van Aken, J. E. (2008). Developing design propositions through research synthesis. *Organization Studies*, *29*(3), 393–413. doi:10.1177/0170840607088020

DHS (Department of Homeland Security). (2013a). *Capability estimation: Comprehensive preparedness guide (CPG) XXX*. Predecisional working draft, for review.

DHS (Department of Homeland Security). (2013b). *Threat and hazard identification and risk assessment guide: Comprehensive preparedness guide (CPG) 201*.

Dieckmann, N. F., Mauro, R., & Slovic, P. (2010). The effects of presenting imprecise probabilities in intelligence forecasts. *Risk Analysis*, *30*(6), 987–1001. doi:10.1111/j.1539-6924.2010.01384.x

Dieckmann, N. F., Peters, E., Gregory, R., & Tusler, M. (2012). Making sense of uncertainty: advantages and disadvantages of providing an evaluative structure. *Journal of Risk Research*, *15*(7), 717–735. doi:10.1080/13669877.2012.666760

Dieckmann, N. F., Slovic, P., & Peters, E. M. (2009). The use of narrative evidence and explicit likelihood by decisionmakers varying in numeracy. *Risk Analysis*, *29*(10), 1473–1488. doi:10.1111/j.1539-6924.2009.01279.x

Dilla, W. N., & Stone, D. N. (1997). Representations as decision aids: The asymmetric effects of words and numbers on auditors' inherent risk judgments. *Decision Sciences*, *28*(3), 709–743. doi:10.1111/j.1540-5915.1997.tb01328.x

European Commission. (2015). *Risk management capability assessment guidelines (2015/C261/03)*. Retrieved from https://publications.europa.eu/en/publication-detail/-/publication/98cd1ee9-3d91-11e5-9f5a-01aa75ed71a1

FAO (Food and Agriculture Organization of the United Nations). (2008). *Disaster risk management systems analysis – A guide book*. Retrieved from http://www.fao.org/3/a-i0304e.pdf

Filinkov, A., & Dortmans, P. J. (2014). An enterprise portfolio approach for defence capability planning. *Defense and Security Analysis*, *30*(1), 76–82. doi:10.1080/14751798.2013.864866

Friedberg, A. L. (1987). The assessment of military power: A review essay. *International Security*, *12*(3), 190–202. doi:10.2307/2538805

Friesen, S. K., Giroux, G., & Villeneuve, A. (2013). *Overview of the all hazards risk assessment (AHRA) automated application and capability assessment management system (CAMS)*. Defence Research and Development Canada. Retrieved from http://cradpdf.drdc-rddc.gc.ca/PDFS/unc140/p538137_A1b.pdf

Gardoni, P., & Murphy, C. (2008). Recovery from natural and man-made disasters as capabilities restoration and enhancement. *International Journal of Sustainable Development and Planning*, *3*(4), 317–333. doi:10.2495/SDP-V3-N4-317-333

Gardoni, P., & Murphy, C. (2009). Capabilities-based approach to measuring the societal impacts of natural and man-made hazards in risk analysis. *Natural Hazards Review*, *10*(2), 29–37. doi:10.1061/(asce)1527-6988(2009)10:2(29)

Gardoni, P., & Murphy, C. (2010). Gauging the societal impacts of natural disasters using a capability approach. *Disasters*, *34*(3), 619–636. doi:10.1111/j.1467-7717.2010.01160.x

Gregor, S., & Jones, D. (2007). The anatomy of a design theory. *Journal of the Association for Information Systems*, *8*(5), 312–335. doi:10.17705/1jais.00129

Hagelsteen, M., & Becker, P. (2013). Challenging disparities in capacity development for disaster risk reduction. *International Journal of Disaster Risk Reduction*, *3*, 4–13. doi:10.1016/j.ijdrr.2012.11.001

Haimes, Y. Y. (2009). On the complex definition of risk: A systems-based approach. *Risk Analysis*, *29*(12), 1647–1654. doi:10.1111/j.1539-6924.2009.01310.x

Hansson, S. O., & Hadorn, G. H. (2018). Argument-based decision support for risk analysis. *Journal of Risk Research*, *21*(12), 1449–1464. doi:10.1080/13669877.2017.1313767

Hemond, Y., & Robert, B. (2012). Preparedness: The state of the art and future prospects. *Disaster Prevention and Management*, *21*(4), 404–417. doi:10.1108/09653561211256125

Hevner, A. R., March, S. T., Park, J., & Ram, S. (2004). Design science in information systems research. *MIS Quarterly*, *28*(1), 75–105. doi:10.2307/25148625

Hills, A. (2005). Insidious environments: Creeping dependencies and urban vulnerabilities. *Journal of Contingencies and Crisis Management*, *13*(1), 12–20. doi:10.1111/j.0966-0879.2005.00450.x

Hilton, N. Z. (2005). Communicating violence risk information to forensic decision makers. *Criminal Justice and Behavior*, *32*(1), 97–116. doi:10.1177/0093854804270630

IFRC (International Federation of Red Cross and Red Crescent Societies). (2016). *World disaster report – resilience: saving lives today, investing for tomorrow*. Retrieved from https://media.ifrc.org/ifrc/wp-content/uploads/sites/5/2016/11/WDR-2016-FINAL_web.pdf

ISO (International Organization for Standardization). (2009). *Risk management – Principles and guidelines* (ISO 31000).

Ivgin, M. (2013). The decision-making models for relief asset management and interaction with disaster mitigation. *International Journal of Disaster Risk Reduction*, *5*, 107–116. doi:10.1016/j.ijdrr.2013.08.005

Jensen, A., & Aven, T. (2018). A new definition of complexity in a risk analysis setting. *Reliability Engineering and System Safety*, *171*, 169–173. doi:10.1016/j.ress.2017.11.018

Johansen, I. L., & Rausand, M. (2012). Risk metrics: Interpretation and choice. In *Proceedings of 2012 IEEE International Conference on Industrial Engineering and Engineering Management*, IEEM 2012, Hong Kong, China, 10–13 December 2012.

Johansen, I. L., & Rausand, M. (2014). Foundations and choice of risk metrics. *Safety Science*, *62*, 386–399. doi:10.1016/j.ssci.2013.09.011

Kahneman, D. (2003). A perspective on judgment and choice: Mapping bounded rationality. *American Psychologist*, *58*(9), 697–720. doi:10.1037/0003-066X.58.9.697

Kahneman, D., & Tversky, A. (1979). Prospect theory: An analysis of decision under risk. *Econometrica*, *47*(2), 263–292. doi:10.2307/1914185

Karlsson, B., Olsson, A. J., & Riedel, M. (2016). *From gaps to caps: Report on national capability and risk assessments and related challenges in the Baltic sea region*. Project funded by the European Commission, DG ECHO, project number ECHO/SUB/2014/693890

Keeney, R. L. (1982). Feature article – Decision analysis: An overview. *Operations Research*, *30*(5), 803–838. doi:10.1287/opre.30.5.803

Klinke, A., & Renn, O. (2002). A new approach to risk evaluation and management: Risk-based, precaution-based, and discourse-based strategies. *Risk Analysis*, *22*(6), 1071–1094. doi:10.1111/1539-6924.00274

Kothari, C. R. (2004). *Research methodology: Methods and techniques*. New Age Publishers.

Kristensen, V., Aven, T., & Ford, D. (2006). A new perspective on Renn and Klinke's approach to risk evaluation and management. *Reliability Engineering and System Safety*, *91*(4), 421–432. doi:10.1016/j.ress.2005.02.006

Kühberger, A. (1995). The framing of decisions: A new look at old problems. *Organizational Behaviour and Human Decision Processes*, *62*(2), 230–240. doi:10.1006/obhd.1995.1046

Levac, D., Colquhoun, H., & O'Brien, K. K. (2010). Scoping studies: Advancing the methodology. *Implementation Science, 5*(69). doi:10.1029/2003JD004173.Aires

Lin, L., Nilsson, A., Sjölin, J., Abrahamsson, M., & Tehler, H. (2015). On the perceived usefulness of risk descriptions for decision-making in disaster risk management. *Reliability Engineering and System Safety*, *142*, 48–55. doi:10.1016/j.ress.2015.04.012

Lin, L., Rivera, C., Abrahamsson, M., & Tehler, H. (2017). Communicating risk in disaster risk management systems: Experimental evidence of the perceived usefulness of risk descriptions. *Journal of Risk Research*, *20*(12), 1534–1553. doi:10.1080/13669877.2016.1179212

Lipshitz, R., Klein, G., Orasanu, J., & Salas, E. (2001). Focus article: Taking stock of naturalistic decision making. *Journal of Behavioral Decision Making*, *14*(5), 331–352. doi:10.1002/bdm.381

Little, R. (2004). A socio-technical systems approach to understanding and enhancing the reliability of interdependent infrastructure systems. *International Journal of Emergency Management*, *2*(1–2), 98–110. doi:10.1504/IJEM.2004.005232

MacInnis, D. J. (2011). A framework for conceptual contributions in marketing. *Journal of Marketing*, *75*(4), 136–154. doi:10.1509/jmkg.75.4.136

March, S. T., & Smith, G. F. (1995). Design and natural science research on information technology. *Decision Support Systems*, *15*(4), 251–266. doi:10.1016/0167-9236(94)00041-2

Marshall, A. W. (1966). *Problems of estimating military power*. Santa Monica, CA: Rand Corporation.

McConnell, A., & Drennan, L. (2006). Mission impossible? Planning and preparing for crisis. *Journal of Contingencies and Crisis Management*, *14*(2), 59–70. doi:10.1111/j.1468-5973.2006.00482.x

McEntire, D. (2007). *Disaster response and recovery: Strategies and tactics for resilience*. Hoboken, NJ: Wiley.

Mennen, M. G., & van Tuyll, M. C. (2015). Dealing with future risks in the Netherlands: The national security strategy and the national risk assessment. *Journal of Risk Research*, *18*(7), 860–876. doi:10.1080/13669877.2014.923028

Ministry of Civil Defense and Emergency Management. (2015). *Civil defence emergency management national capability assessment report*. Retrieved from https://www.civildefence.govt.nz/assets/FINAL-National-Capability-Assessment-Report-2015.pdf

MSB (The Swedish Civil Contingencies Agency). (2013). *Risk- och sårbarhetsanalyser samt förmågebedömning: Underlag inför revidering av föreskrifter och indikatorer* [Risk and vulnerability analyses and capability assessments: Material for revision of regulations and indicators].

MSB (The Swedish Civil Contingencies Agency). (2014a). *Konsekvensutredning för föreskrift om kommuners och landstings risk- och sårbarhetsanalyser* [Impact inquiry regarding regulation on municipalities' and county councils' risk and vulnerability analyses]. Retrieved from https://www.msb.se/siteassets/dokument/regler/rs/997b81ce-2f41-4c52-a8c6-76a26f233686.pdf

MSB (The Swedish Civil Contingencies Agency). (2014b). *Konsekvensutredning för föreskrift om statliga myndigheters risk- och sårbarhetsanalyser* [Impact inquiry regarding regulation on government agencies' risk and vulnerability analyses]. Retrieved from https://www.msb.se/siteassets/dokument/regler/rs/ff20ceaf-8b6d-4ccf-bb89-97c74f6ba447.pdf

MSBFS 2010:6. *Myndigheten för samhällsskydd och beredskaps föreskrifter om kommuners och landstings risk- och sårbarhetsanalyser* [The Swedish Civil Contingencies Agency's instructions on municipalities' and county councils' risk and vulnerability analyses]. Retrieved from https://www.msb.se/siteassets/dokument/regler/rs/d375d4ab-d22d-40df-b215-2942b2418b2d.pdf

MSBFS 2010:7. *Myndigheten för samhällsskydd och beredskaps föreskrifter om statliga myndigheters risk- och sårbarhetsanalyser* [The Swedish Civil Contingencies Agency's instructions on government agencies' risk and vulnerability analyses]. Retrieved from https://www.msb.se/siteassets/dokument/regler/rs/098ca5ef-1f9c-4a96-b6d1-3736d67c15cc.pdf

MSBFS 2015:3. *Myndigheten för samhällsskydd och beredskaps föreskrifter om statliga myndigheters risk- och sårbarhetsanalyser* [The Swedish Civil Contingencies Agency's instructions on government agencies' risk and vulnerability analyses]. Retrieved from https://www.msb.se/siteassets/dokument/regler/rs/53d3cb05-a275-4018-8cdf-9df3cfb179c4.pdf

MSBFS 2015:4. *Myndigheten för samhällsskydd och beredskaps föreskrifter om landstings risk- och sårbarhetsanalyser* [The Swedish Civil Contingencies Agency's instructions on county councils' risk and vulnerability analyses]. Retrieved from https://www.msb.se/siteassets/dokument/regler/rs/ab59ff87-822f-4aa9-8d37-41e43a63b4b4.pdf

MSBFS 2015:5. *Myndigheten för samhällsskydd och beredskaps föreskrifter om kommuners risk- och sårbarhetsanalyser* [The Swedish Civil Contingencies Agency's instructions on municipalities' risk and vulnerability analyses]. Retrieved from https://www.msb.se/siteassets/dokument/regler/rs/15e78831-767b-4714-9fa4-3b4fd0df92a8.pdf

MSBFS 2016:7. *Myndigheten för samhällsskydd och beredskaps föreskrifter om statliga myndigheters risk- och sårbarhetsanalyser* [The Swedish Civil Contingencies Agency's instructions on government agencies' risk and vulnerability analyses]. Retrieved from https://www.msb.se/siteassets/dokument/regler/rs/153e4f90-d672-4fd5-a86f-f0ebb08cea28.pdf

Murphy, C., & Gardoni, P. (2006). The role of society in engineering risk analysis: A capabilities-based approach. *Risk Analysis*, *26*(4), 1073–1083. doi:10.1111/j.1539-6924.2006.00801.x

Murphy, C., & Gardoni, P. (2007). Determining public policy and resource allocation priorities for mitigating natural hazards: A capabilities-based approach. *Science and Engineering Ethics*, *13*(4), 489–504. doi:10.1007/s11948-007-9019-4

Murphy, C., & Gardoni, P. (2008). The acceptability and the tolerability of societal risks: A capabilities-based approach. *Science and Engineering Ethics*, *14*(1), 77–92. doi:10.1007/s11948-007-9031-8

Murphy, C., & Gardoni, P. (2010). Assessing capability instead of achieved functionings in risk analysis. *Journal of Risk Research*, *13*(2), 137–147. doi:10.1080/13669870903126259

Murphy, C., & Gardoni, P. (2012). The capability approach in risk analysis. In S. Roeser, R. Hillerbrand, P. Sandin, & M. Peterson (Eds.), *Handbook of risk theory* (pp. 979–997). Springer Netherlands.

Månsson, P., Abrahamsson, M., & Tehler, H. (2019). Aggregated risk: An experimental study on combining different ways of presenting risk information. *Journal of Risk Research, 22*(4), 497–512. doi:10.1080/13669877.2017.1391315

O'Brien, K. K., Colquhoun, H., Levac, D., Baxter, L., Tricco, A. C., Straus, S., … O'Malley, L. (2016). Advancing scoping study methodology: A web-based survey and consultation of perceptions on terminology, definition and methodological steps. *BMC Health Services Research, 16*(305). doi:10.1186/s12913-016-1579-z

OECD (Organisation for Economic Co-operation and Development). (2003). *Emerging risks in the 21st century: An agenda for action*. Retrieved from https://www.oecd.org/futures/globalprospects/37944611.pdf

OECD (Organisation for Economic Co-operation and Development). (2009). *Innovation in country risk management*. Retrieved from https://www.oecd.org/futures/Innovation%20in%20Country%20Risk%20Management%202009.pdf

OECD (Organisation for Economic Co-operation and Development). (2010). *Risk and regulatory policy: Improving the governance of risk*. doi:10.1787/9789264082939-en

OECD (Organisation for Economic Co-operation and Development). (2011). *Future global shocks: Improving risk governance*. Retrieved from http://www.oecd.org/governance/48329024.pdf

OECD (Organisation for Economic Co-operation and Development). (2015). *The changing face of strategic crisis management*. doi: 10.1787/9789264249127-en

Olsen, O. E., Kruke, B. I., & Hovden, J. (2007). Societal safety: Concept, borders and dilemmas. *Journal of Contingencies and Crisis Management*, *15*(2), 69–79. doi:10.1111/j.1468-5973.2007.00509.x

Oxenham, D. (2010). The next great challenges in systems thinking: A defence perspective. *Civil Engineering and Environmental Systems*, *27*(3), 231–241. doi:10.1080/10286608.2010.482661

Perrow, C. (1999). *Normal accidents: Living with high-risk technology*. Princeton, NJ: Princeton University Press.

Perry, R. W., & Lindell, M. K. (2003). Preparedness for emergency response: Guidelines for the emergency planning process. *Disasters*, *27*(4), 336–350. doi:10.1111/j.0361-3666.2003.00237.x

Petrenj, B., Lettieri, E., Trucco, P., & Milano, P. (2012). Towards enhanced collaboration and information sharing for critical infrastructure resilience: Current barriers and emerging capabilities. *International Journal of Critical Infrastructures*, *8*(2/3), 107–120. doi:10.1504/IJCIS.2012.049031

Pham, M. T., Rajić, A., Greig, J. D., Sargeant, J. M., Papadopoulos, A., & McEwen, S. A. (2014). A scoping review of scoping reviews: Advancing the approach and enhancing the consistency. *Research Synthesis Methods, 5*(4), 371–385. doi:10.1002/jrsm.1123

Quarantelli, E. L. (1998). Major criteria for judging disaster planning and managing their applicability in developing societies. Newark, DE: Disaster Research Center, University of Delaware.

Quarantelli, E. L. (2000). *Emergencies, disaster and catastrophes are different phenomena*. Preliminary paper #304. Newark, DE: Disaster Research Center, University of Delaware.

Rasmussen, J. (1985). The role of hierarchical knowledge representation in decisionmaking and system management. *IEEE Transactions on Systems, Man, & Cybernetics*, *15*(2), 234–243. doi:10.1109/TSMC.1985.6313353

Rasmussen, J. (1997). Risk management in a dynamic society: A modelling problem. *Safety Science*, *27*(2), 183–213. doi:10.1016/S0925-7535(97)00052-0

Rasmussen, J., & Svedung, I. (2000). *Proactive risk management in a dynamic society*. Karlstad: Swedish Rescue Services Agency (Statens räddningsverk).

Reidar, S.-D., & Kruke, B. I. (2018). Preparedness: Unpacking and clarifying the concept. *Journal of Contingencies and Crisis Management*, *26*(2), 212–224. doi:10.1111/1468-5973.12175

Renn, O. (1998). Three decades of risk research: Accomplishments and new challenges. *Journal of Risk Research*, *1*(1), 49–71. doi:10.1080/136698798377321

Renn, O. (2008). *Risk governance: coping with uncertainty in a complex world*. London: Earthscan.

Robson, C. (2002). *Real world research: A resource for social scientists and practitioner-researchers*. Oxford: Blackwell.

Romme, A. G. L. (2003). Making a difference: Organization as design. *Organization Science*, *14*(5), 558–573. doi:10.1287/orsc.14.5.558.16769

Scurich, N., & John, R. S. (2011). The effect of framing actuarial risk probabilities on involuntary civil commitment decisions. *Law and Human Behavior*, *35*(2), 83–91. doi:10.1007/s10979-010-9218-4

Sen, A., & Nussbaum, M. (1993). *The quality of life*. Oxford: Clarendon Press.

SFS 2006:637. *Förordning om kommuners och landstings åtgärder inför och vid extraordinära händelser i fredstid och höjd beredskap* [Regulation on municipalities' and county councils' measures prior to and during extraordinary events in peacetime and during periods of heightened alert]. Retrieved from http://rkrattsbaser.gov.se/sfst?bet=2006:637

SFS 2015:1052. *Förordning om krisberedskap och bevakningsansvariga myndigheters åtgärder vid höjd beredskap* [Regulation on crisis preparedness and surveillance responsible authorities' measures during heightened alert]. Retrieved from http://rkrattsbaser.gov.se/sfst?bet=2015:1052

Simon, H. A. (1996). *The sciences of the artificial*. Cambridge, MA: MIT Press.

SRA (Society for Risk Analysis). (2018). *Society for risk analysis glossary*. Retrieved from https://sra.org/sites/default/files/pdf/SRA%20Glossary%20-%20FINAL.pdf

SOU 2014:134. *Krishantering och civilt försvar i kommuner och landsting* [Crisis management and civil defence in municipalities and county councils]. Retrieved from https://data.riksdagen.se/fil/66C10B44-F3AD-4A63-A268-640D73D732C2

Steen, R., & Aven, T. (2011). A risk perspective suitable for resilience engineering. *Safety Science*, *49*(2), 292–297. doi:10.1016/j.ssci.2010.09.003

Tellis, A. J., Bially, J., Layne, C., & McPherson, M. (2000). *Measuring national power in the postindustrial age*. Santa Monica, CA: Rand Corporation.

Thompson, K. M., & Bloom, D. L. (2000). Communication of risk assessment information to risk managers. *Journal of Risk Research*, *3*(4), 333–352. doi:10.1080/13669870050132559

Tversky, A., & Kahneman, D. (1974). Judgment under uncertainty: Heuristics and biases. *Science*, *185*(4157), 1124–1131. doi:10.1126/science.185.4157.1124

Tähtinen, J., & Havila, V. (2018). Conceptually confused, but on a field level? A method for conceptual analysis and its application. *Marketing Theory*, *X*(XX), 1–25. doi:10.1177/1470593118796677

UNISDR (International Strategy for Disaster Reduction). (2009). *Terminology on disaster risk reduction*. Retrieved from https://www.unisdr.org/files/7817_UNISDRTerminologyEnglish.pdf

UNISDR (International Strategy for Disaster Reduction). (2015). *Sendai framework for disaster risk reduction 2015–2030*. Retrieved from https://www.unisdr.org/files/43291_sendaiframeworkfordrren.pdf

UNISDR (International Strategy for Disaster Reduction). (2017). *Words into action guidelines: National focal points for disaster risk reduction, national platforms for disaster risk reduction, local platforms for disaster risk reduction*. Retrieved from https://www.unisdr.org/files/53055_npslpswiapublicconsultation2017.pdf

van Aken, J. E. (2004). Management research based on the paradigm of the design sciences: The quest for field-tested and grounded technological rules. *Journal of Management Studies*, *41*(2), 219–246. doi:10.1111/j.1467-6486.2004.00430.x

van Aken, J. E. (2005a). Management research as a design science: Articulating the research products of mode 2 knowledge production in management. *British Journal of Management*, *16*(1), 19–36. doi:10.1111/j.1467-8551.2005.00437.x

van Aken, J. E. (2005b). Valid knowledge for the professional design of large and complex design processes. *Design Studies*, *26*(4), 379–404. doi:10.1016/j.destud.2004.11.004

van Asselt, M., & Renn, O. (2011). Risk governance. *Journal of Risk Research*, *14*(4), 431–449. doi:10.1080/13669877.2011.553730

von Neumann, J., & Morgenstern, O. (1944). *Theory of games and economic behavior*. Princeton, NJ: Princeton University Press.

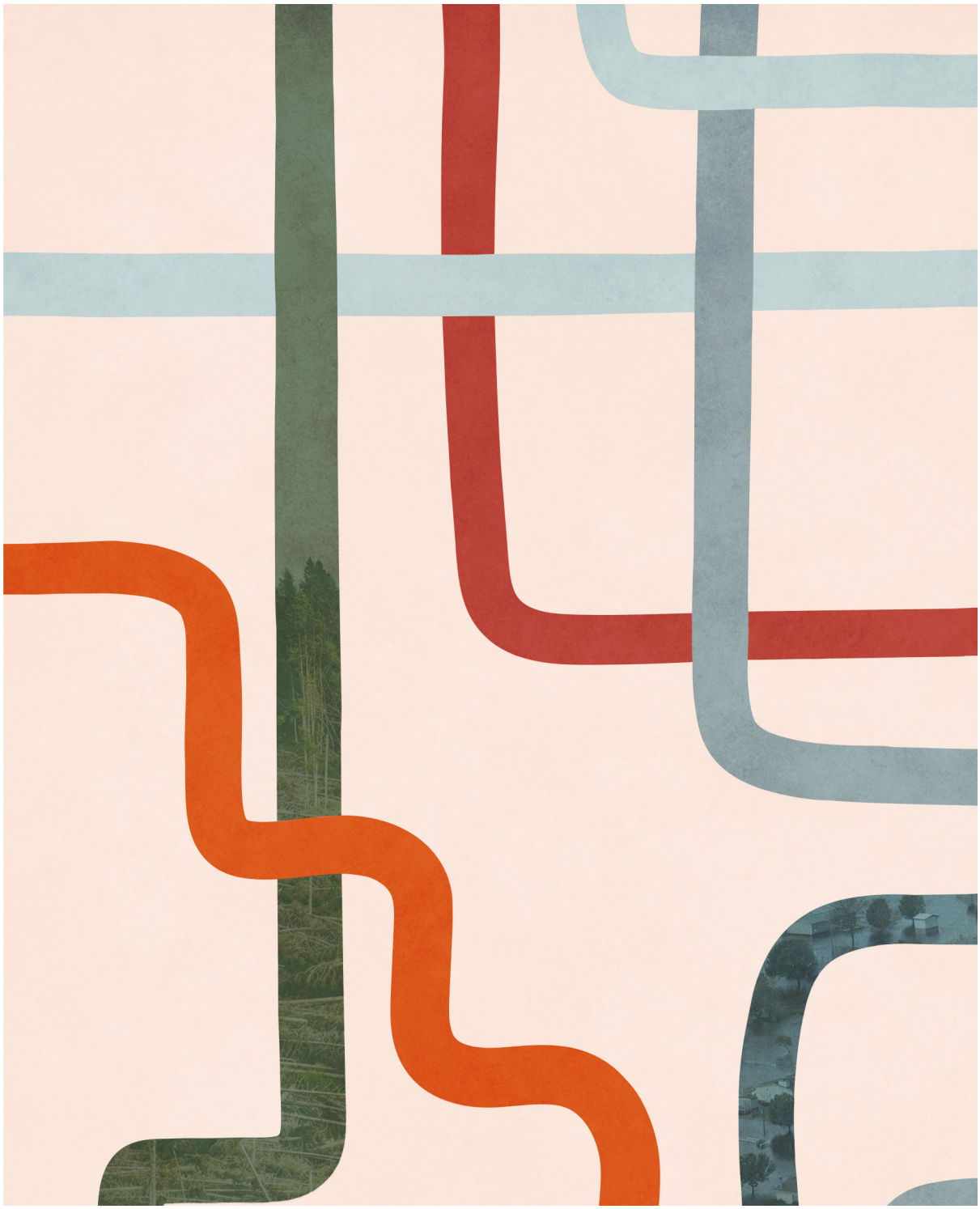
Webb, N. J., Richter, A., & Bonsper, D. (2010). Linking defense planning and resource decisions: A return to systems thinking. *Defense and Security Analysis*, *26*(4), 387–400. doi:10.1080/14751798.2010.534647

Weber, R. P. (1990). *Basic content analysis*. Newbury Park, CA: Sage.

Wood, D. L. (2019). Introduction: An assessment of U.S. military power. Retrieved from https://www.heritage.org/military-strength/assessment-us-military-power

World Economic Forum. (2017). *The global risk report 2017*. Retrieved from http://www3.weforum.org/docs/GRR17_Report_web.pdf

Yue, Y., & Henshaw, M. (2009). An holistic view of UK military capability development. *Defense and Security Analysis*, *25*(1), 53–67. doi:10.1080/14751790902749900



LUND UNIVERSITY

Lund University
Faculty of Engineering
Division of Risk Management and Societal Safety

ISBN 978-91-7895-290-8