Solving complex problems in emergencies

A Fire and Rescue Service perspective

Vylund, Anna Lotta

2024

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

Solving complex problems in emergencies

A Fire and Rescue Service perspective

LOTTA VYLUND
FIRE SAFETY ENGINEERING | FACULTY OF ENGINEERING | LUND UNIVERSITY

Printed by Media-Tryck, Lund 2024 NORDIC SWAN ECOLABEL 3041 0903

Faculty of Engineering
Department of Building & Environmental Technology
Division of Fire Safety Engineering

ISBN 978-91-8104-098-2
ISSN 1402-3504
ISRN LUTVDG/TVBB--1072—SE

Solving complex problems in emergencies

A Fire and Rescue Service perspective

Lotta Vylund

LUND
UNIVERSITY

LICENTIATE DISSERTATION

by due permission of the Faculty of Engineering, Lund University, Sweden. To be publicly defended on August 16th at 10.15 in room V:D, V-huset, John Ericssons väg 1, Lund

Faculty opponent
Dr. Isabell Andersson, Senior Lecturer, Department of Leadership and Command & Control, Division of Leadership and Command & Control, Swedish Defence University, Stockholm, Sweden.

Organization: LUND UNIVERSITY. Faculty of Engineering, Division of Fire Safety Engineering

Document name: LICENTIATE THESIS

Date of issue: 2024-08-16

Author(s): Lotta Vylund

Sponsoring organisation: NordForsk within the project Nordic Services in the Twenty First Century, No. 97830.

Title and subtitle: Solving complex problems in emergencies – A Fire and Rescue Service perspective.

Abstract:

Global trends suggest an increasing level of uncertainty regarding potential risks faced by individuals, organizations, or society as a whole. These trends are likely to alter the risk landscape, necessitating the enhancement of societal capabilities to effectively address emerging risks. Among the key actors dealing with such changes is the Fire and Rescue Service (FRS). However, these challenges can also impact the FRS's ability to effectively manage emergency situations. During emergencies, the FRS needs to solve various and numerous problems that can occur. Problems in emergencies are often complex, characterized by many highly interrelated elements, which pose challenges for solving them. There is a need to improve the understanding of conditions for collective problem-solving and how the FRS solves complex problems today together with the need of adaptation to expected societal change as input to improved future response. The overarching aim of this thesis is to contribute to an increased understanding of how the FRS can enhance its capability for solving complex problems in emergencies. The thesis had two research questions 1) What key factors affect complex problem-solving in emergencies, and 2) How does collaboration in the form of networks affect complex problem-solving in emergencies. The first Paper included in the thesis is about improving complex problem-solving in emergencies – a case study of the Fire and Rescue Service in Sweden. In addition, the second Paper presents a case study regarding understanding FRS practice through problems and problem-solving networks. The paper identified eight factors affecting complex problem-solving in emergencies and proposed a conceptual tool for the FRS to support the gathering of important problem-related information in an incident necessary to find viable solutions to complex problems. Furthermore, the FRS practices could be understood as breaking down complex problems into manageable sub-problems to be able to find necessary resources to solve complex problems. New empirical findings are presented in both Papers and are presented in relation to previous literature and a discussion is also made regarding practical implications together with theoretical contributions.

Key words: Fire and Rescue Service, Complex Problem-Solving, Complex Problems, Problem-Solving Networks

Classification system and/or index terms (if any)

Supplementary bibliographical information

Language: English

ISSN and key title: 1402-3504

ISBN: 978-91-8104-098-2 (print), 978-91-8104-099-9 (pdf)

Recipient’s notes

Number of pages: 60

Price

Security classification

Signature

Date 2024-08-16

Solving complex problems in emergencies

A Fire and Rescue Service perspective

Lotta Vylund

LUND
UNIVERSITY

Coverphoto by Lotta Vylund

Faculty of Engineering Department of Building & Environmental Technology
Division of Fire Safety Engineering

ISBN 978-91-8104-098-2 (print)
ISBN 978-91-8104-099-9 (pdf)
ISSN 1402-3504
ISRN LUTVDG/TVBB--1072—SE

Printed in Sweden by Media-Tryck, Lund University
Lund 2024

Table of Contents

Acknowledgement

I would like to express my sincere gratitude to Nordforsk for providing the funding that supported this research and special thanks to my dedicated supervisors for their invaluable guidance throughout the project.

I extend my appreciation to all those who generously shared their knowledge during interviews and workshops, contributing significantly to the depth and breadth of this study. I am grateful to my past and future employers for their support and encouragement.

Last but not least, thanks to my family for their support, understanding, and patience throughout this academic journey.

Summary

The aim of this thesis is to contribute to an increased understanding of how the Fire and Rescue Service (FRS) can enhance its capability for solving complex problems in emergencies. Emergency situations are often complex and dynamic events characterized by a high level of uncertainty, unpredictability, and ambiguity. Such conditions challenge the ability of the FRS, and other stakeholders, to solve the various and numerous problems that can occur both consecutively and in parallel. To find a solution to a problem, the FRS often relies on previous experience, exercises and plans. However, relying on previous experience or patterns to understand the problem and find a solution is not always possible because many FRS organizations lack extensive experience with larger complex emergencies.

This thesis has explored how FRS can enhance its capability to solve complex problems during emergencies. The findings were drawn from interviews with 20 participants from the FRS, as well as incident reports from 166 large-scale incidents over a two-year period. Through this analysis, eight factors were identified affecting complex problem-solving. In addition, how collaborative networks impact problem-solving in emergencies was explored.

The FRS can use the identified factors to acquire insights into what is needed in complex problem-solving. For example, the identified factors can support the FRS on which problem-related information is important to gather and thereafter how to use this information to find viable solutions to the problems. It offers a practical alternative for gaining a comprehensive understanding of such challenges, where previous experience is lacking, thereby enabling the development of more insightful and effective solutions.

Furthermore, the factors revealed that complex problems in emergencies cannot be resolved solely by the FRS. Effective problem-solving often relies on collaborative efforts within networks, where various actors work together to address complex problems. The findings also indicate that FRS typically deals with complex problems by breaking down the main problem into sub-problems to more easily identify which resources in the network could or should be mobilized.

Theoretical contributions include enhancing the literature on complex problem-solving and advocating for the utilization of the two analysis frameworks employed in this thesis for analyzing FRS responses.

Sammanfattning

Syftet med denna licentiatavhandling är att bidra till en ökad förståelse för hur räddningstjänsten kan förbättra sin förmåga att lösa komplexa problem vid storskaliga olyckshändelser. Större olyckor är ofta komplexa och dynamiska händelser som kännetecknas av en hög grad av osäkerhet, oförutsägbarhet och tvetydighet. Under sådana förhållanden utmanas räddningstjänstens förmåga att lösa de olika och många problem som kan uppstå både i följd och parallellt. För att hitta en lösning på ett problem förlitar sig räddningstjänsten ofta på tidigare erfarenhet, övningar och planer. Men att förlita sig på tidigare erfarenhet för att förstå problemet och hitta en lösning är inte alltid möjligt eftersom många räddningstjänstorganisationer saknar omfattande erfarenhet av större komplexa händelser.

Denna avhandling har utforskat hur räddningstjänster kan förbättra sin förmåga att lösa komplexa problem med avseende på storskaliga händelser. Resultaten baseras på intervjuer med 20 respondenter som varit inblandade i dessa typer av händelser, samt olycksutredningar och händelserapporter från 166 storskaliga händelser under två år. Avhandlingen identifierade åtta faktorer som påverkar komplex problemlösning och visade på hur räddningstjänsten samarbetar i nätverk för att lösa komplexa problem.

Räddningstjänsten kan använda de identifierade faktorerna för att få insikter om vad som krävs för komplex problemlösning. Till exempel kan räddningstjänsten använda de identifierade faktorerna för att veta vilken typ av information som behöver samlas in och därefter använda informationen för att hitta lösningar på problemen. Faktorerna erbjuder ett praktiskt alternativ till att få en omfattande förståelse för komplexa problem, där tidigare erfarenhet saknas, vilket möjliggör utvecklingen av mer insiktsfulla och effektiva lösningar.

Vidare visar faktorerna att komplexa problem inte kan lösas ensamt, utan för att lösa dessa problem behöver räddningstjänsten samarbeta i nätverk. Resultaten indikerar också att räddningstjänsten vanligtvis hanterar komplexa problem genom att bryta ner huvudproblemet i delproblem för att lättare identifiera vilka resurser i nätverk som kan eller bör mobiliseras.

Teoretiskt har denna studie bidragit till att förbättra litteraturen om komplex problemlösning och visat på hur de två analysramverken som använts i studien kan förbättra lärandet efter en räddningstjänstinsats.

1 Introduction

The world we live in is increasingly complex. Despite this increasing complexity there is an expectation that the Fire and Rescue Service (FRS) are equipped to solve problems both today and in the future. Therefore, the aim of this thesis is to contribute to an increased understanding of how the FRS can enhance its capability for solving complex problems in emergencies. This chapter presents the background and motivation of the thesis, together with the thesis aim and research questions, publications and delimitations. Chapter 2 explains the conceptual framework and Chapter 3 explains the research methods employed throughout the thesis. Chapter 4 summarizes the main findings from the individual papers and serves as input for the subsequent discussion in Chapter 5, where the implications, significance, and broader context of the findings are discussed. Finally, Chapter 6 presents the conclusions and Chapter 7 presents ideas for further research.

1.1 Background

Global trends indicate growing uncertainty of potential risks that individuals, organizations or society may encounter (Markert et al., 2023). This requires thoughtful planning and execution to navigate and address risks within challenges such as climate change (IFRC, 2020), evolving technologies (WEF, 2024), and security issues (Jordan, 2017). At first, climate change is expected to contribute to more frequent extreme weather events, including heavy rain, winds, floods, and prolonged droughts with water shortages and wildfires (EEA, 2023). Next, rapid technological advancements, such as the development of sustainable technologies or digitalization and artificial intelligence, offer opportunities but also pose risks (WEF, 2024). Last, increased polarization in society and a greatly deteriorated security situation may contribute to heightened instability (Jordan, 2017). Overall, these trends will inevitably lead to a change in the risk landscape and a need to enhance emergency response capabilities to adeptly handle the challenges posed by these emerging risks. One of the key actors that has to deal with such change is the FRS, while at the same time these challenges can affect the ability of the FRS to manage emergency situations effectively.

The FRS is organized in a hierarchical structure designed to efficiently respond to emergencies such as fires, traffic accidents, natural hazards and drownings with

their primary mission to protect lives, property, and the environment (FEMA, 2017). Typically, the public sector (municipality, county, state or nation) is responsible for organizing the FRS (FEMA, 2017). How the FRS responds to an emergency is dependent on the scale of the emergency, and simultaneously constrained by the resources and time available (Coppola, 2006). However, in the event of emergencies, the response is provided by a variety of actors, with different roles depending on both the type of emergency and its geographical location. Collaborations between the actors can be both formalized prior to an event or emerge in response to the emergency itself (Zappa & Lomi, 2015; Zappa & Lomi, 2016); and, even though the FRS is organized in a hierarchical structure, research argues that flexible and horizontal collaborations are needed to foster a comprehensive approach to emergency preparedness and response (Kapucu, Arslan, & Collins, 2010; Moynihan, 2009). This collaboration can be seen as taking place through networks, which can be helpful to quickly identify and access resources, share information, and coordinate efforts (Bodin & Nohrstedt, 2016; Hu & Kapucu, 2016; Hu et al., 2022; Kapucu, Arslan, & Collins, 2010; Moynihan, 2009; Provan & Kenis, 2008; Sparf & Petridou, 2018).

Emergency situations are often complex and dynamic events and many definitions of emergency exist (see e.g. Lagadec, 2007; Quarantelli, 1988, 1997; Quarantelli et al., 2018; Quarantelli et al., 2007)). Related terms such as disaster, crises and catastrophes can be used to describe various societal disruptions and these terms can have different meanings for different individuals ('t Hart & Boin, 2001). However, the FRS can encounter complex problems in different response situations and to increase the understanding of how the FRS can enhance its capability for solving complex problems this thesis will use the term emergency to reflect those types of incidents where the FRS is required to address complex problems. Therefore, this thesis defines emergencies as situations characterized by a high level of uncertainty, unpredictability, and ambiguity. Under such conditions, emergency response challenges the ability of the FRS, and other stakeholders, to solve the various and numerous problems that can occur (Frykmer et al., 2018), both consecutively and in parallel.

Problems in emergencies are often complex, or wicked, i.e. they are unclear, difficult to define and require adaptive management and a comprehensive approach (Gustavsson et al., 2021; Head & Alford, 2015). Not only does modern society lead to new types of problems that need to be solved in the field of the FRS, but complexity is also expected to increase due to the inherently interconnected nature of modern society as characterized by multiple interdependencies (Frykmer et al., 2018). For example, in a fire emergency, consider firefighting efforts that depend on various interdependent factors such as water supply, communication systems, and coordination between multiple response teams. If any of these elements face challenges or breakdowns, this will complicate the overall firefighting response,

illustrating how the interconnected nature of modern society increases the complexity of managing emergencies.

Moreover, in the FRS, problem solvers such as firefighters face new challenges due to the changing landscape of modern society (Markert et al., 2023), which introduces new requirements like technological advancements or security issues. In dealing with emergencies, it is therefore not always possible to rely on previous experience or response plans to solve the problems that arise (Mishra et al., 2015). Hence, there is a clear and pressing need for the FRS to comprehend and adapt to the problems already existing and those arising in the face of a changing risk landscape.

In summary, global trends indicate a need to improve the understanding of conditions for problem-solving and how the FRS solves complex problems today as input to improved future responses.

1.2 Research aim

The overarching aim of this thesis is to contribute to an increased understanding of how the FRS can enhance its capability for solving complex problems in emergencies. In pursuit of this aim, the research focuses on two research questions and their interpretation is guided by the conceptual framework outlined in Chapter 2. This framework serves to narrow down the potential range of answers to the otherwise broad research questions.

1.3 Research process and research questions

The research process undertaken for this thesis included a series of phases where the initial phase involved identifying the problem area to then boil it down to the overarching aim and research questions, i.e. problematization (Alvesson & Sandberg, 2013). The thesis was designed according to scientific methods (see Chapter 3) where formulation of research questions was followed by data collection, analysis, discussion, and at last leading to the presentation of conclusions. Figure 1 illustrates the research process, highlighting its iterative nature, e.g., continuously revisiting the area of knowledge during the research process and adjusting the aim and research questions accordingly.

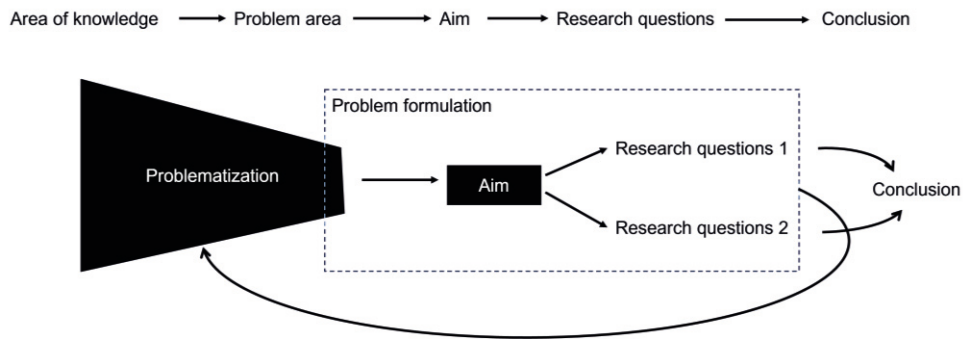

Figure 1: The research process, adapted by Säfsten and Gustavsson (2020), illustrates how the area of knowledge was continuously revisited during the research process.

At first, the research process explored the area of knowledge related to problems and problem-solving in an emergency context. The area of knowledge encompasses literature in the field, relevant courses, previous research projects conducted by the author, and practical experience working in an FRS organization. This knowledge contributed to identifying the problem area as the necessity for the FRS to tailor response activities for solving complex problems in emergencies. Thus, this leads to the overarching aim of the need to increase the understanding of how the FRS can enhance its capability for solving complex problems in emergencies. In order to address the overall research aim, the first research question focuses on identifying factors that influence complex problem-solving:

- *Research question 1*: What key factors affect complex problem-solving in emergencies?

The purpose of asking "what" was to form classifying knowledge (Säfsten & Gustavsson, 2020), aiming to categorize complex problem-solving into factors to facilitate understanding of the problem-solving process. The area of knowledge also revealed that there was a need to find out more about collaboration in a problem-solving context, leading to the second research question:

- *Research question 2:* How does collaboration in the form of networks affect complex problem-solving in emergencies?

However, the research process was not linear, and the research questions were refined by continuously revisiting the area of knowledge during the two studies connected to the research questions. This ensured that the research questions addressed the actual needs of the FRS from both practical and theoretical perspectives.

1.4 Publications

This thesis is based on the following research papers:

- Paper 1: Vylund, L., Jacobson, J., Frykmer, T., Eriksson, K. "Improving complex problem-solving in emergency response - a study of the Fire and Rescue Service in Sweden". *Submitted to a scientific journal*.
- Paper 2: Vylund, L., Frykmer, T., McNamee, M., Eriksson, K. 2024. Understanding Fire and Rescue Service Practices Through Problems and Problem-Solving Networks: An Analysis of a Critical Incident. *Fire Technology 2024* https//doi.org//10.1007/s10694-024-01582-0

The author of the thesis led the development of and was responsible for both Papers and was actively involved in all aspects of the research process as outlined in Table 1.

Table 1. The author's contribution to the research process in the thesis Papers.

	Author's contributions	
Research process	**Paper 1**	**Paper 2**
Formulating aim and planning for the research design	Main responsible for formulating the research question and how to answer this.	Contributed together with the other authors to the study conception and design.
Data collection	Main responsible for collecting the empirical data for one of the studied cases and the literature review. Contributed to the other data collection.	Main responsible for collecting the empirical data. Contributed to the other data collection methods.
Analysis	Main responsible for the analysis.	Main responsible for the analysis.
Writing the Paper	Main responsible for the development of the final manuscript for submission.	Wrote the first draft and together with the other authors contributed to the development of the final manuscript for submission
Presenting the Paper in a scientific conference	-	Poster presentation at the 31th Annual Conference for the Society of Risk Analysis Europe. Presentation at Nordic Fire Safety Day.

During this process, the following conference abstracts have been developed and conference presentations made:

- Abstract 1: Vylund, L., McNamee, M., Frykmer, T., Eriksson, K. 2023. Key factors in emergency response to better meet future needs**.** In book of

abstract for Society for Risk Analysis Europe 2023, 18-21 June 2023 in Lund, Sweden, p. 158

- Abstract 2: Vylund, L., Gjøsund, G., Markert, F. 2024. The importance of Problem-Solving Networks in emergencies. Abstract accepted to the Nordic and Fire Safety Days, 18-19 June 2024 in Lund, Sweden.

Following related publications have been published during the research process:

- Eriksson, E., Alirani, G., Johansson, R., Vylund, L. 2023. Policy Development in Swedish Crisis Management: Restructuring of Fire and Rescue Services. In Zahariadis et al. (2023). *Edward Elgar Publishing*. https://doi.org/10.4337/9781802209822.00023
- Granström, A., Sjöström, J., & Vylund, L. 2023. Perception of wildfire behaviour potential among Swedish incident commanders, and their fire suppression tactics revealed through tabletop exercises. *International Journal of Wildland Fire*, 32(3), 320-327
- Amon, F., Orrell, L., Millgård, U., Vylund, L. 2022. Evaluation Report, Deliverable D7.6. In the EU-project ASSISTANCE (Adapted situation awareneSS tools and taIlored training curricula for increaSing capabiliTie and enhANcing the proteCtion of first respondErs), Project ref. no. H2020 – 832576.

1.5 Limitations

The thesis does not aim to understand the whole emergency response cycle (mitigation, preparedness, response, recovery, evaluation), instead the focus is on understanding the response phase. However, the different phases in the emergency response cycle are interconnected (Coetzee & Van Niekerk, 2012; Neal, 1997), and therefore the knowledge gained from this phase contributes to improving our understanding of future emergency strategies and capabilities in all phases.

Emergency response is dependent on the collaboration of a diversity of actors working together to mitigate potential harm to individuals and society. However, this thesis focuses on the study of emergency response from an FRS perspective and data collection is limited to FRS personnel. Furthermore, data collection is limited to the geographical scope of the Swedish FRS. Data collection has, however, been conducted in the context of a Nordic research project and discussed with colleagues from Norway and Denmark which has added depth to the analysis.

Additionally, it should be noted that the findings presented in the two papers serve as a condensed representation of the actual problem-solving. Conversely, the

inherent dynamic nature of emergency-driven problem-solving indicates a constant state of change. A specific representation of the problem-solving process holds relevance solely within defined temporal and spatial limitations, thus introducing a limitation in this thesis.

Finally, this thesis is constrained to complex emergency situations, i.e., excluding those only requiring routine procedures and/or only engaging FRS organizations. Instead, the focus is on situations that challenge the response organization, are out of the 'ordinary' and require multiple and diverse actors to solve the encountered problems.

2 The conceptual framework

This chapter explains the conceptual framework employed throughout the thesis. It starts with defining problem and problem-solving, including how problems are solved collectively, as used in this thesis. Last, the two analysis frameworks used in this thesis are explained.

2.1 Problems and problem-solving

A dominant perspective in the problem-solving literature suggests that a problem is characterized by an undesirable current state and a desired goal state and that there is no direct or obvious way to go from the current state to the goal state (Duncker & Lees, 1945; Mayer, 1992; Newell & Simon, 1972). When the Fire and Rescue Service (FRS) responds to an emergency, they often need to handle various and numerous problems in parallel (Frykmer et al., 2018). These problems are often considered complex or wicked (Rittel & Webber, 1973), ill-defined (Reitman, 1964; Simon, 1973) or unstructured-unbounded (Mitroff & Linstone, 1992). Here, current states and goal states are difficult to define, and whether a problem exists or not is highly subjective. Indeed, there may not even be agreement between participants in the problem-solving process on how to reach the goal or what the problem is ('t Hart & Boin, 2001; Klein, 1998; Smith, 1992).

In addition, these types of problems can be related to a complex system of problems, where in emergencies, at any given moment, some problems are identified while others may be anticipated as potential future problems. This complex system of problems is characterized by problems continuously changing, interacting with each other, and that are challenging to define (Ackoff, 1979), making it difficult to predict outcomes or determine straightforward solutions. In such cases, one often has to make do with a “good enough” solution. These complex systems, including non-linear interactions, openness to the surrounding environment, and continuously varying situations, require comprehension of the system as a whole and consideration of the interdependencies between different problems, as understanding cannot be achieved by only focusing on one individual problem (Cilliers, 2005; Kauffman, 1993). Although complex problems require comprehension of the whole system, Head and Alford (2015) posit that it is possible in most cases to break the complex problems down into sub-problems that could be

easier to understand. While acknowledging the risk of losing the holistic understanding, this could be a necessary first step in addressing the whole system of complex problems in emergencies where there is often a need for swift actions.

Research into problem-solving is diverse and there are many research areas that have contributed to the understanding of complex problem-solving (Fischer et al., 2011). To align with an influential perspective in the literature, this thesis uses the definition proposed by Newell and Simon (1972), and further developed by Simon (1996), of problem-solving as a search process using actions to reduce or eliminate the difference between the current state and the goal state. They illustrate this process through the so-called *problem space*, see Figure 2. Here, the nodes represent the current state, the goal state, and possible solution steps in between. The lines between the nodes illustrate that there may be several ways to reach the goal state from the current state.

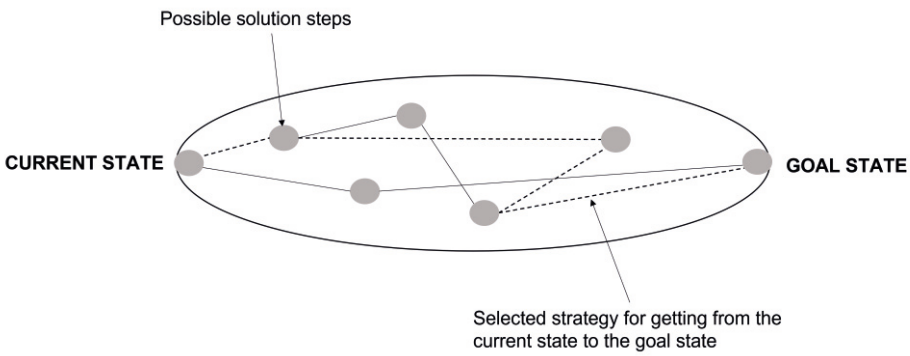

Figure 2: The problem space with the current state, goal state, possible solution steps and the selected strategy (Paper 2).

Problem-solving in emergencies can also be described as a non-linear process consisting of the following four general steps: representing the problem, generating a course of action, evaluating the course of action, and carrying out the course of action (Klein, 1998). Problem solvers need to understand what the problem is by systematically compiling relevant information, analyzing its significance, recognizing patterns within the information, interpreting the information and thereafter structuring the resources accordingly to move toward the anticipated solution (Lipshitz & Bar-Ilan, 1996). To find a solution to a problem, the FRS often relies on previous experience, exercises and plans (Klein, 2008; Klein, 1993), or on the simplification of cognitive processes through the use of heuristics (see e.g. Kahneman, 2011; Kahneman et al., 2021; Kahneman & Tversky, 1979). However, relying on previous experience or patterns to understand the problem and find a solution is not always possible (Mishra et al., 2015). Therefore, to solve complex problems, it is imperative to also employ analytical reasoning and critical thinking skills (Albanese & Paturas, 2018; Mishra et al., 2015).

To maintain focus on solving complex problems, where it is important to comprehend the whole system of problems, the concept of complex problem-solving by Fischer et al. (2011) has been found useful as it relies on the above definition of the concept of complexity, problem space and problem-solving. They particularly emphasize that not only the problem can be complex, but also the solution, thereby extending previous research on problem-solving in complex situations. Instead of the process described by Klein (1998), consisting of four steps, Fischer et al. (2011) mean that the process of complex problem-solving is divided into two phases, which the problem solver iterates between. The first phase, knowledge gathering, contains information generation and information reduction, necessitated by the limited capacity of the problem solver's working memory. As part of this first phase, the problem solver builds an internal model of the problem based on the identified information. The second phase, goal-oriented knowledge application uses the knowledge gathered in the first phase to reach the desired goal state. This phase includes continuously monitoring the ongoing solution due to the complex and dynamic environment, to possibly go back to acquire more information and adjust the model or solution, before returning to the knowledge gathering phase.

Complex problem-solving, rooted in complexity theory (Cilliers, 2005), is based on the principle that no actor can fully grasp the functioning of the entire system. To support an increased understanding of how the FRS can enhance its capability for solving complex problems, this thesis explores how problem-solving processes, in connection with emergency response, are managed collectively.

2.1.1 Collective problem-solving

Problem-solving in emergencies relies on collective efforts, requiring organizations to collaborate and work together to address the challenges that arise (Frykmer, 2020, 2021; Nohrstedt, 2016; Waugh Jr & Streib, 2006). Various theories exist to illustrate how actors collectively respond to emergency situations, e.g. through teamwork (Jouanne et al., 2017; Schraagen et al., 2010), inter-team work (Power, 2018), or social networks (Bodin & Nohrstedt, 2016). While teamwork is often discussed in terms of how two or more people cooperate, coordinate and communicate towards a common goal, the formation and development of networks are frequently examined in wider terms, drawing on organizational, contextual, inter-organizational or structural factors (Hu et al., 2022). Likewise, Moynihan (2009) emphasizes that effective problem-solving often relies on collaborative efforts within networks, where various organizations work together to address complex problems. For example, police, ambulance and FRS working together to solve problems in emergencies. Collaborating in networks is a well-known feature in the emergency management literature (see e.g. Kapucu, Arslan, & Collins, 2010; Kapucu & Garayev, 2016; Moynihan, 2009). However, to be able to further understand how the FRS collectively solves complex problems in emergencies, this

thesis concentrates on networks that specifically emerge in response to identified problems. Milward and Provan (2006) refer to these networks formed for collective problem-solving in emergencies as Problem-Solving Networks (PSN) characterized by a set of inter-organizational relationships formed to solve problems requiring immediate response.

However, to further understand how PSN work in emergencies, this thesis adopts the view that networks are related to general systems theory (Skyttner, 1996). In this context, networks that solve a particular problem are interpreted as a collection of components interconnected by relationships that allow for the exchange, transfer, or flow of information, resources, or entities between the components. Components in this sense are not limited to people or organizations, instead they include anything that could be a part of solving the problem at hand. This perspective is valuable because general systems theory is inherently qualitative and descriptive, aiming towards understanding. Therefore, general systems theory proves useful for leveraging knowledge about PSN in emergencies by providing a qualitative and descriptive framework for comprehensive understanding.

In conclusion, this thesis broadens Milward and Provan's (2006) definition of PSN, to encompass the components and relationships needed to find solutions to the problem without limiting the network to only inter-organizational relationships.

2.2 Analysis frameworks

During the research process, the following two analysis frameworks have been used as guidance in the data analysis phase.

2.2.1 Possibility space

In order to investigate which factors affect complex problem-solving as a whole, the theoretical concept called "*possibility space for action*" proposed by Brehmer (2013) is used during the data analysis phase.

According to Brehmer, the possibility space can be said to be the scope of action available at a specific point in time for a particular response, or the space within which we can act in an operational environment. In other words, the possibility space for acting in response operations could be used to identify which set of solutions is possible. The concept of possibility space was developed for the purpose of military decision-making and was inspired by Rasmussen (1997), who defines the range where operators can choose safe work methods and can be used to explore why they might choose otherwise. Brehmer also claims that this concept can be used in FRS operations. The space is not infinitely large and Brehmer proposed six

factors that affect the ability of the FRS to act in emergencies, see Figure 3. These factors are: the *task*, which can be more or less clearly formulated concerning the needs that should be met, the *resources*, in terms of available quantity and type, as well as their state, the *time* available, the *incident*, the *legal framework* within which the work takes place, and the *environment* in which the incident has occurred. For example, only actions that correspond to the task that needs to be solved and using available resources are possible to be implemented.

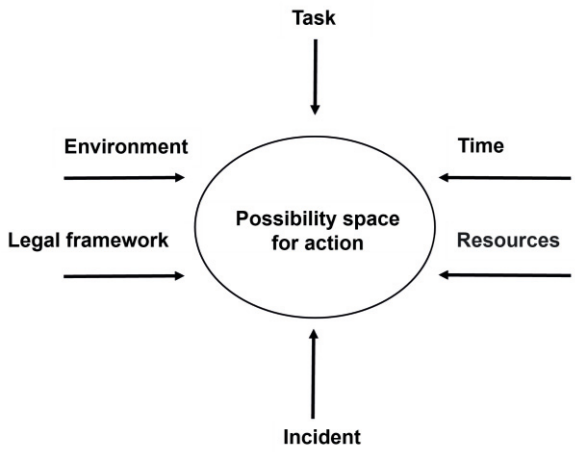

Figure 3: The possibility space for action (Paper 1).

The factors have been empirically investigated by Andersson and Uhr (2019), in both police and military operations. Andersson and Uhr (2019) concluded that the proposed factors are relevant. However, they proposed the inclusion of *command conditions* and *collaboration conditions* as additional factors. *Command conditions* relate to how the opportunities to act may be limited or influenced by how well the leadership performs. *Collaboration* becomes crucial when two or more organizations are involved in response efforts, especially this was proved important in police settings.

The concept of possibility space can be connected to complex problem-solving in emergencies. Here, it can guide which knowledge to gather and how to build an internal model that allows for identifying possible solutions within the set of factors limiting the ability to act (phase 1 – knowledge gathering). Thereafter, the gathering of knowledge phase serves as a basis for deciding which different solutions to the problem could be implemented and which of these are most urgent to implement to reach the goal state (phase 2 – goal-oriented knowledge application).

2.2.2 Complexity Theory Framework

Bergström et al. (2016) present a complexity theory framework to analyze emergency response as a method to understand emergency management operations. The framework is based on Cilliers' perspective on complexity (Cilliers, 2005), emphasizing the analysis of multiple interpretations of complex systems, the importance of transparent analytical choices, and the acknowledgment that additional interpretations will always be possible. The framework facilitates an understanding of what needs to be achieved to obtain direction and coordination in disaster response management and allows for multiple perspectives in the same analysis. In this thesis, the framework was used to facilitate systematic division of emergency response into problems, actors and activities that are needed to find solutions to any given problem. The framework breaks down the response in terms of three separate but related aspects: Scope, Resolution and Dimension, to create clarity in the discussion and assessment of emergency response. By combining these three aspects, the methodology creates a systematic way to look at problem-solving from a number of different perspectives, ensuring clarity is maintained concerning similarities and differences between perspectives. What is meant by these three aspects of the model is described in more detail below.

Scope is perhaps the most easily recognizable aspect of an emergency response analysis from a conceptual point of view. The scope refers to the delineation or boundaries defining which actors and relationships to include in the analysis. Scope could for example be related to geographical boundaries.

The aspect of resolution relates to the detail of the network developed. As larger scopes are chosen for analysis, the network necessarily becomes less detailed. The value of the application of resolution is that it allows the user to vary the resolution as part of the analysis, to capture comprehensive information about connections between individuals or groups of stakeholders, or to take a birds-eye view of connections between organizations for an overview of the problem-solving networks.

The dimension of the system being analyzed relates to what components the system consists of and their relationships, e.g. components such as human, organization or technical aid and their relationships such as information flows, trust or technological dependence.

Figure 4 exemplifies the methodology in terms of how a system of humans in different groups communicates to resolve a specific problem within the emergency scenario chosen for analysis. In this example, the scope is the problem to be solved, and the analytical boundary could be drawn around the components and relationships engaged in solving that problem. The dimension consists of humans and communication relationships, and resolution consists of groups.

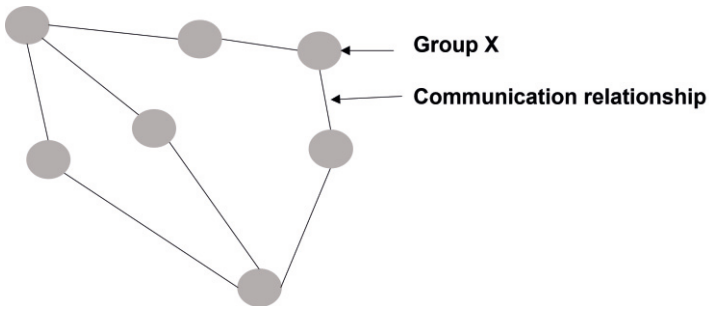

Figure 4: Example of how the complexity theory framework could be used to analyze how communication between different groups works to resolve a problem chosen for analysis. In this example the scope is the problem to be solved, resolution is groups, and the dimensions consist of humans connected by relationships of communication.

2.3 Summary of key terms

Table 2 summarizes key terms used in this thesis, along with their definitions as described in this chapter.

Table 2: Key terms along with their definition used in this thesis.

Term	Definition
Problems	A problem is characterized by an undesirable current state and a desired goal state where there is no direct or obvious way to go from the current state to the goal state.
Complex problems	Refers to a situation that involves multiple interconnected elements or factors, often characterized by uncertainty, ambiguity, and dynamic interactions. These problems are challenging to fully understand and resolve due to their intricate nature and the unpredictability of outcomes.
Problem-solving	A search process using actions to reduce or eliminate the difference between the desired goal state and the current state.
Process of complex problem-solving	Complex problem-solving is divided into two phases, which the problem solver iterates between: *knowledge gathering* and *goal-oriented knowledge application*.
Problem-Solving Network (PSN)	A network of components and relationships formed to solve complex problems in emergencies.
Complexity theory framework	A framework for analyzing the response system in terms of three separate but related aspects: *Scope*, *Resolution* and *Dimension*.
Possibility space for action	The scope of action available at a specific point in time for a particular response, or in other words the space within which we can act in an operational environment.

3 Research methods

This chapter first describes how the philosophical standpoint in this thesis influenced the selection of research methods. Thereafter, this chapter provides information about research methods, including data collection techniques, and the data analysis employed in the appended papers. This chapter also describes which ethical considerations were made as part of the research.

3.1 Navigating the researcher's position

Diverse views of the world and various philosophical approaches to science reflect the researcher's position in relation to different paradigms, such as ontology (the view of the nature of reality), epistemology (how knowledge is achieved), scientific ideal (norms concerning what is considered good research) and ethical guidelines for how research is to be carried out (Säfsten & Gustavsson, 2020). In this thesis, the guiding philosophical approach is pragmatism as it provides insight into actors' practical rationality and problem-solving within dynamic settings (Heinonen & Strandvik, 2022). Furthermore, this approach acknowledges the complexity, instability, and uncertainty inherent in crisis situations (Ansell & Boin, 2019).

Pragmatism relates to the different paradigms by which an idea, theory, or method may be confirmed through its practical consequences and usefulness. Here, gathering research knowledge is primarily considered a tool to solve problems and serves as a guide for practical action (Gustavsson, 2000). Reality is constructed from situations perceived by individuals as real and is manifested through human actions. There is no concept of absolute truth; instead, truth is synonymous with the practical consequences arising from actions and holds value solely in relation to its practical utility. In alignment with the underlying research philosophy of pragmatism, the common premise running through the appended Papers is rooted in a scientific ideal of induction which guides the relationship between theory, empirical data, and conclusions (Säfsten & Gustavsson, 2020). Induction involves constructing patterns from the bottom up, with the primary aim of generating practical knowledge.

An example of a research method aligned with the goal of practical applicability is action research, which involves collaboration between researchers and practitioners to address real-world problems. It emphasizes the active involvement of participants

in the research process, aiming to produce practical solutions or improvements in the context under study. This method is specifically designed to bridge the gap between academic research and practical work, focusing on addressing issues in the everyday work context within natural settings (Herr & Anderson, 2014). This thesis has adopted a specific form of action research known as interactive research. A fundamental principle of interactive research is a collaborative engagement between researchers and practitioners. Together, they define problems, conduct research and development activities, and jointly interpret and understand the findings and their effects. This approach is well-suited when the goal is to collaboratively create knowledge together with practitioners, which is important when generating knowledge of practical use (Svensson et al., 2007). In this thesis, the formulation of the research questions as well as the interpretation and understanding of findings and effects, has been a collaborative effort involving both the researcher and practitioners.

From the perspective of this research method, qualitative research was deemed most suitable for data collection and data analyze. This approach aims to offer an in-depth understanding of people's experiences and perspectives within the context of their personal circumstances or settings (Spencer et al., 2003). Qualitative research is typically exploratory, flexible, and driven by the data itself (Moser & Korstjens, 2018) which is appropriate when identifying problems and problem-solving networks.

3.2 Methods and materials

The research in the thesis used different data collection techniques, to facilitate triangulation of research results (Yin, 2018). Employing triangulation in the analysis is motivated by the idea that weaknesses in one technique (e.g., interview) can be compensated for by strengths in another technique (e.g., document study), thereby enhancing the overall quality of the study. Table 3 presents an overview of the methods and materials used. More detailed descriptions can be found in the respective Papers. All studies were documented to ensure transparency, reliability and replicability.

Table 3: Methods and materials

Paper	Method	Material
1	Case study	Multiple-case design
	Interviews (primary data)	20 participants from the Fire and Rescue Service and volunteers
	Document analysis (secondary data)	166 incident reports including information about the type of incident, time, location, response time, utilized resources and methods, as well as details regarding property damage and injuries/deaths

2	Case study	Single-case design
	Interviews (primary data)	9 participants from the Fire and Rescue Service
	Document and multi-media analysis (secondary data)	Incident assessment reports, video and various media articles

3.2.1 Case study

Case studies are appropriate when a deeper understanding of a situation is desired or when specific aspects of a situation need detailed description. These methods are particularly useful for addressing questions related to "how" and "what" (Yin, 2018), making them advantageous for studying less explored phenomena such as problem-solving in emergencies. The selection of cases was made to study the phenomenon of complex problems. Therefore, the cases were identified based on their perceived challenging and complex nature for the FRS to handle. In addition to their complex nature, the cases were also selected due to being the most common types of incidents handled by the FRS (e.g. building fires and wildfires).

The first case involved a major explosion in Gothenburg, Sweden in 2021 (MSB, 2022b). The explosion and the following fire resulted in smoke spreading throughout the building which endangered residents from around 60 apartments. A large number of units from the FRS and other first responders were called to the scene and the evacuation of residents took almost two hours. The fire was under control after approximately 10 hours, and the rescue operation ended after around 24 hours after the explosion.

The second case consisted of a major wildfire in the southern part of Sweden, in 2021 (Idh, 2021). The wildfire was small when the first FRS unit arrived, but due to a prolonged absence of rain and extreme drought conditions, extinguishing the fire became challenging. For various reasons, there were initially few resources on site and when the wind increased in the afternoon, the fire spread quickly. Over the next two days, around a hundred firefighters, volunteers and national resources worked to get the fire under control.

Paper 1 concerns both cases, while Paper 2 is specifically about the explosion. The use of a multi-case study design (Paper 1) offered the advantage of facilitating comparisons between different cases and enhanced the potential for generalizing the results (Yin, 2018), meanwhile a single case study (Paper 2) offered the opportunity to create more in-depth knowledge and comprehensive understanding of FRS practices when addressing problems and developing PSN.

3.2.2 Interviews

Interviews serve as a valuable method for data collection when researchers seek insights, perceptions, and experiences related to a specific phenomenon (Säfsten & Gustavsson, 2020). To gain a profound understanding of the problem-solving processes in emergencies, a qualitative in-depth interview study was deemed essential. Semi-structured interviews were chosen for their balanced approach, providing a certain level of structure while affording respondents the flexibility to answer in more detail should they so desire, thus revealing how respondents comprehend and frame issues of interest (Brinkmann, 2014). To mitigate validity concerns, including potential biases arising from respondents' unwillingness to share certain information or efforts to answer in a way the researcher wants, trust-building measures were implemented (Kvale & Brinkmann, 2009). For example, all identified individuals were contacted, provided with information about the study, and, following informed consent, were invited to participate in an interview. The questions were formulated using the language commonly used by practitioners, deliberately avoiding unnecessarily scientific language requiring specialized expertise.

Moreover, two researchers participated in each interview; one researcher conducted the interview while the other observed. In order to extract the desired information comprehensively, the observer was explicitly empowered to ask follow-up questions using techniques such as prompting, probing, and checking (Denscombe, 2017). Prompting aimed to encourage respondents to elaborate on any aspects they might have overlooked, probing sought to elicit more detailed responses, and checking involved summarizing the respondent's input or inviting them to add further insights. The advantage of two interviewers lay in their ability to complement each other. However, a potential drawback might be the respondent's perception of vulnerability in the presence of two interviewers (Säfsten & Gustavsson, 2020). This was mitigated by informing the interviewee at the outset of the different roles of the two interviewers.

Each interview was conducted within approximately one hour. To ensure transparency and make it possible to revisit the content, all interviews were transcribed[1]. All interviews were confidential and anonymized, and handling of personal details was in accordance with Lund University and RISE Research Institutes of Sweden policy for personal data handling, in line with EU's General Data Protection Regulation (GDPR), and the Swedish Data Protection Act.

The sampling procedure started with the implementation of strategic selection and the use of a snowball sampling technique (Denscombe, 2017). The sampling technique involves recruiting participants through recommendations from existing

[1] A transcript is a verbatim written copy of the interview which does not require confirmation by the interviewee.

individuals included in the study, creating a chain-like process of recruitment. While it can be argued that snowball sampling may introduce bias to the data collection process, its utilization was deemed necessary to identify individuals within the Fire and Rescue Service (FRS) who were involved in the incident in a variety of ways. The strategic selection was based on a combination of the following:

- Recommendations from the FRS incident investigators,
- Recommendations from those involved in initial interviews, and
- Availability to participate in the interviews.

Interviews were conducted with twenty respondents involved in the two cases, nine associated with the building fire and eleven involved in the wildfire. Seventeen of the participants worked as Incident Commander at different levels and the remaining three worked administratively, in the insurance industry and two as volunteers respectively. Paper 1 utilized interview data from both cases, while Paper 2 specifically employed data from the building fire.

Validity concerns may arise due to the selection of respondents, potentially leading to misleading results (Säfsten & Gustavsson, 2020). Additionally, individual perceptions of a given situation or circumstance may significantly differ due to unique experiences, biases, or roles in a specific emergency context. This implies that what one individual considers to be a problem, another may not ('t Hart & Boin, 2001; Smith, 1992). Consequently, the result could have been influenced if different or additional respondents had been involved in the interviews.

To address the validity concern, Malterud et al. (2016) suggest a model of "information power" for assessing the adequacy of a given sample size. This model suggests that the richness of relevant information within the sample directly influences the required number of participants for the study. The model employs five criteria to assess the concept of "information power" within the sample, with higher information power corresponding to a reduced requirement for sample size (N). The model is based on the following criteria: (a) the aim of the study, (b) sample specificity, (c) the use of established theory, (d) quality of dialogue, and (e) analysis strategy. How these criteria are related to the two interview studies in this thesis are discussed below:

a) The aim of the two studies conducted in this thesis was considered broad which implies a large sample size. However, the more focused research questions narrowed down the scope, and the sample size required to gather relevant data and insights.
b) A more homogeneous or specialized sample may require fewer participants compared to a diverse or heterogeneous sample. In the cases included in this thesis, the respondents involved a homogeneous group which implies a smaller sample size is needed.

c) The theoretical grounding of problem-solving in emergencies and the complexity of the theoretical concepts as a part of these studies may contribute to the need of a larger sample size. However, the analysis framework provided concepts that offered a coherent explanation of the relationships between various aspects of the data, which implies a smaller sample size to reach sufficient information power.
d) The quality of interaction and dialogue during data collection, such as the richness of responses, depth of insights, and level of engagement with participants, can lead to enough information power with a smaller number of participants. The used techniques such as prompting, probing, and checking during the interviews led to high-quality dialogue-enhanced rich responses which contributed to a deeper understanding of the study phenomena.
e) The analysis complexity and depth of exploration impact participant numbers. Detailed coding or theory development may require more respondents for saturation, meanwhile focusing on specific themes or patterns (as in these studies) requires fewer respondents.

In addition, the sample size was also evaluated by employing snowball sampling techniques, which enabled the researcher to identify new respondents until the sample size obtained sufficient information (Denscombe, 2017). Recent research by Hennink and Kaiser (2022) further underscores that in studies involving homogenous populations, a sample size of nine to seventeen interviews often reached sufficient information, and therefore the number of 9 respectively 20 participants in the two different studies appears suitable. To further mitigate validity concerns associated with interview data, document analysis complemented the interview studies, as described in the subsequent chapter.

3.2.3 Document analysis

A document analysis (secondary data) complemented the interviews (primary data) as it was possible to quickly gather plentiful and readily accessible data from a source unaffected by the researchers. The main drawback of document studies is that they have been produced for purposes other than the research questions for this thesis (Denscombe, 2017). The majority of the reviewed documents are accessible on the internet or publicly through Swedish authorities. This aspect enhances the reliability since other researchers can access the same information and validate the findings from the research conducted in this thesis.

The incident reports included in Paper 1 are regulated by The Swedish Civil Contingencies Agency (MSB). MSB stipulates that incident reports must be written and submitted to MSB, for all events classified as incident response according to

the Swedish Civil Protection Act[2] (SFS 2003:778). Incident reports contain relevant data from the incident, such as type of incident, time, location of the incident, response time, staff and methods used, property damage and injuries/deaths. The incident reports were chosen to reflect large-scale incidents as these were perceived as being challenging and complex for the FRS to handle. The analysis included incidents from all parts of Sweden to reflect a broad range of different FRSs, both the size of the organization and geography. In order to narrow down the selection of incident reports for study to a manageable number, the analysis focused on incidents where the total number of working hours for the FRS exceeded 200 hours per incident and was limited to the years 2021 and 2022. This timeframe resulted in the examination of 166 incident reports, encompassing over 200 pages of data.

The documents used in Paper 2 included the incident assessment report created on behalf of the Swedish Civil Contingencies Agency (MSB) (MSB, 2022b), the local FRS assessment report (RSG, 2022), an educational video developed by MSB (MSB, 2022a), and various media articles (see e.g. Ivarsson, 2021). The variety of secondary data has added to the validity of the research.

3.3 Data analysis

A qualitative rather than quantitative approach was chosen as it was deemed most suitable to receive an in-depth understanding of people's experiences and perspectives within their contexts (Spencer et al., 2003). There are various techniques for analyzing qualitative data, (e.g., grounded theory analysis, thematic analysis, content analysis). While all these techniques involve sorting data using codes, with each code serving to describe a particular identified phenomenon within a data segment, there are some notable differences between them. For example, grounded theory begins without any pre-determined ideas, theories, or themes, whereas content analysis assumes that the researcher has some expectations about the likely codes that will emerge from the data. Thematic analysis and content analysis are similar in that both aim to condense data into a summarized format, and they are sometimes treated similarly. However, content analysis often involves quantifying the frequency of specific words or expressions, whereas thematic analysis focuses on identifying and interpreting patterns and themes without emphasizing the number of occurrences (Braun & Clarke, 2006). Thematic analysis uses coding to identify and apply themes to chunks of data. Themes are patterns found in the data that are significant for describing, organizing, or interpreting different aspects of the topic within the data (Säfsten & Gustavsson, 2020).

[2] In Swedish: Lag (2003:778) om skydd mot olyckor, LSO

Thematic analysis was chosen for this thesis because it is particularly advantageous when dealing with extensive written data and focuses on categorizing patterns into more general themes (Säfsten & Gustavsson, 2020). Furthermore, thematic analysis can generate unanticipated insights, which is beneficial for maintaining an open-minded approach to the analysis process. It is also useful for producing qualitative analyses that inform practitioners (Braun & Clarke, 2006).

The first step in the present application of the thematic analysis involved familiarization with the data by making notes of interesting findings. Thereafter, the data underwent a systematic analysis, where codes were assigned to interesting phenomena. These codes were utilized to organize and find sections of text in the material discussing the same thing. Coding was conducted by reading from the interview transcripts and secondary data documents. After the first coding was done, codes that had similarities in patterns and wording were grouped into themes that could answer the research questions. This was an iterative process where the themes were continually checked against the coded extracts and the entire data material to ensure coherence. The themes were derived from the interpretation of underlying meanings rather than from explicit expressions in the text, a concept referred to as latent themes (Erlingsson & Brysiewicz, 2017). To assist the coding process the data was entered into the computer-assisted qualitative data analysis software program NVivo 12. It provides tools for organizing, coding, analyzing, and visualizing qualitative data such as interviews, surveys, focus groups, and documents. However, in qualitative research, the researcher serves as the primary analytical tool. The analysis is not executed by the software, instead it assists the researcher in the analysis process (Leech & Onwuegbuzie, 2011).

In Paper 1, the primary and secondary data were analyzed to identify factors affecting the problem-solving process in emergencies from an FRS perspective. The application of the concept of the possibility space for action proposed by Brehmer (2013) was used to explore what shrinks or expands the possibility space related to complex problem-solving in emergencies. In other words, the data was coded based on finding factors that influence the ability to identify, decide on, and implement action to reduce the space between the current state and the goal state of problems faced by the FRS. The coding was carried out by the first and second authors, while the conclusion/verification phase involved all authors. The coding phase comprised the first author coding the interviews, and the second author coding the incident reports. During the coding process, the second author also coded a few interviews, whereas the first author also coded some of the incident reports and subsequently compared the coding. Throughout this process, the two authors displayed the data according to the conceptual framework in the Paper and regularly discussed the coding to ensure consistency. The conclusions were deliberated among all authors until agreement on the interpretation of the data was reached.

In Paper 2, primary and secondary data were analyzed using the perspective of the problem space, including the identification of the main problem and sub-problems,

and the application of the complexity framework (Bergström et al., 2016). During this coding process, two of the authors coded a small number of interviews independently and then compared their coding to ensure that they were similar. After this comparison, the first author conducted the remaining coding independently, while the analysis involved all authors. To gain a deeper understanding of the selected case study, secondary data was identified and included in NVivo 12 for coding in the same way as the interview material. Also here, the findings of the coding were discussed among the authors until agreement concerning the interpretation of the data was reached.

3.4 Ethical consideration

The thesis followed the ethical principle of CUDOS norms which are a number of ethical principles that researchers should adhere to (Vetenskapsrådet, 2017). CUDOS encompasses the principles of *Communism*, emphasizing shared ownership of outcomes and a commitment to transparency. *Universality* involves the evaluation of research based on universal criteria. *Disinterestedness* underscores the researcher's dedication solely to contributing new knowledge, free from personal gain. *Organized Scepticism* encourages questioning and reviewing and a factual basis before presenting judgments. To summarize, CUDOS is about research being transparent, evaluated objectively, contributing to new knowledge and questioning and assessing on factual grounds.

This research involved humans, and the ethical issues primarily revolved around managing the individuals participating in the interviews. Before the start of data collection, ethical approval was considered. However, as sensitive personal data, such as ethnicity, religious belief or sexual orientation, was not of relevance for this research project, ethical approval was not sought. Other ethical considerations could include, but not be limited to, whether interview subjects could feel uncomfortable when asked to recall difficult situations, or the potential to incite blaming when recalling events. This was avoided by keeping the interviews neutral in terms of never asking questions of responsibility or blame.

The interview study corresponds to EU's General Data Protection Regulation (GDPR), and the Swedish Data Protection Act and individuals who participate in research projects must be able to trust that the researchers handle their personal data in accordance with existing legal frameworks and ethical principles. Therefore, each participant was informed, and signed a consent form before the interview began. The consent form included information about the overall plan for the research, the purpose of the research, the methods used, the person responsible for the research, and that participation was voluntary. The interviewee was in control of continuing the interview and they could choose to end their participation at any time. The

consent form also contained information about how personal information was handled, e.g. the contact information, interview recordings, and anonymized transcripts that were used for analysis were processed to prevent unauthorized access. Transcriptions of recordings were anonymized using codes for participants, and in the research outputs, all data was made unidentifiable with no identifiable information about the participants.

4 Summary of papers

This chapter summarizes the main findings from the individual papers and serves as input for the subsequent discussion in Chapter 5, where the implications, significance, and broader context of the findings will be thoroughly examined and analyzed.

4.1 Paper 1

Improving complex problem-solving in emergency response – a study of the Fire and Rescue Service in Sweden.

Paper 1 aimed to contribute to an increased understanding of what is needed to enhance collective problem-solving in emergencies by analyzing what key factors affect complex problem-solving in large-scale incidents from a Fire and Rescue Service (FRS) perspective. The analysis included two case studies including interviews with 20 respondents from the FRS, an insurance company and volunteers. This was complemented by a document study of 166 incident reports containing information about the type of incident, time, location, response time, utilized resources and methods, as well as details regarding property damage and injuries/deaths. To identify key factors, a conceptual framework based on the concept of complex problem-solving (Fischer et al., 2011) and the "possibility space for action" (Brehmer, 2013), was used. The collected data was coded on what influences the ability to identify, decide on, and implement action to reduce the space between the current state and the goal state of problems faced by the FRS. Codes with similarities in patterns and wording were grouped into themes representing factors affecting the possibility space.

The factors were identified in relation to the complex problem-solving process, where the FRS needs to generate essential knowledge to be able to identify, choose, and evaluate which solutions are possible and necessary in order to reach the goal state. The eight key factors are described in Table 4.

Table 4: Key factors for problem-solving in emergencies

Key factor	Content
Problem identification	The identification of the undesired current state and the desired goal state, i.e. what is the problem.
Incident development	Interpretation of how the incident could develop.
Capability	The quantity of resources in the form of personnel and equipment available to implement different solutions, and the competence of those resources.
Logistics	Coordination of timely and efficient deployment of resources, personnel, and supplies to respond effectively to incidents.
Collaboration	The necessity for the FRS to collaborate to solve problems in emergencies.
Management	The management of the response, such as organizing the response, giving orders, assigning tasks, and coordinating with other actors. Connected to problem-solving, this concerns the possibility for the emergency management to implement solutions.
Time available	Time available to implement solutions.
Legal framework	The legal framework encompasses rules and regulations determining which actions are allowed.

The analysis revealed a "*possibility space for problem-solving*" consisting of the eight factors that are seen to shrink or expand the possible scope for problem-solving in a given situation and at a specific moment in time, see Figure 5. In other words, the figure illustrates that the possibility space for action is not infinitely large and the actionable space to solve the problem depends on how the key factors increase or decrease the possibility space.

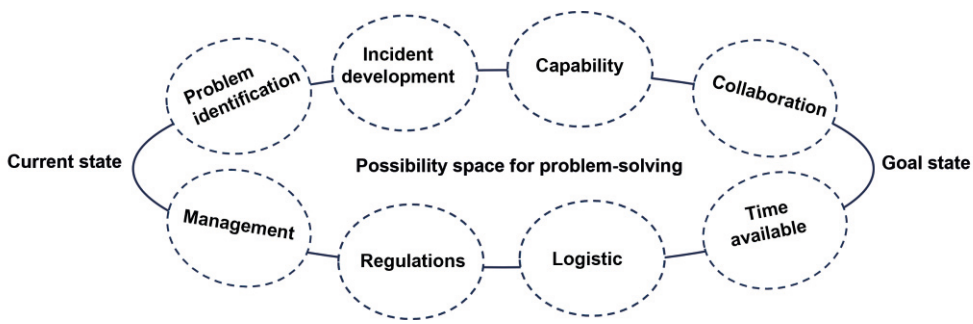

Figure 5: The possibility space for problem-solving illustrates the space within which it is possible to act to solve a problem in emergencies at a specific moment in time. This space is limited by eight key factors, with the dashed line indicating that each factor can either shrink or expand the range of possible actions to resolve the problem (Paper 1).

Problem identification was a crucial factor especially in the early stages of an emergency and challenges in interpreting and understanding the situation often made problem identification less clear. The data analysis showed that when it was

easy to identify the problem, this correlates with an enhanced understanding of possible solutions. In contrast, when the problem identification becomes challenging, this introduces difficulties in determining the required solutions. The data analysis also showed how the emergency management tried to understand how the incident could evolve over time, namely *Incident development.* This factor is closely linked to problem identification but places a greater emphasis on anticipating future developments. The *Capability* factor affects the possibility of finding solutions to the problems because it is only possible to implement solutions connected to available capability (equipment, personnel and knowledge).

Furthermore, equipment delays, such as hoses and breathing air, were critical, highlighting *Logistics* as a key factor. The factor *Collaboration* indicated a reliance on external resources for finding and implementing viable solutions. The factor *Management* expressed difficulties in implementing solutions when the leadership did not function well. The factors *Legal framework* related to rules and regulations that guide and dictate the parameters under which such decisions can be made. Finally, *Time available* affects the range of solutions by necessitating an immediate response, often without the opportunity to select the optimal solution.

Considering the possibility space for problem-solving may assist the FRS in mapping potential solutions based on the identified factors. In other words, the FRS can gather information based on the identified factors and explore which solutions are possible in order to solve the problems at hand.

4.2 Paper 2

Understanding Fire and Rescue Service practices through problems and problem-solving networks: An analysis of a critical incident.

Paper 2 presented a single case study that investigated how the FRS can better prepare for solving complex problems in emergencies by using the concepts of problems and Problem-Solving Networks (PSN). The purpose of a PSN is to solve a particular problem and include components and relationships needed to find solutions to the problem at hand. Primary and secondary data from an extensive fire incident were analyzed, including semi-structured interviews and incident assessment reports. The analysis involved coding problems and sub-problems encountered during emergency response, along with their corresponding PSN. To identify sub-problems and corresponding PSNs during the analysis phase, a conceptual framework based on the concept of problem space and complexity theory was used. Consequently, the scope was defined in terms of what sub-problems the FRS encountered, and the analytic boundaries were drawn around what components and relationships were involved in solving those sub-problems

(defined as dimension in the complexity framework), and the corresponding level of detail (defined as resolution in the complexity framework).

In this case, the current state of the main problem is represented as a burning building and residents in danger, while the goal state was the safety of the residents as well as extinguishing the fire. However, beyond the main problem, the data revealed how the FRS is handling a complex system of problems by breaking down the main problem into different sub-problems, such as evacuating residents in danger, locating the fire in the building, personnel management, safety issues, information to other stakeholders, handling documentation, building stability, and taking care of residents after the evacuation. In Paper 2, the two sub-problems of evacuation of residents and locating the fire were further analyzed regarding how PSN were formed around these sub-problems.

Connected to the complexity framework, these sub-problems make up the scope of the two analytic interpretations, where the scope of locating the fire is summarized here. Figure 6 illustrates how the PSN was created to locate the fire within a larger building. The dimension consists of artifacts and humans connected by relationships of information flow. The resolution was on both single and group levels.

The problem of locating the fire was centered around the Incident Command, which was responsible for establishing relationships of information flow between different actors and artifacts such as a floorplan drawing, smoke from the building, fire teams, residents, building owner etc. In the figure, the upper part shows how actors and the floorplan drawing provide insights into the building layout. The lower part in the figure shows how visual observation of smoke created different sub-networks, each of which evaluated the presumed location of the fire.

The analysis shows that the FRS practice in this case could be understood as breaking down complex problems into manageable sub-problems, which facilitate the identification of components and relationships needed within the PSN. Components include people, organizations and artifacts. The findings further highlight the importance of relationships in PSN to address complex problems during emergencies. For instance, the Incident command function needed different types of information to understand where the fire was located, leading to the creation of the PSN for the purpose of gathering information. Consequently, establishing relationships of information flow between different components guided the FRS to solve the problem of locating the fire.

Figure 6: Problem-solving network created to find the location of a fire. Red color symbolizes actors and/or artifacts connected to the FRS (Paper 2).

5 Discussion

This chapter presents a discussion of the research questions at the basis of this thesis and the overarching aim of the work.

5.1 Addressing the research questions

Research question 1: What key factors affect complex problem-solving in emergencies?

The key factors for complex problem-solving in the FRS were addressed in both papers. Paper 1 nominally identifies key factors and Paper 2 exemplifies how a selection of these factors affects PSN in conjunction with a specific incident. The eight key factors are: *Problem identification, Incident development, Capability, Logistics, Collaboration, Management, Time available* and*, Legal framework*. A thorough analysis of the factors' validity can be found in Paper 1. However, how the factors were also exposed in Paper 2 is discussed below.

First, Paper 2 strengthens the evidence for how the factor *Collaboration* affects complex problem-solving in emergencies, by showing how PSN are formed to solve problems in emergencies. The analysis included components and relationships that contribute to solving different problems. In particular, both papers highlight the importance of collaboration, as it enables the integration of diverse perspectives, skills, and knowledge among emergency actors. Therefore, this thesis relates to well-known literature in the emergency management field on collaboration (see e.g. Ford & Schmidt, 2000; Nohrstedt, 2016; Waugh Jr & Streib, 2006). However, this thesis also connects to important problem-solving literature that emphasizes the importance of multiple perspectives when solving complex problems (Baer et al., 2013; Lyles & Mitroff, 1980; Rittel & Webber, 1973).

Paper 1 emphasizes that *Capability* encompasses equipment and personnel, including their knowledge. This differs from previous research by Brehmer (2013) who primarily mentions resources and their status. In other words, PSNs developed to solve emergencies are seen to involve both humans (and their knowledge) and artifacts (Paper 2). This finding indicates that not only the quantity or status of resources should be considered, but also their capability, such as knowledge. In

addition, artifacts (e.g., equipment) are also important when examining factors influencing complex problem-solving.

Paper 2 also highlights that PSNs could be developed by the need for establishing information flow for effective problem-solving (see Figure 6). This is related to the factor *Management*, as highlighted in Paper 1, where it is noted that, in emergencies, communication tends to become more complex (Paturas et al., 2016).

The key factors are characterized by their significant influence or importance in the problem-solving process and they were identified in relation to the complex problem-solving process as described in Chapter 4.1. However, complex problems are characterized by non-linear interactions, openness to the surrounding environment, continuously varying requirements to comprehend the system as a whole and consideration of the interdependencies between different problems (Mitroff & Linstone, 1992; Reitman, 1964; Rittel & Webber, 1973; Simon, 1973). For this reason, it should be noted that there are no clear-cut boundaries between the factors, i.e., they are often intertwined. Also, the suggested factors depend on the level of detail and how various phenomena are grouped under each factor.

This thesis contributes to the development of theories and practical applications. It provides practitioners with a set of identified factors that offer valuable insights into the requirements for effectively solving complex problems in emergency situations. Theoretically, this thesis has contributed to supporting and extending Brehmer's concept of possibility space to the context of complex problem-solving for FRS.

Research question 2: How does collaboration in the form of networks affect complex problem-solving in emergencies?

The point of departure to answer this research question was to explore how problems and sub-problems can be used as a means to understand collaboration in the form of PSN, and how such networks are established and developed in emergencies. The importance of collaboration is highlighted in Paper 1 and exemplified in Paper 2 by showing that the rationale behind PSN in emergencies seemingly lies in the relationships that contribute to solving the sub-problems. These findings contribute to a deeper understanding of how these networks influence complex problem-solving in emergencies.

To understand the rationale behind PSN the study first recognized that problems arising in an emergency are often considered complex (Mitroff & Linstone, 1992; Reitman, 1964; Rittel & Webber, 1973; Simon, 1973) which are difficult to define and thereby identify suitable solutions. However, the FRS is seemingly dealing with complex problems by breaking down the main problem into sub-problems as a way to match the situation to previous experience (Klein, 2008) and therefore more easily identify which action to take. Action in this context can be interpreted as the FRS searching for which capability (or components in the network) are needed to solve the problem and a PSN is formed based on the type of relationships needed to

solve the problem. For instance, in Paper 2, PSNs were formed around the need to create relationships of information flow to be able to solve, e.g. the sub-problems of locating the fire.

This is consistent with previous studies where it is argued that it is possible to divide complex problems into more manageable sub-problems (Head & Alford, 2015) and manage the sub-problems through sub-networks that operate within the larger response network (Bodin & Nohrstedt, 2016; Kapucu, Arslan, & Demiroz, 2010; Moynihan, 2009). However, by forming PSN around sub-problems, the findings in Paper 2 also illustrate the risk of losing the overall holistic understanding of the situation when breaking down a problem into sub-problems. For example, in the case of locating the fire, the FRS encountered difficulties in comprehending the full situation when fragmenting the fire location problem into several sub-problems. This is consistent with Cilliers (2005) work which recognized that a complex understanding cannot be achieved by only focusing on individual problems. However, breaking the main problem into sub-problems is viewed as a first step in dealing with complex problems.

Furthermore, previous research defines PSN as a set of inter-organizational relationships that are shaped by an imminent problem that requires immediate attention and response (Milward & Provan, 2006). The findings in Paper 2 indicate that the rationale behind PSN are not found in the main problem itself, nor the sub-problems per se, but rather in the relationships that contribute to the process of using actions to reduce or eliminate the difference between the current state and goal state of the problems. It is not only inter-organizational relationships that explain why PSN are established and developed; rather all components and relationships, that affect the process of finding a solution to the sub-problem, should be included. Components should therefore not only include organizations and humans within organizations, but also different artifacts relevant for reducing the difference between the current state and the goal state.

Insights into how PSN are established and developed contribute to a deeper understanding of how these networks influence complex problem-solving in emergencies. This understanding enables the FRS to identify the key components for collaboration in the problem-solving process (Hu et al., 2022). By identifying relationships and components needed to solve problems in emergencies before they occur, the FRS can plan and train for important components of problem-solving to be used during further emergencies (Moynihan, 2009). Such insights can help the FRS to better prepare for complex problems by understanding what kind of sub-problems could be encountered and which network could or should be mobilized.

Theoretically, this research has contributed to the literature on PSN, as exemplified in Milward and Provan (2006), by showing that the definition of a PSN should be extended and not only consist of inter-organizational relationships. Furthermore,

this research has contributed to more knowledge of what lies in the relationships within a network, an area identified as crucial by Hu et al. (2022).

5.2 Addressing the research aim

The research aim is to contribute to an increased understanding of how the Fire and Rescue Service can enhance its capability for solving complex problems in emergencies.

To be able to address the research aim, a closer examination of the process of complex problem-solving is needed. As described in the conceptual framework, the process of complex problem-solving can be divided into two phases, *knowledge gathering* and *goal-oriented knowledge application*, between which the problem solver iterates. Knowledge gathering is often oriented toward finding information that aligns with previous experiences and recognizable patterns (Klein, 2008). This may prove problematic because these emergencies are few in number and it can therefore be assumed that many FRS lack extensive experience. In light of this challenge, the identified factors in Paper 1 provide an alternative approach to more experience-oriented knowledge gathering. The identified factors, revealed as key factors influencing complex problem-solving, offer the FRS a practical alternative for gaining a comprehensive understanding of complex problems. Using these factors enables practitioners to formulate strategic questions (Mishra et al., 2015), allowing for critical thinking (Albanese & Paturas, 2018), and thereby facilitating more insightful and effective solutions.

Complex problems in emergencies cannot usually be solved solely by the FRS, and Paper 2 confirms that the FRS typically works in PSNs in order to solve complex problems. As the findings from Paper 2 indicate, FRS typically deals with complex problems by breaking down the main problem into sub-problems to more easily identify which key components are needed for collaboration in the problem-solving process. The factors outlined in Paper 1 could be associated with general sub-problems that must be addressed to solve the main problem. Consequently, the FRS can utilize these factors to identify which components in the network are essential to establish relationships with for effective problem-solving. However, as highlighted in Paper 2, breaking down the main problem into sub-problems carries the risk of losing the overall understanding of the situation. Therefore, being mindful of considering all the factors can help mitigate this risk.

To exemplify, consider a scenario involving a building fire as illustrated in Figure 7. The factor *Problem identification* can be interpreted as the need to establish relationships with components crucial for identifying the problem. For instance, the building owner could describe the building layout and thereby facilitate the work of locating the fire and the understanding of how the fire can spread (associated with

the factor *Incident development*). Furthermore, the factor *Logistics* can be viewed as the necessity to form relationships with components indispensable for the transportation of materials, such as personnel providing breathing apparatus to the firefighting personnel. The factor *Time available* can be viewed as identifying components that may enhance the efficiency of reaching the building fire promptly, such as determining the optimal routes for travel. *Management* could be exemplified with components such as radio equipment for effective communications or personnel providing managerial support. Additionally, *Legal framework* could be exemplified by what components in form of equipment are needed to fulfill regulations (e.g. protective clothing and water if internal extinguishment is needed). The example illustrates that components within the various sub-networks may be associated with multiple factors (e.g. the building owner could also be linked to collaboration and equipment could also be connected to capability). Thus, the factors should not be regarded as something that the main problem must always be divided into; instead, this can serve as a conceptual tool to facilitate the identification of crucial problem-solving components and how they can be integrated into the broader response network.

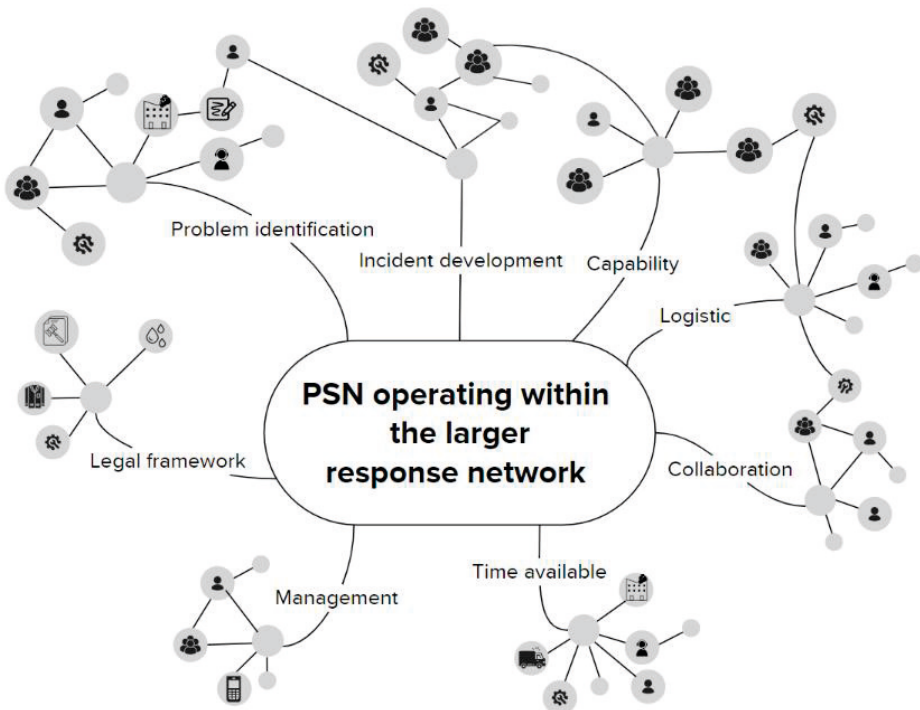

Figure 7: An example of sub-networks working within the larger response network

To summarize, Figure 7 illustrates how a PSN can be developed through sub-networks consisting of relationships related to the key factors, where the sub-networks are connected with the overall PSN operating within the larger response network. This approach enables the FRS to break down the main complex problems into necessary sub-problems (or factors in this case) as a first step to understand the main problem (Head & Alford, 2015). However, by understanding the importance of including all the factors to achieve a more holistic understanding of the situation, the risk of missing crucial aspects of the problem can be reduced. Therefore, the FRS can enhance its capability for solving complex problems in emergencies by leveraging an understanding of the factors and the importance of PSN.

5.3 Reflections on complex problem-solving

Problem-solving is traditionally approached through a linear phase model (Lipshitz & Bar-Ilan, 1996), identifying a logical sequence of steps to be followed in order to achieve a successful outcome. While employing such steps could have been a method to study how FRS tackles complex problems, the nature of complex problems, characterized by many highly interrelated elements, challenges the validity of linear logic in real-world settings (Klein, 1993, 1998). This argument underscores the importance of studying the complex problem-solving process as a holistic entity. Furthermore, complex problem-solving is embedded in various interconnected theories, including human problem-solving, expertise, decision-making, and intelligence (Fischer et al., 2011). Rather than conflicting with these theories, complex problem-solving is viewed as a more inclusive concept involving these theories.

Complex problem-solving, grounded in complexity theory (Cilliers, 2005), requires constructing multiple interpretations, acknowledging that additional interpretations will always be possible. The findings in this thesis are valid only within the specific temporal and spatial limitations studied, and additional interpretations could consistently emerge, contributing to further development of the findings. Furthermore, the dynamic nature of emergencies (Van de Walle et al., 2016) and the complex system of problems make it difficult to predict outcomes (Ackoff, 1979). The findings should thus be considered as a framework that facilitates deeper comprehension and invites future interpretation, also adding to the understanding.

Finally, complex problem-solving requires a diversity of perspectives, skills, and knowledge and, therefore, supports the need for different emergency actors to come together and work towards a common goal (Ford & Schmidt, 2000; Nohrstedt, 2016; Waugh Jr & Streib, 2006). Various theories attempt to explain how actors respond collectively to problems in emergency situations. This thesis specifically focuses on the theory of networks formed to address immediate response problems (Milward

& Provan, 2006), and extending its application to general systems theory (Skyttner, 1996). While exploring collaborations linked to other theoretical concepts like teamwork or social networks could have broadened the insights, the chosen approach allows for a more comprehensive examination of collaboration. By aligning networks with general systems theory, the study encompasses all components and relationships necessary for solving complex problems, facilitating a better understanding of system complexity.

5.4 Reflection on research methods

The findings in this thesis depend on interviews and incident reports, both offering post-event perspectives. This retrospective nature may introduce biases due to individuals possibly recalling events differently in retrospect (Säfsten & Gustavsson, 2020). Additionally, contextual details or real-time dynamics may be overlooked, impacting the accuracy of identified factors. Nonetheless, employing multiple sources and diverse perspectives, known as triangulation (Yin, 2018), in data collection and analysis has strengthened the findings and mitigated biases. Also, employing the interactive research method involving both researchers and practitioners has enhanced familiarity in the topic, enabling a more thorough exploration and interpretation of findings.

The selection of cases naturally influences the findings; however, as these cases represent the most prevalent types of large-scale incidents handled by the FRS, they afforded the opportunity to collect substantial data regarding complex problem-solving processes. These large-scale incidents and their perceived challenging and complex nature provided an opportunity to generalize the data to other incidents related to global trends with growing uncertainty of potential risk.

This thesis used an interactive research approach where the formulation of the research questions as well as the interpretation and understanding of findings and effects, has been a collaborative effort involving both the researcher and practitioners. Here, however, a potential drawback is the risk that the research process can lead to unintended biases or skewed results if certain viewpoints dominate the discussion. This drawback was mitigated by ensuring diversity among participants from both practitioners and researchers to include a range of perspectives. Also, during the research process, it was important to maintain the role of the researcher and not become a part of the studied phenomenon (Denscombe, 2017).

The author of this thesis prior understanding enabled a deeper exploration of the phenomenon, yielding richer insights. While the researcher's pre-existing understanding can deepen exploration, it may inadvertently introduce biases or limit

consideration of alternative perspectives which was important to consider during the research process.

6 Conclusion

This thesis has explored how the Fire and Rescue Service (FRS) can enhance its capability to solve complex problems in emergencies. It identified eight factors affecting complex problem-solving and examined how collaboration in networks affects complex problem-solving in actual emergencies. The conclusion is summarized as follows:

- The eight factors are: *Problem identification, Incident development, Capability, Logistics, Collaboration, Management, Time available and, Legal framework*.
- The identified factors can serve as a conceptual tool for the FRS to support the gathering of important problem-related information in an incident necessary to find viable solutions to complex problems.
- The concept of possibility space, first developed by Brehmer (2013), is valid to use within the context of complex problem-solving for FRS.
- The FRS current practice can be understood as breaking down complex problems into manageable sub-problems, which facilitates the identification of components and relationships within the Problem-Solving Network (PSN) needed to solve complex problems.
- The FRS can enhance its readiness for solving complex problems by considering the factors identified in Paper 1 and thereby assisting in identifying essential relationships and components necessary for problem-solving, i.e. identifying essential PSN.
- The definition of PSN should include all relationships and components important for the problem-solving process.

Overall, this thesis has provided valuable insights that can assist the FRS in effectively addressing complex problems during emergencies. It offers a practical alternative for gaining a comprehensive understanding of such challenges, thereby enabling the development of more insightful and effective solutions. Theoretical contributions include enhancing the literature on complex problem-solving and advocating for the use of the analysis frameworks used in this thesis in analyzing FRS responses.

7 Future research

This thesis has focused on understanding the response phase of the so-called emergency cycle (i.e., mitigation, preparedness, response, recovery, and evaluation). Future research can explore how the findings can be used to improve other phases of the emergency cycle as these phases are interconnected. For example, are the factors valid for evaluating response and enhancing learning capabilities?

The thesis focused on a Fire and Rescue Service (FRS) perspective, limiting data collection to FRS personnel. However, given that FRS cannot address emergencies in isolation and relies on collaboration within networks, future research could examine complex problem-solving from the perspectives of different first responders. In future research, the findings could undergo further investigation by collecting data in various empirical settings. Furthermore, experimental settings could, for instance, be employed to test and validate the findings.

Investigating the dynamic nature of key factors can provide important insight into how these factors affect complex problem-solving over time. Such insight can, for example, be useful for understanding which factors might be valuable at what time during an emergency, to further improve the solving of complex problems in this context.

Last, the findings from this thesis are limited to the view of the conceptual framework and future research can contribute to a deeper understanding of complex problem-solving by exploring data from different theoretical angles.

8 References

't Hart, P., & Boin, A. (2001). Between crisis and normalcy: The long shadow of post-crisis politics. *Managing crises: Threats, dilemmas, opportunities*, 28-46.

Ackoff, R. L. (1979). Resurrecting the future of operational research. *Journal of the operational research society*, *30*(3), 189-199. https://doi.org/10.2307/3009290

Albanese, J., & Paturas, J. (2018). The importance of critical thinking skills in disaster management. *Journal of business continuity & emergency planning*, *11*(4), 326-334.

Alvesson, M., & Sandberg, J. (2013). *Constructing research questions: Doing interesting research*. Sage.

Andersson, I., & Uhr, C. (2019). *Vad kan vi göra nu? Möjlighetsrummets avgränsningar och dess potential vid civil-militär samverkan [What can we do now? The boundaries of the oppertunity space and its potential in civil-military cooperation]*. Technical report, Swedish National Defence College, Stockholm, Sweden.

Ansell, C., & Boin, A. (2019). Taming deep uncertainty: The potential of pragmatist principles for understanding and improving strategic crisis management. *Administration & Society*, *51*(7), 1079-1112. https://doi.org/10.1177/0095399717747655

Baer, M., Dirks, K. T., & Nickerson, J. A. (2013). Microfoundations of strategic problem formulation. *Strategic Management Journal*, *34*(2), 197-214. https://doi.org/10.1002/smj.2004

Bergström, J., Uhr, C., & Frykmer, T. (2016). A complexity framework for studying disaster response management. *Journal of Contingencies and Crisis Management*, *24*(3), 124-135. https://doi.org/10.1111/1468-5973.12113

Bodin, Ö., & Nohrstedt, D. (2016). Formation and performance of collaborative disaster management networks: Evidence from a Swedish wildfire response. *Global Environmental Change*, *41*, 183-194. https://doi.org/https://doi.org/10.1016/j.gloenvcha.2016.10.004

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative research in psychology*, *3*(2), 77-101. https://doi.org/10.1191/1478088706qp063oa

Brehmer, B. (2013). *Insatsledning: Ledningsvetenskap hjälper dig peka åt rätt håll [Command and control of missions]* Technical report, Swedish National Defence College, Stockholm, Sweden, Issue. urn:nbn:se:fhs:diva-4448

Brinkmann, S. (2014). Unstructured and semi-structured interviewing. *The Oxford handbook of qualitative research*, *2*, 277-299.

Cilliers, P. (2005). Complexity, deconstruction and relativism. *Theory, culture & society*, *22*(5), 255-267.
Coetzee, C., & Van Niekerk, D. (2012). Tracking the evolution of the disaster management cycle: A general system theory approach. *Jàmbá: Journal of Disaster Risk Studies*, *4*(1), 1-9.
Coppola, D. (2006). *Introduction to international disaster management*. Elsevier.
Denscombe, M. (2017). *EBOOK: The good research guide: For small-scale social research projects*. McGraw-Hill Education (UK).
Duncker, K., & Lees, L. S. (1945). On problem-solving. *Psychological monographs*, *58*(5), i-113. https://doi.org/10.1037/h0093599
EEA. (2023). *Trends and projections in Europe 2023* (EEA Report 07/2023, Issue. https://www.eea.europa.eu/publications/trends-and-projections-in-europe-2023
Erlingsson, C., & Brysiewicz, P. (2017). A hands-on guide to doing content analysis. *African journal of emergency medicine*, *7*(3), 93-99.
FEMA. (2017). *National Incident Management System*. https://www.fema.gov/sites/default/files/2020-07/fema_nims_doctrine-2017.pdf
Fischer, A., Greiff, S., & Funke, J. (2011). The process of solving complex problems. *Journal of Problem Solving*, *4*(1), 19-42. https://ssrn.com/abstract=2097374
Ford, J. K., & Schmidt, A. M. (2000). Emergency response training: strategies for enhancing real-world performance. *Journal of hazardous materials*, *75*(2-3), 195-215. https://doi.org/10.1016/S0304-3894(00)00180-1
Frykmer, T. (2020). " What's the problem?"-Toward a framework for collective problem representation in emergency response management. *Journal of emergency management (Weston, Mass.)*, *18*(6), 511-524. https://doi.org/10.5055/jem.2020.0504
Frykmer, T. (2021). *Improving emergency and disaster response management performance: A problem-solving perspective* Lund University. Lund.
Frykmer, T., Uhr, C., & Tehler, H. (2018). On collective improvisation in crisis management–A scoping study analysis. *Safety science*, *110*, 100-109. https://doi.org/https://doi.org/10.1016/j.ssci.2018.02.028
Gustavsson, B. (2000). Kunskapsfilosofi [The philosophy of knowledge]. *Stockholm: Wahlström & Widstrand*.
Gustavsson, J., Carlsson, G., & McNamee, M. S. (2021). Barriers and facilitators for implementation of individualized fire safety (IFS) in Sweden. *Fire technology*, *57*(5), 2707-2736. https://doi.org/10.1007/s10694-021-01138-6
Head, B. W., & Alford, J. (2015). Wicked problems: Implications for public policy and management. *Administration & Society*, *47*(6), 711-739. https://doi.org/10.1177/0095399713481601
Heinonen, K., & Strandvik, T. (2022). applying pragmatism to stimulate service research and practice–a European perspective. *Journal of Services Marketing*, *36*(4), 467-475. https://doi.org/10.1108/JSM-06-2021-0211
Hennink, M., & Kaiser, B. N. (2022). Sample sizes for saturation in qualitative research: A systematic review of empirical tests. *Social science & medicine*, *292*, 114523. https://doi.org/10.1016/j.socscimed.2021.114523

Herr, K., & Anderson, G. L. (2014). *The action research dissertation: A guide for students and faculty*. Sage publications.
Hu, Q., & Kapucu, N. (2016). Information communication technology utilization for effective emergency management networks. *Public Management Review*, *18*(3), 323-348. https://doi.org/10.1080/14719037.2014.969762
Hu, Q., Yeo, J., & Kapucu, N. (2022). A systematic review of empirical emergency management network research: formation and development, properties, and performance. *The American Review of Public Administration*, *52*(4), 280-297. https://doi.org/10.1177/02750740221077348
Idh, I. (2021). *Insatsutvärdering- Skogs-markbranden i Finsjö 2021-06-18, värdering av räddningstjänstens agerande under första timmen av insatsen [Incident evauation of Finsjö fire]*. https://rib.msb.se/Filer/pdf/30351.pdf
IFRC. (2020). *World Disaster Report 2020*. https://media.ifrc.org/ifrc/world-disaster-report-2020
Ivarsson, K. (29 december 2021). In *Explosionen på Övre husargatan*. Svergies Radio https://sverigesradio.se/artikel/ny-podd-om-explosionen-pa-ovre-husargatan
Jordan, J. (2017). Political and social trends in the future of global security. A meta-study on official perspectives in Europe and North America. *European Journal of Futures Research*, *5*(1), 1-11.
Jouanne, E., Charron, C., Chauvin, C., & Morel, G. (2017). Correlates of team effectiveness: An exploratory study of firefighter's operations during emergency situations. *Applied ergonomics*, *61*, 69-77.
Kahneman, D. (2011). *Thinking, Fast and Slow*. Farrar, Strauss and Giroux.
Kahneman, D., Sibony, O., & Sunstein, C. R. (2021). *Noise*. Harper Collins Publishers.
Kahneman, D., & Tversky, A. (1979). Prospect theory: An analysis of decision under risk. *Econometrica*, *47*(2), 363-391. https://doi.org/10.1142/9789814417358_0006
Kapucu, N., Arslan, T., & Collins, M. L. (2010). Examining intergovernmental and interorganizational response to catastrophic disasters: Toward a network-centered approach. *Administration & Society*, *42*(2), 222-247.
Kapucu, N., Arslan, T., & Demiroz, F. (2010). Collaborative emergency management and national emergency management network. *Disaster prevention and management: An international journal*. https://doi.org/10.1108/09653561011070376
Kapucu, N., & Garayev, V. (2016). Structure and network performance: Horizontal and vertical networks in emergency management. *Administration & Society*, *48*(8), 931-961. https://doi.org/10.1177/0095399714541270
Kauffman, S. A. (1993). *The origins of order: Self-organization and selection in evolution*. Oxford University Press, USA.
Klein, G. (2008). Naturalistic decision making. *Human factors*, *50*(3), 456-460. https://doi.org/10.1518/001872008X288385
Klein, G. A. (1993). A recognition-primed decision (RPD) model of rapid decision making. *Decision making in action: Models and methods*, *5*(4), 138-147.
Klein, G. A. (1998). *Sources of power: How people make decisions*. MIT press.
Kvale, S., & Brinkmann, S. (2009). *Interviews: Learning the craft of qualitative research interviewing*. sage.

Lagadec, P. (2007). Crisis Management in the Twenty-First Century: "Unthinkable" Events in "Inconceivable" Contexts. In H. Rodríguez, E. L. Quarantelli, & R. R. Dynes (Eds.), *Handbook of Disaster Research* (pp. 489-507). https://doi.org/10.1007/978-0-387-32353-4_30

Leech, N. L., & Onwuegbuzie, A. J. (2011). Beyond constant comparison qualitative data analysis: Using NVivo. *School psychology quarterly*, *26*(1), 70.

Lipshitz, R., & Bar-Ilan, O. (1996). How problems are solved: Reconsidering the phase theorem. *Organizational Behavior and Human Decision Processes*, *65*(1), 48-60.

Lyles, M. A., & Mitroff, I. I. (1980). Organizational problem formulation: An empirical study. *Administrative Science Quarterly*, 102-119. https://doi.org/https://doi.org/10.2307/2392229

Malterud, K., Siersma, V. D., & Guassora, A. D. (2016). Sample size in qualitative interview studies: guided by information power. *Qualitative health research*, *26*(13), 1753-1760. https://doi.org/10.1177/1049732315617444

Markert, F., Holmvaag, O. A., & Johansson, N. (2023). Risk Landscape of Today: Mapping the present recognized risk in Denmark, Norway, and Sweden.

Mayer, R. E. (1992). *Thinking, problem solving, cognition*. WH Freeman/Times Books/Henry Holt & Co.

Milward, H. B., & Provan, K. G. (2006). *A manager's guide to choosing and using collaborative networks* (Vol. 8). IBM Center for the Business of Government Washington, DC.

Mishra, J., Allen, D., & Pearman, A. (2015). Information seeking, use, and decision making. *Journal of the association for information science and technology*, *66*(4), 662-673. https://doi.org/10.1002/asi.23204

Mitroff, I., & Linstone, H. (1992). *The Unbounded Mind*. Oxford University Press.

Moser, A., & Korstjens, I. (2018). Series: Practical guidance to qualitative research. Part 3: Sampling, data collection and analysis. *European journal of general practice*, *24*(1), 9-18.

Moynihan, D. P. (2009). The network governance of crisis response: Case studies of incident command systems. *Journal of Public Administration Research and Theory*, *19*(4), 895-915. https://doi.org/10.1093/jopart/mun033

MSB. (2022a). *Explosin-Brand Göteborg* [movie]. https://90sekunderplay.msb.se/#

MSB. (2022b). *Olycksutredning - Explosion och brand i flerbostadshus Göteborg, 28 september 2021 [Incident investigation - Explosion and fire in apartment building]* (MSB1931- 978-91-7927-246-3). https://rib.msb.se/filer/pdf/29921.pdf

Neal, D. M. (1997). Reconsidering the phases of disaster. *International Journal of Mass Emergencies & Disasters*, *15*(2), 239-264. https://doi.org/10.1177/028072709701500202

Newell, A., & Simon, H. A. (1972). *Human problem solving* (Vol. 104). Prentice-hall Englewood Cliffs, NJ.

Nohrstedt, D. (2016). Explaining mobilization and performance of collaborations in routine emergency management. *Administration & Society*, *48*(2), 135-162. https://doi.org/10.1177/0095399712473983

Paturas, J. L., Smith, S. R., Albanese, J., & Waite, G. (2016). Inter-organisational response to disasters. *Journal of business continuity & emergency planning*, *9*(4), 346-358.

Power, N. (2018). Extreme teams: Toward a greater understanding of multiagency teamwork during major emergencies and disasters. *American Psychologist*, *73*(4), 478.

Provan, K. G., & Kenis, P. (2008). Modes of network governance: Structure, management, and effectiveness. *Journal of Public Administration Research and Theory*, *18*(2), 229-252. https://doi.org/10.1093/jopart/mum015

Quarantelli, E. L. (1988). Disaster Crisis Management: A Summary of Research Findings. *Journal of Management Studies (Wiley-Blackwell)*, *25*(4), 373-385. https://doi.org/10.1111/j.1467-6486.1988.tb00043.x

Quarantelli, E. L. (1997). Ten criteria for evaluating the management of community disasters. *Disasters*, *21*(1), 39-56. https://doi.org/10.1111/1467-7717.00043

Quarantelli, E. L., Boin, A., & Lagadec, P. (2018). Studying Future Disasters and Crises: A Heuristic Approach. In *Handbooks of Sociology and Social Research.* (pp. 61-83). Springer International Publishing. https://doi.org/10.1007/978-3-319-63254-4_4

Quarantelli, E. L., Lagadec, P., & Boin, A. (2007). A Heuristic Approach to Future Disasters and Crises: New, Old, and In-Between Types. In *Handbooks of Sociology and Social Research.* (pp. 16-41). Springer New York. https://doi.org/10.1007/978-0-387-32353-4_2

Rasmussen, J. (1997). Risk management in a dynamic society: a modelling problem. *Safety science*, *27*(2-3), 183-213.

Reitman, W. R. (1964). Heuristic decision procedures, open constraints, and the structure of ill-defined problems. *Human judgments and optimality*, *282*, 283-315.

Rittel, H. W., & Webber, M. M. (1973). Dilemmas in a general theory of planning. *Policy sciences*, *4*(2), 155-169.

RSG. (2022). *Olycksutredning: Brand och explosion i byggnad, flerfamiljshus Övre Husargatan, Göteborg 2021-09-28 [Incident investigation: Fire and explosion in building, apartment building]*. https://www.rsgbg.se/globalassets/dokument/om-oss/olycksutredning-2022-02-23.pdf

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

SFS 2003:778. *Skydd Mot Olyckor [Swedish Civil Protection Act]*. Sweden Retrieved from https://www.riksdagen.se/sv/dokument-och-lagar/dokument/svensk-forfattningssamling/lag-2003778-om-skydd-mot-olyckor_sfs-2003-778/

Simon, H. A. (1973). The structure of ill structured problems. *Artificial intelligence*, *4*(3-4), 181-201. https://doi.org/10.1016/0004-3702(73)90011-8

Simon, H. A. (1996). *The sciences of the artificial, (third edition)* (Vol. 33). MIT Press. https://doi.org/10.1016/S0898-1221(97)82941-0

Skyttner, L. (1996). General systems theory: origin and hallmarks. *Kybernetes*, *25*(6), 16-22.

Smith, G. F. (1992). Towards a theory of managerial problem solving. *Decision Support Systems*, *8*(1), 29-40. https://doi.org/10.1016/0167-9236(92)90035-N

Sparf, J., & Petridou, E. (2018). Collaborations in routine emergency management: Lessons from Sweden. *Procedia engineering*, *212*, 302-308. https://doi.org/10.1016/j.proeng.2018.01.039

Spencer, L., Ritchie, J., Lewis, J., & Dillon, L. (2003). *Quality in Qualitative Evaluation: A framework for assessing research evidence* 07715 04465 8).

Svensson, L., Ellström, P.-E., & Brulin, G. (2007). Introduction–on interactive research. *International journal of action research*, *3*(3), 233-249.

Säfsten, K., & Gustavsson, M. (2020). Research methodology: for engineers and other problem-solvers. In: Studentlitteratur AB.

Van de Walle, B., Brugghemans, B., & Comes, T. (2016). Improving situation awareness in crisis response teams: An experimental analysis of enriched information and centralized coordination. *International Journal of Human-Computer Studies*, *95*, 66-79.

Vetenskapsrådet, S. (2017). Good research practice. *Stockholm: Swedish Research Council*.

Waugh Jr, W. L., & Streib, G. (2006). Collaboration and leadership for effective emergency management. *Public administration review*, *66*, 131-140. https://doi.org/10.1111/j.1540-6210.2006.00673.x

WEF. (2024). *Global Risks Report 2024*. https://www.weforum.org/publications/global-risks-report-2024/in-full/?utm_source=google&utm_medium=ppc&utm_campaign=globalrisks&gad_source=1&gclid=CjwKCAiAxaCvBhBaEiwAvsLmWCElPHXQQpBdIlaSttww3_lB7Wc1Qjbc0AbVJIz4OLVqA1w4-L4AaxoC03QQAvD_BwE

Yin, R. K. (2018). *Case study research and applications* (Vol. 6). Sage Thousand Oaks, CA.

Zahariadis, N., Herweg, N., Zohlnhöfer, R., & Petridou, E. (2023). *A Modern Guide to the Multiple Streams Framework*. Edward Elgar Publishing.

Zappa, P., & Lomi, A. (2015). The Analysis of Multilevel Networks in Organizations: Models and Empirical Tests [Article]. *Organizational Research Methods*, *18*(3), 542-569-569. https://doi.org/10.1177/1094428115579225

Zappa, P., & Lomi, A. (2016). Knowledge Sharing in Organizations: A Multilevel Network Analysis. In *Multilevel Network Analysis for Social Scientists* (pp. 333-353). Springer International. https://doi.org/10.1007/978-3-319-24520-1_14