FIRE21 – FINAL REPORT

Nordic Fire and Rescue Services, Problem-solving in the 21st Century

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Abstract

The FIRE21 Final Report examines problem-solving networks within Nordic Fire and Rescue Services (FRS) in Sweden, Norway, and Denmark, addressing challenges posed by climate change, technological advancements, and evolving risk landscapes. Through case studies, risk assessments, and theoretical analyses, the project identifies key organizational and individual qualities required for effective emergency response. Findings highlight the need for stronger cross-border collaboration, enhanced digital tools, and improved training in decision-making under uncertainty. By leveraging Nordic cooperation, FIRE21 provides recommendations to modernize problem-solving networks, ensuring more resilient and adaptive emergency response systems across the region.

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Preface

This report is the final report of the FIRE21 project – Nordic Fire and Rescue Services in the Twenty First Century. The project is a collaboration between Norway, Sweden and Denmark, funded by NORDFORSK.

The project is comprised of five work packages (WP): WP1 – Project management; WP2 Benchmarking network-based decision making in the FRS; WP3 Description of risk landscape – today and in the future; WP4 Problem-solving networks of tomorrow; WP5 Dissemination.

Special thanks are given to members of MSB Swedish Civil Contingencies Agency (Sweden), DSB Directorate for Civil Protection and Emergency (Norway) and DEMA Danish Emergency Management Agency (Denmark) who have participated in workshops throughout the project and freely provided much needed and appreciated input.

In addition to the authors of this final report, the following researchers are acknowledged for their participation in the research: Dr Christian Uhr, Dr Stian Antonsen, Dr Lars Schiøtt Sørensen, Ole Anders Holmvaag, Spilios Iliopoulos, Marius Vigen, Madeleine Varang and Cristina Sanfeliu Melia.

The WP leaders for the project were:

- Chapter 1 and 2: WP1-leader Professor Margaret McNamee (LU, Project leader)
- Chapter 3: WP2-leader Gudveig Gjøsund (NTNU Social Research)
- Chapter 4: WP3-leader Dr Frank Markert (DTU) and WP1-leader
- Chapter 5: WP4-leader and Deputy Project Leader Dr Tove Frykmer (LU)
- Chapter 6: WP5-leader Lotta Vylund (RISE)
- Chapter 7: WP1-leader Professor Margaret McNamee and Deputy PL Dr Tove Frykmer

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Executive Summary

The FIRE21 project investigates problem-solving capabilities within Nordic Fire and Rescue Services (FRS) in Sweden, Norway, and Denmark. Given the increasing complexity of emergency response due to, e.g. technological advancements, demographic shifts, climate change, and geopolitical uncertainty, this project aims to evaluate and enhance the formal and informal problem-solving networks of the FRS and identify recommendations for future FRS qualities.

The key objectives of the project were:

- Understanding the Risk Landscape: Examining current and emerging risks, including climate change and geopolitical threats.
- Assessing Problem-Solving Networks: Investigating formal and informal networks in the emergency management life cycle.
- Developing Future-Oriented Strategies: Creating recommendations to improve collaboration, leadership, and technological integration.
- Identifying key qualities for the FRS of the future.

The project was structured into five Work Packages (WPs): WP1 – Project Management: Oversaw coordination and administration; WP2 – Benchmarking Network-Based Decision-Making: Evaluated existing problem-solving networks in each country; WP3 – Understanding the Risk Landscape: Analyzed current and future risks affecting FRS operations; WP4 – Problem-Solving Networks of Tomorrow: Developed strategies for improving problem-solving in future scenarios; and, WP5 – Dissemination: Shared findings via publications, workshops, and conferences.

Research methods included identification of typical types of response situations for the FRS in each of the participating countries followed by selection of a small number of cases for more detailed study. In total, nine case studies were included covering a diversity of incident types such as urban fires, wildfires, flooding, and industrial accidents, highlighting differences in FRS structures, challenges, and response strategies.

Key findings from the project can be divided into three main areas:

- **Terminological overview**: A glossary of terms for typical incidents with definitions in English and translations into Swedish, Danish and Norwegian was developed.
- **Risk Trends:** Climate change is expected to increase extreme weather events. While geopolitical instability was outside of the scope of the FIRE21 project, it is clear that changes in the geopolitical situation could lead to heighten civil defense challenges.
- **Problem-Solving and Problem-Solving Networks:** Effective collaboration between agencies, municipalities, and emergency services is crucial for emergency management.
- **Competency Development:** Future FRS personnel require enhanced skills in digital tools, leadership, and cross-disciplinary cooperation.

Key findings highlight the increasing complexity of the risk landscape; the fact that effective emergency management relies on well-functioning problem-solving networks, where collaboration between agencies, municipalities, and emergency services plays a crucial role; and, identifies that future emergency responders must develop advanced competencies, including digital literacy, leadership skills, and cross-disciplinary cooperation, to navigate rapidly evolving scenarios. FRS networks are essential but require constant modernization, where expertise must evolve in response to the changing risk landscape. FRS personnel need to exhibit greater adaptability, decision-making under

uncertainty, and digital literacy, including the use of AI and drones. It seems that technology is underutilized, and that advanced data-sharing systems and AI-based decision support could significantly enhance problem-solving efficiency.

To address these challenges, FIRE21 recommends strengthening collaboration between emergency services and municipal organizations, enhancing training programs to cover emerging risks such as battery fires and AI-driven decision-making, and integrating advanced technologies like drones and predictive analytics into operational strategies. Furthermore, the well-being of FRS personnel remains a priority, emphasizing both physical safety and psychological resilience.

Overall, the FIRE21 project underscores the need for adaptive, technology-driven, and collaborative problem-solving networks to meet the demands of modern emergency response. By fostering innovation and strategic cooperation, Nordic Fire and Rescue Services can enhance their effectiveness in protecting lives and communities in the 21st century. By implementing the recommendations highlighted here (and others in the report), the Nordic FRS can become more resilient, ensuring efficient emergency response in an increasingly complex world.

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1 Introduction

1.1 Background

Incident response in a modern society

The renowned disaster researcher Enrico Quarantelli, suggested that emergencies and disasters generate two types of demands: agent-generated and response-generated demands (Quarantelli, 1997). Agent-generated demands come from the hazard itself. This could mean the need to extinguish a fire and deal with its consequences, or the need to pile sandbags to inhibit the progress of a flood. Response generated demands are created from the efforts of organizing a response, typically including needs for communication and coordination. Incident response is all about dealing with these two types of demands, both agent- and response-generated, at the same time. Such efforts represent different parts of the emergency management network, which is activated during response, but largely developed prior to the response phase of emergency management (Berthod, Grothe-Hammer et al., 2017). The efforts to meet both agent- and response-generated needs, harmonizes with the view on external and internal problem-solving, i.e. problem-solving associated with either the incident or the response (Brehmer, 2006). A key managerial challenge during response operations is to handle varying and numerous external and internal problems more or less simultaneously. The capacity to deal with these challenges is connected to relations that have been built up prior to the acute situation (Waugh Jr, 2003; Kapucu, Hu and Khosa, 2017). Such connections have been termed a variety of things but in the context of this project we have chosen to apply the concept of *problem-solving networks*.

Problem-Solving Networks

Research into problem-solving is scattered and there is no single dominant approach for how to grasp the concept. Smith's (1989) definition of a problem as a disharmony between preferences and perceived reality, and Simon's (1996) definition of problem-solving as a search process using actions to reduce or eliminate these differences between preference and reality, have been applied in the context of the research presented here. To support efficient emergency management, our main interest has been not the individual cognitive aspects of problem-solving, but rather how problem-solving processes in connection with incident response, preparedness and recovery are managed in various networks. Indeed, Hung (2013) argues that problems in modern society exceed the cognitive capacity of any individual and call for problem-solving in teams. Similarly, many researchers (Lyles and Mitroff, 1980; Massey and Wallace, 1996; Baer, Dirks and Nickerson, 2013) agree that problem-solving under messy conditions, such as in emergencies, needs input from multiple perspectives in a collective. There are multiple explanations for this interpretation of problems and problem-solving. To begin with, a modern society is inherently interconnected and characterized by interdependencies (Frykmer, Uhr and Tehler, 2018). An incident, such as a wildfire or a breakdown in a major operational technology can cause cascading effects (Lönnermark and Lange, 2017). Cascading effects call for collaboration in multidisciplinary teams in order to solve interconnected problems, both internal and external.

Understanding the problem-solving process relies on identification of connections between stakeholders, and the development of meaning structures which transcend the established institutional problem-solving structure. Without this understanding, we are presently in a position where institutional structures are put in place during non-response phases of emergency management which may not work as expected during the response phases. Previous research on incident response has shown that social relations shape how professional responders connect when collectively dealing with a hazard (Uhr, 2009). The same research shows how trust relations can easily override formal bureaucracies. It is likely that such conditions have been in play as long as we have formally organized our societies; however, we do not know how, or indeed if, the patterns, impacts and vulnerabilities of social relations will influence the ability to collectively solve problems in the same way in future incident management as it does today or whether this will change in response to changing risks and social structures.

Almklov recently investigated the role of social relations between firefighters in the local community and suggested that trust is an important social resource in emergency situations (Almklov, Nilsen and Gjøsund, 2018). Informal decision-making structures include improvised structures that can emerge during an on-going emergency. Andresen's analysis of the Lærdal fire clearly identifies social networks as a critical resource in improvised local crisis management (Andresen, 2017). Indeed, social networks are a resource that is little understood and is used in a reactive rather than proactive manner in most emergency situations. Improving our understanding of problem-solving networks in emergency response has the potential to improve planning and training in such networks in the future.

Our Changing World

The list of Global Trends and associated challenges can be made long; but from the perspective of safety and security, the global trends listed recently by the European Environment Agency (EEA, 2015; 2023) and in a position paper published by the International Association of Fire Safety Science (McNamee, Meacham et al., 2019), are particularly relevant. Climate change, population growth and urbanization are changing the basic foundations of important societal functions such as those provided by the Fire and Rescue Service (FRS), and there is a pressing need for these functions to understand and adapt to these changes in support of societal resilience. In this context, societal resilience is seen as the ability of a social system to respond to and recover from disasters (Cutter, Ahearn et al., 2013).

The United Nations has developed the concept of Disaster Risk Reduction in support of societal resilience (UNDRR, 2022). In an international context, the Sendai Framework for Disaster Risk Reduction provides a starting point of optimization of cooperation on a global scale which should be analyzed to determine its applicability to the Nordic regions (UN, 2015). Solutions to these challenges are typically seen in terms of technical solutions, in particular technologies that reduce the carbon dioxide footprint of various human activities, many of which have direct implications for the FRS in terms of new and rapidly changing risk situations.

The development of sustainable technologies is apparent in all areas of society ranging from renewable energy production, to new energy carriers in the transport sector, and sustainable buildings and infrastructures. Renewable energy is produced by wind power and photovoltaic, storage could include e.g. batteries or/and conversion into hydrogen. Vehicles are fueled by electricity using Li-ion batteries or fuel cell/hydrogen systems. Challenges arise from the use of such vehicles in existing infrastructure not necessarily designed for such loads, e.g. the transport of cryogenic or very high-pressure hydrogen through tunnels. Sustainable changes in infrastructure and building industries result in e.g. increasing use biomaterials and wooden products that are inherently combustible, the desire to minimize energy use in buildings which leads to increased use of insulation which can result in tragic incidents for which firefighter strategies are inadequate (Meacham and McNamee, 2020). Many of these changes have direct implications for problem-solving by the FRS in the face of new technology and a continually changing risk landscape.

Not only does modern society lead to partly new types of problems that need to be solved in the field of the FRS, it also provides the problem solvers active in FRS organizations with new prerequisites and tools for problem-solving in networks. Social media, for example, is a potential game-changer for how different network configurations among problem-solvers will evolve (Dufty, 2011).

1.2 Objectives

Societal change is accelerating through, e.g. rapid population growth and/or significant changes in demographics, technological advances, and increasing inter-connectedness between various established organizations and infrastructures. In the Nordic countries, changes in demographics leading to an aging society can be particularly challenging. Together with climate change and a new global security situation such trends inevitably lead to changes in the overall risk landscape. One of the key stakeholders charged with dealing with such change is the Fire and Rescue Service (FRS). The FRS

are both governed by, and dependent on, formal and informal networks. There is a clear risk that these formal and informal networks are slow to recognize and adjust to a rapidly changing world, which could inhibit the application of new technology or the translation of national and international directives to local implementation, ultimately leading to inefficient handling of crises.

This project has studied existing formal and informal networks in the Nordic context, how they are established and used throughout the whole emergency management life-cycle including prevention, preparedness, response and recovery. Based on scenario analysis, qualitative methods and tools from network theory, this project has then developed strategies to proactively change emergency management networks in support of a future risk landscape.

1.3 Limitations

The focus of FIRE21 has been on the Fire and Rescue Services (FRS) in Sweden, Norway and Denmark. Therefore, not all Nordic countries have been included in the comparisons contained in this report. Further, numerous stakeholders have been included in the deconstruction of cases, but the focus always has been on the FRS.

2 Project management

The project began 1st November 2020. Work package 1 has been on-going for the whole of the project thus far and is expected to continue until the end of the project.

2.1 Management

In the project application, the project management was proposed to consist of an operational level, a strategic level and an administrative level, see Figure 1.

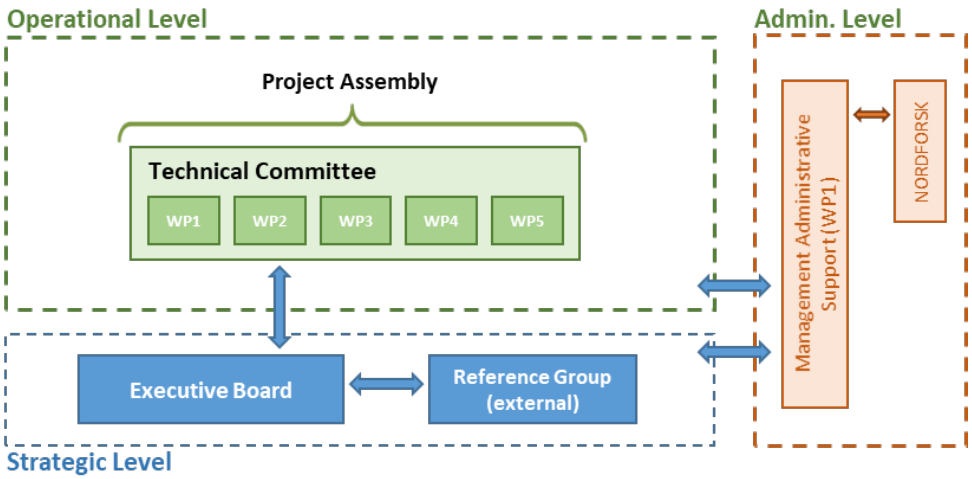

Figure 1: Management structure for FIRE21.

At the outset of the project the various committees were constituted as follows:

- **Project Assembly (PA):** comprised of all partners in the project, including all active members rather than one representative per organisation.
- **Technical Committee (TC)**: comprised of the WP-leaders with the Project Leader as Chair (see list in introduction). In addition, the Project Communicator (Susanne von Hebel) and the Deputy Project Leader (Tove Frykmer) have been co-opted to participate in the TC meetings.
- **Executive Board (EB)**: comprised of the Project Leader and Deputy Project Leader.
- **Management Administrative Support (MAS)**: Loella Ainetoft was assigned MAS.
- **Reference Group (external)**: has been eliminated from the project.

As part of the project contract development with NORDFORSK a Consortium Agreement was signed between all partners to ensure clear definition of project expectations.

A project Teams space was established with the following folders for sharing project documents with all participants:

- Approved Application
- Terminology
- WP1 Project Management
- WP2 Benchmarking Network Based Decision Making in the FRS
- WP3 Description of Risk Landscape Today and in the Future
- WP4 Problem-solving Networks of Tomorrow
- WP5 Dissemination

2.2 Meetings

The project has been divided into a number of different meeting formats to assist development of the research:

- Monthly TC meetings (minuted)
- Quarterly PA meetings (minuted)
- At need EB meetings in preparation for the TC and PA meetings
- Quarterly meetings between the Project Leader and MAS
- WP-meetings defined on an ad hoc basis by the WP-leader based on WP needs (minuted informally)

The project established a Teams space for shared documents. All meeting minutes are stored there for easy access by all project participants.

2.3 Funding

The project was funded by NORDFORSK under the funding scheme *Nordic societal security in light of the emerging global and regional trends,* contract #97830.

3 Terminological foundation

In the project, several workshops were organised to discuss key terminology and contribute to an understanding of how each project member viewed key terms in the project. The purpose of these exercises was to better understand different views of key terminology and contribute to coherent communication and joint research efforts in FIRE21 by reducing misunderstandings deriving from a semantic tangle. The intention was not to "force" all project members to use the same terminology but to create a common foundation for understanding each other.

3.1 Terms denoting type and scale of incidents

First, a workshop around terminology related to types and scales of incidents was conducted at the outset of the project. Here, each project "group" (Lund University fire and risk divisions, RISE in Sweden, NTNU Social Research/NTNU and DTU) were first given the task to collectively hand in answers to the following questions:

- How would you define the following terms in English: disaster, crisis, emergency, catastrophe?
- How would you categorise these according to frequency and consequence?
- In FIRE21, we consider the whole emergency management life cycle, conceptualized as prevention, preparedness, response and recovery (e.g. according to FEMA (Federal Emergency Management Agency in the US) and scholars like Coppola (2015)). Do you see any problems with this conceptual framework?
- How would you translate the terms into your language?
- Which types of incidents should we consider/exclude in FIRE21?
- What does problem-solving and decision-making mean to you, and how do these concepts relate to each other?

The answers were summarised and discussed at a workshop. Overarching, the contributions confirmed what research in the field has demonstrated for many years: taxonomy and terminology are not consistent, and there is no single standard that all involved disciplines/discourses agree on.

When it comes to the English definition of terms, the outcome can be summarised as follows:

Emergency = Unwanted event, requiring immediate action, normally not engaging others than first response organisations. Routine procedures, designed for the system, localized. Sudden event, limited in time.

Disaster = very harmful, social disruption, (major) challenges to societal functions, puts severe stress to society's response, causing great damage or loss of life that exceeds society's ability to cope with own resources, sudden, big discrepancy between various needs and the capacity to take care of them.

Crisis = exceeds the capacity of the responding organization(s) and its normal resources and routines to cope with it, urgent threat to core values or life-sustaining functions, which must be dealt with under conditions of uncertainty. Primarily associated with political decision making. Other actors involved than the normal "first responders" and requires collaboration. A time of intense difficulty or danger. No disaster has materialized just yet, but the prospect is imminent. The threat in question may still be averted.

Catastrophe = large area affected, most everyday functions and institutions interrupted. Puts very severe stress to society's response system, which are often heavily impacted. Normal routines are not/less applicable. Beyond imagination, e.g. "extinction".

It was discussed that how we define these "bad things" depends on the perspective taken: from an FRS perspective, from a community perspective, from an individual perspective, actors involved etc.

In particular, NTNU Social Research suggested that for emergency organisations, a response to crises, catastrophes and disasters are largely similar. The main differences are the effects to society outside it. The terms were roughly categorised according following picture relating to frequency and consequence of events, where the focus of FIRE21 was suggested to be on crises/disasters, see Figure 2.

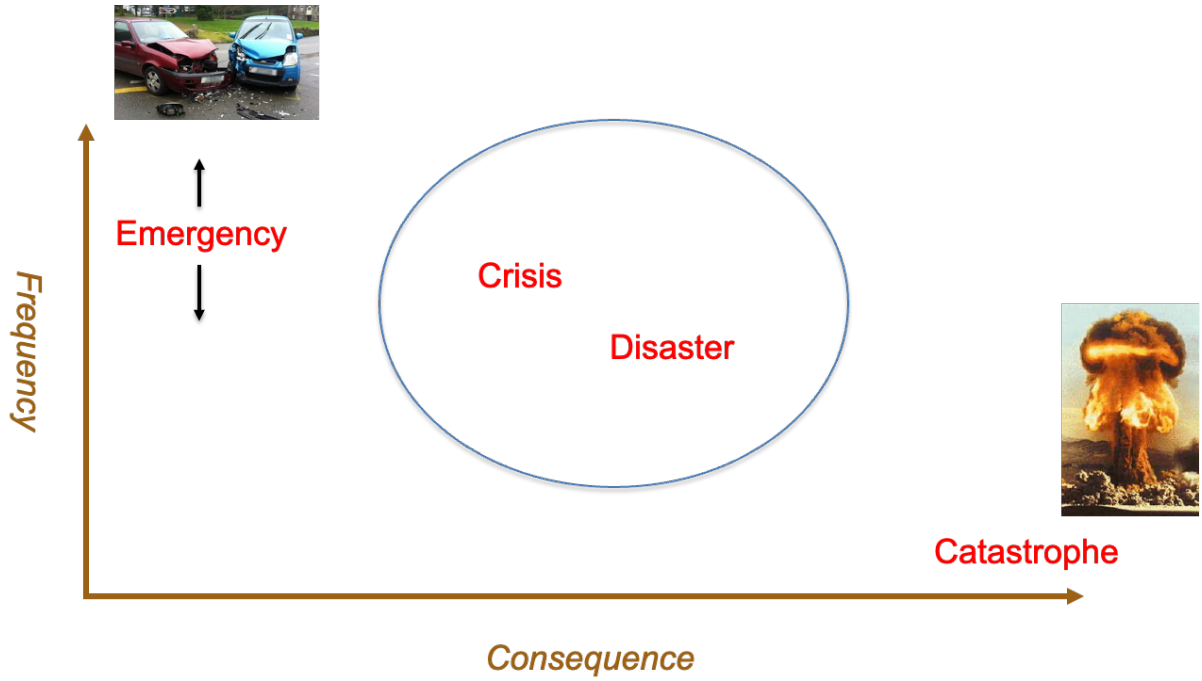

Figure 2: A categorisation of different types of events according to frequency and magnitude. The circle identifies the types of events studied in FIRE21.

The project agreed that the emergency management cycle (dividing it into phases like prevention, preparedness, response and recovery) is a well-established framework that can be useful for FIRE21. However, it was also discussed that handovers between these phases are not necessarily seamless (because of different actors involved) and needs to be considered. In addition, it is a quite simplified approach and does not grasp various perspectives nor the fact that the consecutive nature of the cycle belies the potential for phases to have greater or lesser temporal separation in different situations. For instance, preparedness and response can happen at the same time.

In terms of translation to the project languages, this is summarised below.

Norwegian: Disaster = katastrofe, Svært alvorlig situasjon med tap av liv, natur, verdier i et betydelig omfang; Crisis = krise, Krisesituasjon med potensial for eskalering, krever profesjonell innsats & En hendelse som har potensial til å true viktige verdier og svekke en virksomhets evne til å utføre sine samfunnsfunksjoner; Emergency = unntakstilstand, nødsituasjon, ulykke, Akutt nødsituasjon som krever innsats fra privatpersoner og evt profesjonelle; Catastrophe = katastrofe, Uforutsett katastrofe med potensial for tap av liv, natur, verdier i stort omfang.

Swedish: Disaster = katastrof, kris, extraordinär händelse; Crisis = kris, extraordinär händelse; Emergency = vardagshändelse, olycka, nödsituation; Catastrophe = katastrof.

Danish: Disaster = en pludselig ulykke eller en naturlig katastrofe, der forårsager store skader eller tab af menneskeliv; Crisis = en tid med intense vanskeligheder eller fare; Emergency = en alvorlig, uventet og ofte farlig situation, der kræver øjeblikkelig handling; Catastrophe =en begivenhed, der forårsager store og normalt pludselige skader eller lidelser.

What types of incidents that should be investigated in FIRE21 was also discussed. It was concluded that the focus should be on incidents, now and in the future, where the FRS has a formal key role, incidents that are included in the FRS purview. Not only fires, despite the organisational name in English, but also other types of FRS incidents. Rather, the project should develop/define what is inside and outside of FRS.

FIRE21 should not investigate incidents where the FRS only has a supporting role, or deals with something that is not supposed to be solved by the FRS. The project should not focus on armed conflict, social unrest, pandemics, climate change.

Related to problem-solving/decision-making, following reflections were made:

- Decision-making involves problem-solving, but you take it a bit further and also conclude which way to go.
- Problem-solving might involve multiple decisions.
- Problem-solving is relevant when a problem has arisen, whereas a decision could take place in the planning phase.
- Problem-solving is more «on the fly». Decision making more an analytical process.
- In an emergency operation, problem-solving and decision-making might appear in a circular form in which problem identification and solving lead to a decision that leads to new problem-solving, and so on. There are different phases: Establish the situation, assess the problem, decide on what to do, take action, go back to problem-solving mode.

The terminology exercise and documentation thus constituted a foundation which project members could revert to when needed. It also defined a specific focus on types and magnitudes of events, to guide project ideas and publications.

3.2 The concepts of “common operational picture” and “risk”

A second exercise concerned thematic discussions of how the group viewed the question of “common operational picture” (COP) and “risk”.

Common operational pictures are a central part of the Swedish crisis management system. The Swedish Civil Contingencies Agency considers the creation of a COP a central part of the development of a Common Management System for municipal Fire and Rescue Services (FRS) (Ahlström, Cedergårdh et al., 2022). The theoretical foundation is rather inconsistent, but in general COPs should facilitate situational awareness. They can be viewed as both a product (of operational activities) and a process (evolving over time). As such, COPs can be seen as a collective representation of the problems at hand, and possible solutions to these problems, that can be discussed among responding organizations. Frykmer and Svenbro (2023), argue that a problem-solving perspective (such as that applied in FIRE21) is useful.

There are interesting differences between Sweden, Norway and Denmark that are relevant to consider in the FIRE21 project when comparing case analysis, e.g. in Sweden, COPs are very much determined

based on the operational needs whereas this seems to be much more formalized than in Norway and Denmark. Given these differences, there is a need to define better what we mean if investigating COPs moving forward, since the concept has many connotations and purposes. Ultimately, no formalised investigation of COP was conducted within the project, despite it being discussed further in one of the Norwegian cases (Stavanger), but remains an issue for future research.

As with the discussion of COPs, the concept of risk is very broad. A discussion of "traditional" and "new" views of risk lead to an understanding that risk can potentially be varied in the project. Risk can have different definitions and connotations depending on the perspective taken. We will need to be more specific with the concept of risk when writing about the various case studies, although we do not have to agree on one single definition. In particular, the role of uncertainty and how it can be integrated into traditional definitions of risk (often referred to as probability × consequences), was discussed. Uncertainty can relate do many dimensions of risk: ontological/aleatoric uncertainty, epistemological uncertainty, uncertainty in decision making (affected by politics), and relational uncertainty (complexity in the actor network). We concluded that precision in terminology is important when discussing risk, to avoid misunderstandings or false disagreements. The project, therefore, created a terminological basis for continued discussions of risks in the project as presented in this chapter.

4 Problems, problem-solving and problem-solving networks

Problems, problem-solving and problem-solving networks are naturally a fundamental basis in the project FIRE21. The need to identify solutions to problems as part of an incident response is as obvious as it is challenging. Some of the problems are easy to understand and solve, others are more difficult or cannot even be understood or solved. Some problems occur immediately, while others appear along the way. As a theoretical concept, problem-solving is part of many fields and studied in many different ways. It has played, and still plays, an important role in various fields like mathematics, psychology and computer science. Theories and ideas that develop in such diverse fields are not always in sync and quite often in conflict with each other. Therefore, one of the project deliveries has been to summarise and clarify the theoretical foundation used in the project. The purpose was not to present a comprehensive review on problem-solving research, but rather to describe literature and ideas concerning problems, problem-solving and problem-solving networks that have been relevant to FIRE21. It has also served to contribute to a common understanding of these concepts for FIRE21 project members, an understanding that was used in common deliverables in the project. The thinking presented in this chapter is a summary of a more detailed overview developed by Frykmer (2024b).

When it comes to what a problem is, there is reasonable agreement that this means: "*there is some form of undesirable current state, it is desired to be in another state and there is no direct, obvious way to move from the given to the goal state*" (Mayer, 1992). This resonates well with influential authors in the problem-solving domain, such as Newell and Simon (1972), and represents the view on problems in this document.

The project has looked at different types of problems. One way to classify problems are according to if they are simple, complicated or complex. The latter category refers to problems that are ambiguous, unconstrained and there are no objective solutions to be found, and, in fact, whether there is a problem or not may be highly subjective (Smith, 1992; 't Hart and Boin, 2001), and how to reach the goal might not be easily agreed upon (Klein, 1998). In addition, these types of problems cannot be separated from the environment, i.e., they are difficult to place boundaries around, and they appear to have an infinite number of solutions, where a "good enough" solution often has to make do. Evaluation of implemented solutions is also challenging with these problems, due to the complex surroundings consisting of a multitude of interrelated factors and the issue of not being able to find objective solutions (Rittel and Webber, 1973). Even though the perception of a problem depends on the eye of the beholder, many problems in emergencies and disasters are nevertheless considered wicked, or ill-defined, in the literature (see e.g. Boin, Ekengren and Rhinard (2020); Christensen, Lægreid and Rykkja (2016); Roberts (2001)). Several publications in FIRE21 refer specifically to solving complex problems (Vylund, Frykmer et al., 2024a; Vylund, Jacobson et al., 2024b).

In the project, Newell and Simon's (1972) idea of the *problem space* has been used to represent problem-solving, see Figure 3. The problem is represented through the current state, the goal state, and possible solution steps along the way. The problem solver must, after recognising and understanding the problem, define the problem space and a strategy for getting from the current state to the goal state via relevant solution steps. Problem-solving is thus a method for finding activities that reduce or eliminate the difference between the current state and the goal state (Simon, 1996). In addition to the problem solver's capability to define the problem space and the solution steps, Newell and Simon (1972) describe the importance of analysing the environment in which the problem is located, which also affects the problem space.

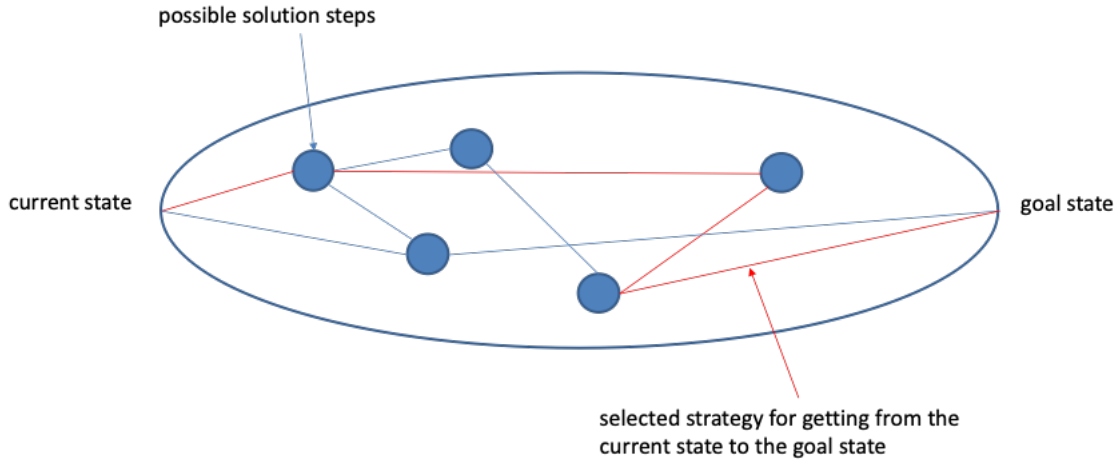

Figure 3: The problem space with the current state, goal state, possible solution steps and the chosen solution strategy. Based on Newell and Simon (1972).

Another way of illustrating problem-solving is through *phase models*, which show a logical sequence of steps to be taken in the problem-solving process and argue that the outcome will be more successful if the steps are followed. Figure 4 illustrates a model that can be used to analyse problem-solving in emergency and disaster response management, which has been used in the project. It is emphasised that the model is used as a tool for reasoning and that it does not necessarily show how problems *should* be solved. The model is not a description of how problem-solving necessarily takes place but shows potential steps and paths in a problem-solving process. In fact, there is still a need for empirical studies investigating the prescriptive validity of the problem-solving process as a whole, although it has been shown that effective problem-solving relies on proper execution of early steps in the process, such as problem representation (Lipshitz and Bar-Ilan, 1996).

The arrows with the dashed lines in Figure 4 point to the possible paths of problem-solving. This illustrates the *iterative* aspects of the problem-solving process, where all steps can be revisited during the process. In this model, the focus is not on the precise details in each step, or which steps are followed, and which are not in a specific problem-solving situation, rather it aims to explain *how* problem-solving can be accomplished, to provide a link to emergency and disaster response management.

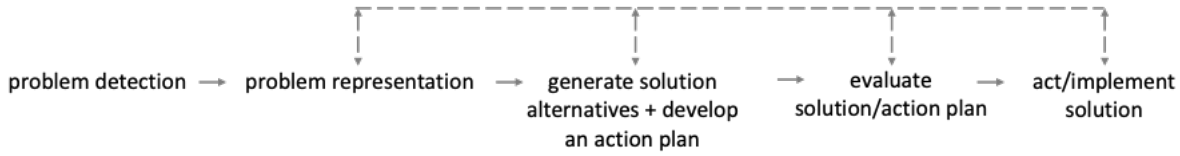

Figure 4: A model of the problem-solving process, with its steps and possible paths.

When it comes to solving complex problems, denoted complex or dynamic problem-solving (Fischer, Greiff and Funke, 2012; Greiff, Wüstenberg and Funke, 2012; Fischer, Greiff and Funke, 2017), this is described as a process divided into two phases, between which the problem solver iterates. The first phase, *knowledge gathering*, contains generating and reducing information, 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. Going through these phases enables the

problem solver to apply analytical reasoning and critical thinking skills, which is imperative for solving complex problems (Albanese and Paturas, 2018). These ideas have been related to the FRS context in (Vylund et al., 2024b).

When it comes to problem-solving networks (PSN) in the FRS, a literature study in the project concluded that not much literature exists. Therefore, publications from FIRE21 constitute a fundamental contribution to the topic. In this final report, we illustrate PSN in the FRS through the publication by Vylund et al. (2024a). The authors connect problems and sub-problems with PSN through combining Newell and Simon's problem space with the framework in Bergström, Uhr and Frykmer (2016). The ideas of main problem and sub-problems, as described in these publications, were then applied to an FRS case of an explosion in a residential building in central Gothenburg, Sweden. This was a complex response operation, and the data shows that the FRS focused on several sub-problems, of which two were selected for a deeper analysis. The two cases: evacuation of residents and identification of the location of the fire, represented the scope in the two analytical interpretations. The results show that the FRS develop PSN by breaking down problems into manageable sub-problems. The PSN developed assisted in solving these sub-problems. Dividing complex problems into sub-problems is a way to match the situation to previous experience and to more easily identify which actions to take. Actions in this context can be interpreted as the FRS searching for which resources (or components in the network) are needed to solve the problem. To exemplify, Figure 5 below illustrates the PSN for the sub-problem of locating the fire.

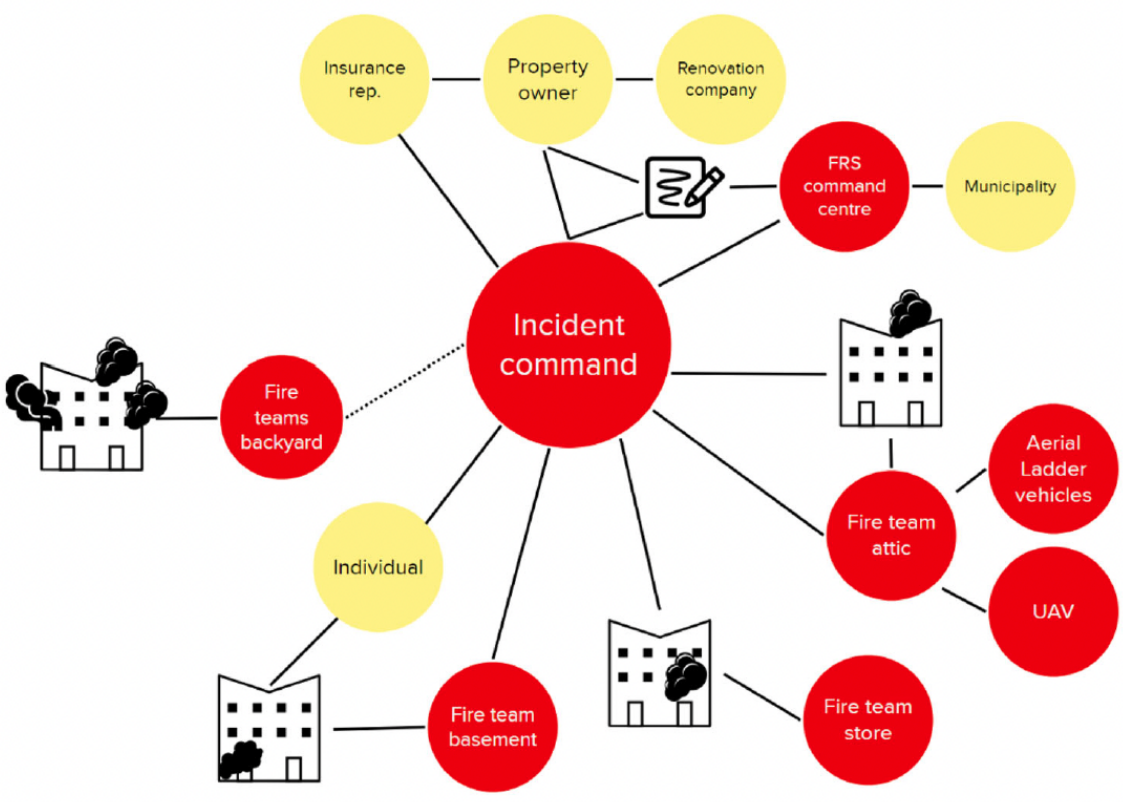

Figure 5: PSN for locating the fire (Vylund et al., 2024a).

Finally, publications in FIRE21 describe how problem-solving in the FRS is affected by a number of factors, which are seen to decrease or increase the so-called *possibility space for problem-solving.* Expanding on the work by Brehmer (2013) and Andersson and Uhr (2019), Vylund et al. (2024b) identified eight factors in the FRS context: how the *problem is identified*, how the *incident development* is interpreted*,* the *capability* of resources*,* timely and efficient execution of *logistics,* the necessity of

collaboration, the *management* of the response*, time available* to implement solutions and the *legal framework* determining which actions are allowed. Combining these factors with Brehmer (2013) and Andersson and Uhr (2019), Figure 6 shows that in a given situation, the possibility space for problem-solving. It should be noted that there are no clear-cut boundaries between the factors, i.e. they are often intertwined. For example, the identification of the problem is highly dependent on whether the problem is perceived as simple or complex, but for pedagogical reasons these are presented as stand-alone conditions in the figure.

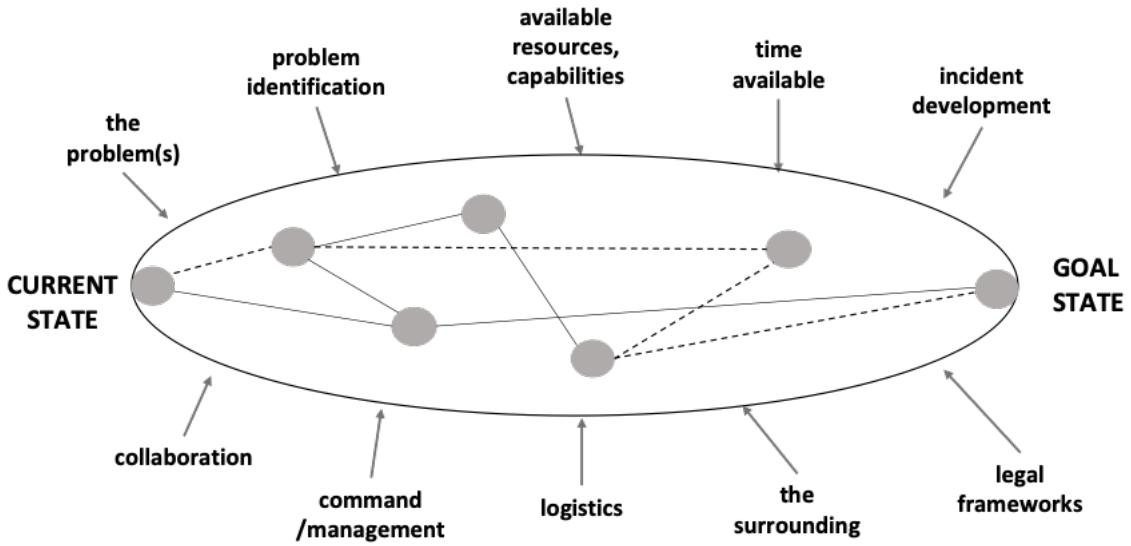

Figure 6: The possibility space for problem-solving in a given situation (adapted by Vylund et al. (2024b)). The constraining/enabling factors impacting the probability space are depicted surrounding the space itself.

The possibility space for problem-solving can be used to analyse how the room for action increases or decreases, according to prevailing conditions. The factors which enable or constrain the possibility space can be seen to expand or shrink the space in any given situation. For example, the legal framework sets limits what means can be used to solve a problem, and the available time determine which solution steps a problem solver has time to develop. It is reasonable to assume that the problem itself largely determines the desired goal state. As such, the possibility space can form the basis for a more active approach, where one can see the factors as compensatory, if one factor decreases, one can try to increase another to maintain the room for action.

5 Fire and Rescue Service (FRS) organisation

5.1 Overview of FRS organisation in Sweden, Norway and Denmark

Sweden, Norway and Denmark have similar regulations governing the FRS with some minor differences.

In Sweden, the FRS is defined under the Civil Protection Act (SFS2003:778). According to the Civil Protection Act, the local municipality is responsible for the provision of a fire and rescue *service*. Little detail is provided concerning how this "service" is provided other than the need to ensure protection of people, property and the environment. In addition, the Swedish Local Government Act (SFS2017:725) awards municipalities a high degree of autonomy expressed through their publicly elected political boards. This inherent autonomy allows each municipality and region to decide on the local organization of their services, such as the FRS. Complicating this issue in Sweden is the fact that annual planning for the FRS is governed by municipal business planning while there is an additional layer of planning mandated under the Civil Protection act every four years (in line with political mandates) which is submitted directly to MSB. This method of planning means that there are inherent differences between municipalities in terms of resources. Large municipalities, such as the major city centers, have commensurately larger budgets and personnel which means that they are largely self-sufficient. Smaller municipalities tend to require greater assistance from the national authorities to provide their citizens with sufficient services.

In Norway, fire and rescue services (FRS) are a municipal responsibility (kommunalt ansvar), primarily regulated by the Fire and Explosion Prevention Act (Brann- og eksplosjonsvernloven) and its associated regulations (DSB, 2023). Norway has 356 municipalities and 197 FRS, meaning that many municipalities have established cooperation through merged FRSs to optimize resources and improve service delivery. However, due to Norway's vast geographic variation and population differences, there are significant disparities in how FRS are organized and dimensioned. Larger municipalities with professional, full-time personnel are better equipped, while smaller municipalities often rely entirely on part-time firefighters (PTFF). Approximately 80% of firefighters in Norway are PTFF, but since these roles involve only a small percentage of working hours, part-time positions account for just 20% of the total full-time equivalents (DSB, 2023). This variation affects the capacity of individual FRS to perform tasks and the level of competence with which these tasks are solved. Responses to fires are fewer than responses to other types of incidents, such as traffic accidents and health missions. Especially in rural areas, where centralization has reduced the density of police and health actors, the FRS play a crucial role in incidents that are not related to fire.

The FRS in Norway are organized and dimensioned to handle local incidents, with few exceptions for national or regional emergency response capacity. This differs from neighboring countries, where there are more centralized or regional support resources. Norway relies on a tiered rescue coordination system, where the Main Rescue Coordination Centers (HRS, Hovedredningssentralene), based in Southern and Northern Norway, coordinate large-scale or complex operations and have authority over the Local Rescue Centers (LRS, Lokal Redningssentral) in each police district. LRS handle more localized incidents but escalate to HRS when additional resources or cross-regional coordination are required (HRS, 2024).

In Denmark, the FRS is regulated under the Danish Preparedness Act from January 1st, 1992 (Beredskabsloven, see: retsinformation). The Danish Emergency Management Agency (DEMA) is organized with one Main facility (Headquarter) and six regional support centers. The regional support center's primary function is to support the local municipal based FRS. Furthermore, there are 32 local municipal FRS established as of January 1st, 2022. These are serving Denmark's 98 local municipalities mainly with rescue, firefighting and related tasks. The FRS employ full-time firefighters, part-time firefighters and volunteers. The Danish Preparedness Act declares in §24 that each of the ministers shall within their respective areas plan for maintenance and continuity of the society's functions in

case of larger accidents and catastrophes, including emergency plans. This means that all municipalities are required to build and maintain an emergency response in situations of a crisis. The capabilities and resources of the municipal fire and rescue services are different, as reflected by the population density being different from region to region, where the density in the Copenhagen area is by far the highest, followed by the areas of the other major town down to the more rural areas, e.g. in Jutland.

DEMA became per August 29th, 2024 part of the newly established Ministry of Resilience and Preparedness (MRP). Prior to this date, it was part of the Danish Ministry of Defense. The new ministry embraces also the Center for Cybersecurity, the Emergency Maritime Agency and the Coastal Rescue Service. Furthermore, the Agency for Supply Security, the coordination of the national emergency management, Alarm Centers and other tasks transferred to the MRP from the Ministry of Environment, the Ministry of Finance and the Ministry of Business and Industry. The MRP was established to improve Denmark's capacity to cope with large accidents, extreme weather situations and hydride threads.

5.2 Authorities' views on the FRS in the Nordic countries

Before the data collection started, a webinar was arranged where representants from each national authority with responsibility for the FRS was invited, i.e.: Swedish Civil Contingencies Agency (MSB), Danish Emergency Management Agency (DEMA/Beredskabsstyrelsen) and The Norwegian Directorate for Civil Protection (DSB).

The program contained presentations from the three directorate representants, including their reflections on the organization of the FRS in their respective countries (today). In addition, there was time for discussion between the national representatives and the research team, allowing the authorities an opportunity for reflection on similarities and differences between the countries. Finally, the research group could ask questions concerning, both planned and spontaneously, relating to their research interests in the project.

The three presenters talked about the same themes in order to obtain comparable cross-country information, and it was important that the themes were of interest for all work packages in FIRE21. The themes included:

- The most important tasks and roles DSB/MSB/DEMA has when it comes to FRSs in their country (e.g. supervision, coordination, exercises, guidance, education etc.)
- The formal organization of Fire and Rescue in their country – from bottom to top (laws/regulation/legislation)
- The actors that are important for DSB/MSB/BS (formal and informal, as premise providers, collaborators, recipient)
- How their directorate collaborates with the two other countries directorates (DSB/MSB/DEMA)
- Future challenges and future development (technology, dimensioning, emerging risks).

In all three countries, the representatives described a situation where even if they cooperate with the local FRS and encourage them to work in particular ways, they cannot give them orders due to separation of power between national authorities and local government. It is not always easy to know whether the government or the local authorities are responsible in specific situations. The FRS within each country is very different when it comes to capacities, demography (of the municipality), local challenges and so on. In the largest municipalities, the FRS often organize themselves and can provide for their resource needs, while the FRS in smaller municipalities need more national support.

The overall impression is that there are some differences, but mostly similarities between the three countries. The differences are primarily due to different areas of responsibility that arise because of different demographic challenges in the three countries. For example, Sweden (MSB) and Norway

(DSB) have more competence and experience of forest fires, while Denmark (DEMA) has more experience of incidents related to the coastline, flooding and dams.

There is cooperation, so called “close border relations”, between Denmark and Sweden, and between Sweden and Norway, in many different areas. Border-municipalities often know each other in person and may have more or less formal agreements between them (it should be noted that no effort was made to map boarder agreements). There are agreements, such as the NORAD-agreement, which structures the cooperation between countries when it comes to national incidents. When it comes to local incidents in municipalities close to the border, there are no formal agreements.

5.3 About mapping

Mapping of formal relationships between organisations was studied using numerous formal public documents available in all three countries with a focus on Sweden and Norway. Documents included, but were not limited to legal texts governing the FRS and municipal documents representing guidelines for management of the FRS. Documents were entered into NVivo and coded based on stakeholders mentioned and relationships between them.

The map of formal network relations of FRS in Norway as outlined in official regulations and guidelines is presented in Figure 7.

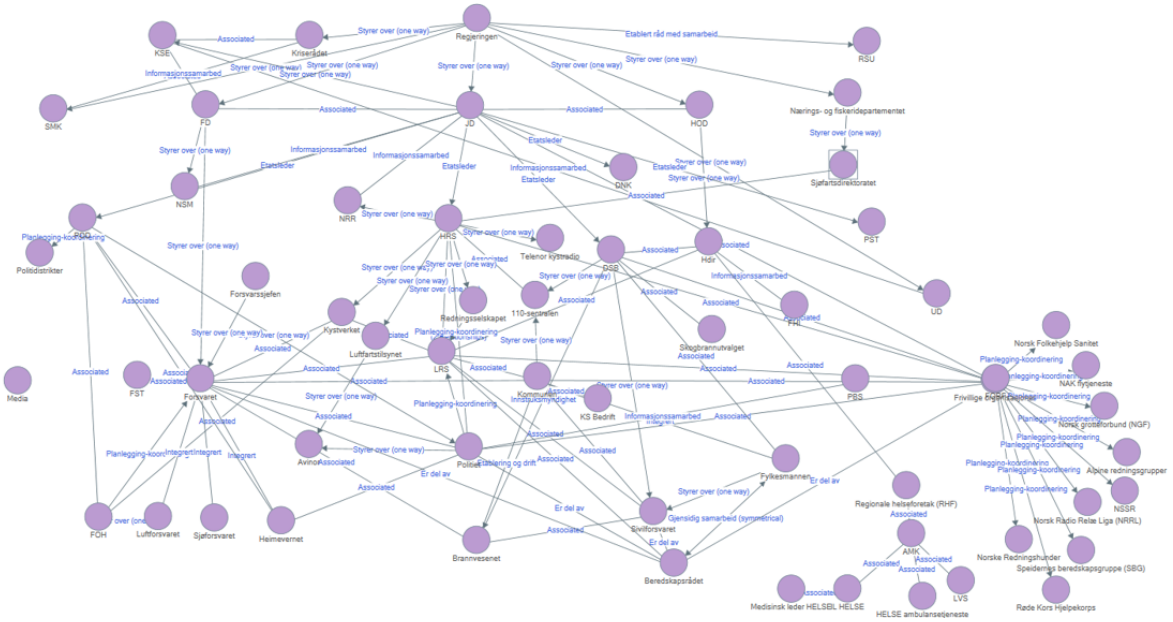

Figure 7: Overview of stakeholders identified through document analysis in Norway.

Figure 7 shows the formalized ties between organizations in Norway for responses during an emergency. The ties indicate which organizations are supposed to contact, listen to and work with which other organizations. Ties are activated incident-dependent. The map also shows the different levels on which the involved organizations are located from local (below) to national (top). The documents also clarify who is in charge of whom and who is chief of command.

In these formal relations, we can make some interesting observations. Central nodes – i.e., organizations with central positions in the network and many relations – are the LRS (Main Rescue Coordination Centers) and HRS (Main Rescue Coordination Center), the police, and the municipalities (kommuner). The fire services are more peripheral in this graph and mainly connected to the municipality and the DSB. This is, however, a logical effect of the fire services being the responsibility of the municipalities. One interesting finding is that the EMS are only peripherally mentioned in these national regulations and guidelines. Also, “voluntary organizations” are often mentioned in the

document as kind of a container variable, although the category comprises a large diversity of different organizations.

The mapping of the nationally outlined formal relations is an important mirror to what we find as actual relations in practice on the local and regional levels. Unsurprisingly, the actual response networks in local and regional emergencies look much different. This is on the one hand because often organizations become involved *ad hoc*, and on the other hand not all local and regional relations can be meaningfully formalized in national regulations and guidelines. The mapping gave us important context information as to which local and regional network ties are nationally prescribed, and which are developed on the local level. On the one hand, several of the organizations that we show in the map are seldom involved in actual emergency responses. On the other hand, the EMS are obviously crucial in almost any emergency situation, but interestingly this importance is not mirrored in the formal regulations and guidelines we reviewed for interorganizational responses. Overall, the mapping provided us with the background of nationally prescribed network relations, which are then enacted, adapted, and supplemented in actual responses.

Comparisons between the different countries were not completed due to lack of time in the project. The respective mapping work for Denmark is shown in Figure 8 and in Figure 9 for Sweden, as well.

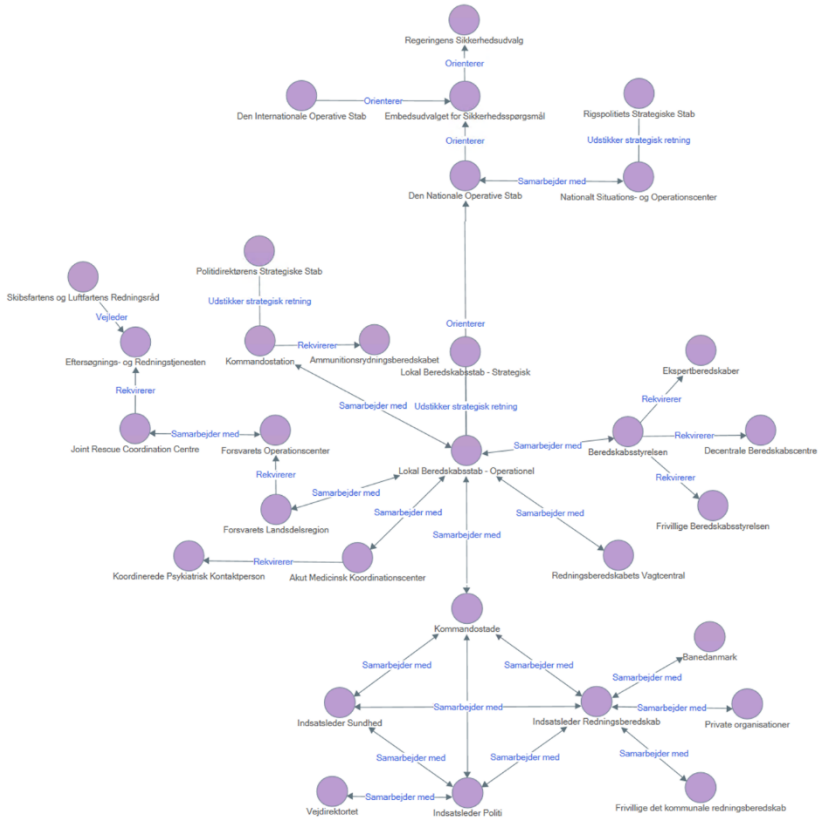

Figure 8. Overview of stakeholders identified through document analysis in Denmark (Allerup, Hansen and Markert, 2025).

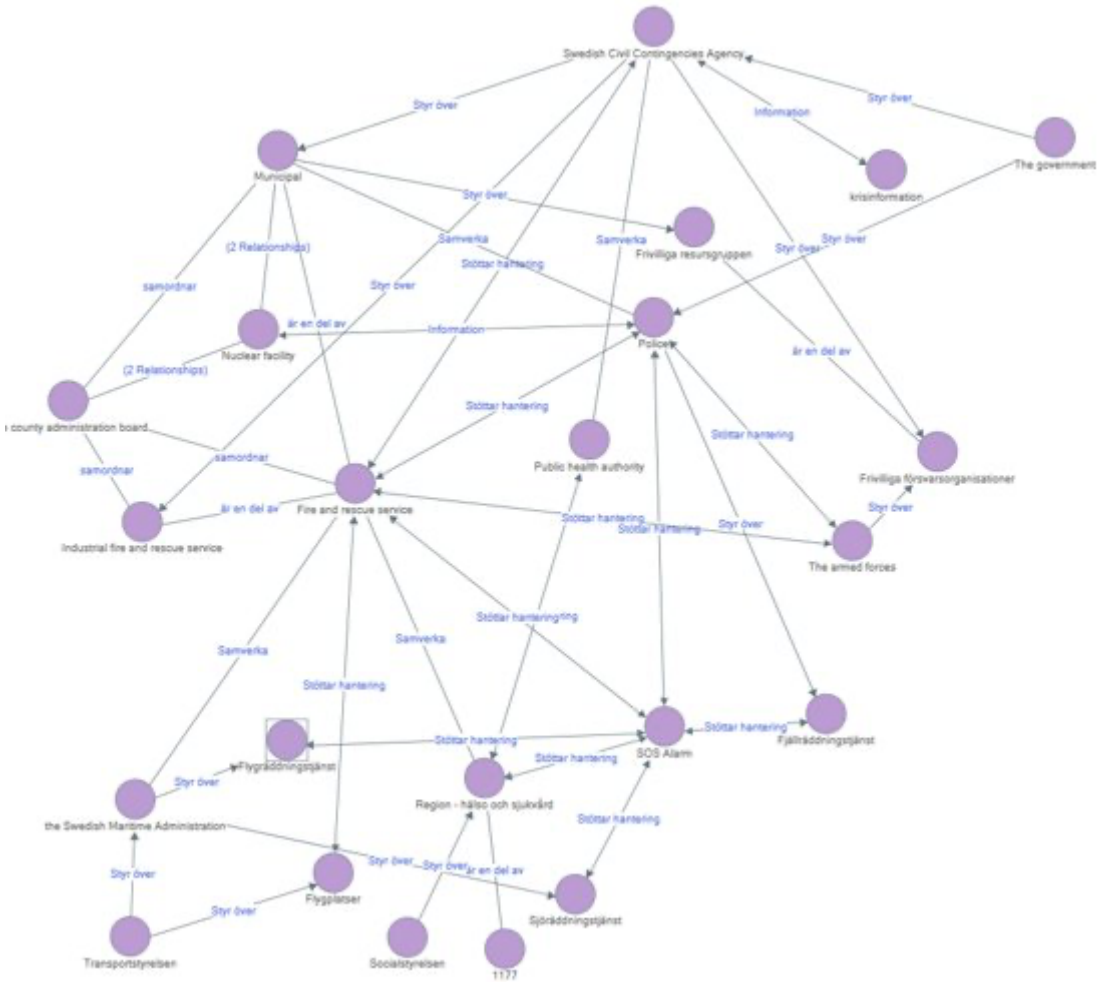

Figure 9: N-Vivo map of Swedish National Problem-Solving network.

6 Methodology

The project consisted of five work packages (WP1-5). Figure 10 shows a schematic view of the interaction between the various WPs with each WP described in more in the following text.

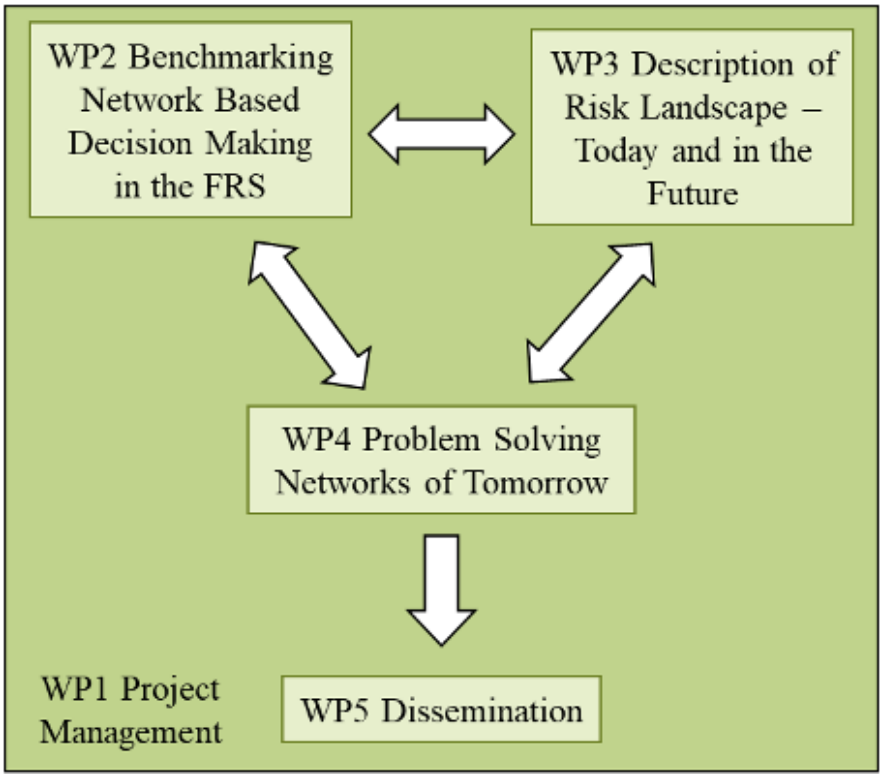

Figure 10: Schematic view of the project showing relationship between WPs.

WP1 Project management (WP-Leader: LU Fire Safety Engineering (FSE)). This WP refers to the management of the activities of FIRE21 and project administration. All partners were involved by way of annual general meetings which were held in person. In addition, quarterly meetings were held with the full project group digitally.

WP2 Benchmarking Network Based Problem-Solving in the FRS (WP-Leader: NTNU Social Research). The aim of this WP was to establish an understanding of the problem-solving networks and associated capabilities presently existing in each of the partner countries. Here, two main activities were conducted: mapping of multilevel problem-solving networks in each country and investigating networks that developed during a small number of large-scale incidents in each country.

Case studies for each country were selected based on the following criteria: 1) 3 case studies in each country, 2) each country will cover at least 2 different incidents (within the 3 case studies), and 3) cases that represents different types of FRSs, i.e. rural and urban FRS, different collaborative organizational models. A summary of the selected cases is given in Chapter 8. Case studies included collection of primary data through semi-structured interviews and secondary data in terms of media reporting, post-incident investigations (where available) and other relevant documentation. The interview guide used in the semi-structured interviews was partly similar for all cases to ensure a basis for comparison between cases and countries. Topic to be covered in all interviews were: organization of the FRS, today's problemsolving networks and needs for tomorrow's solving networks. The interview guide differed when it came to the explore the different incidents. All interviews were recorded and fully transcribed.

Case studies have provided the basis for both peer-review journal articles, conference abstracts, articles and presentations, and a licentiate thesis. In addition, two scientific journal articles and one full conference paper are under production.

WP3 Understanding the Risk Landscape from an FRS perspective – Today and in the Future (WP-Leader: DTU). The aim of this WP was to create a picture of the global (with a Nordic and European focus) risk landscape today and a projection of potential risk landscapes of the future starting from a global perspective but rapidly narrowing the picture down to risks specifically relevant for the FRS.

The outcome from WP3 in the form of a suggested risk landscape from an FRS perspective is described in Chapter 7. The method for development of this risk landscape was through comparison between risks identified in each country using national statistics, an analysis of prioritised hazards at the national level and compilation of methods for foresight in each country. In addition to the description in Chapter 7, the work is summarised in a project report (Markert, Holmvaag and Johansson, 2023) and has been presented at several conferences, e.g. SRA and NFSD.

Additionally, input from other on-going projects concerning hazard and risk analysis as input to FRS planning was input to the overall analysis of the risk landscape, e.g. from the MSB funded project Extreme-Index.

WP4 Well connected? – Problem-Solving Networks of Tomorrow (WP-Leader: LU-Risk). The overall aim of this WP was to develop recommendations to support the development of resilient problem-solving networks of tomorrow, including an understanding of how these networks work and what capabilities are needed to support their problem-solving. To reach this objective, two parts were addressed: individual qualities for effective collective problem-solving were investigated and recommendations from the project were gathered and summarised.

To identify which individual qualities that are needed to functionally operate in tomorrow's problem-solving networks following activities were conducted. First, interviews with key academics in the field of problem-solving and a subsequent in-depth literature review focusing on key individual qualities for collaboration under stressful conditions was carried out. In parallel, we conducted workshops with professionals to collect their experiences on what qualities are believed to be key for collaboration. Workshops with FRS organisations in Sweden and Denmark were conducted, and a survey was used to gather Norwegian data. The results are presented in chapter 9.

To collect project recommendations, an internal workshop with project partners was conducted towards the end of the project. Here, all project members discussed and presented suggestions of how well the existing problem-solving networks in each country support the present risk landscape and what changes might be necessary to support the development of appropriate networks for the future. In addition, professionals in Sweden and Norway were asked about future needs, which is incorporated into the project recommendations. These are presented in chapter 12.

WP5 Dissemination (WP-Leader: RISE). This WP focused on strategic planning, practical implementation and evaluation of communicative ventures. Key findings and reports from each WP have been made publicly available through the project newsletter, conference proceedings and presentations and peer-review publications. A full list of publications produced as part of the project is given in

Table 1.

Table 1: Summary of dissemination activities in FIRE21.

Year	Publication	Type
2025	How urban and rural emergency services successfully achieve stability and flexibility for their response operations: an empirical comparison, M. Grothe-Hammer, P. Almklov, G. Gjøsund, T.K. Haavik, IRSPM 2025, Bologna	Conference abstract and presentation
	Allerup, C.R., Hansen, M. F. & Markert, F., 2024., Kortlægning af det samlede danske krisestyringssystem: Et overblik over det formelle netværk, kommandoveje og samarbejde på tværs af beredskabsaktører og myndigheder., DTU report, DOI: 10.11581/ba19bab0-ddf0-4435-8ee5-65ff7b87c7d3	Technical report
	Allerup, C.R., Hansen, M. F. & Markert, F. 2024., Benchmarking Network Based Decision Making - danske case studier: Rapport for WP2 i FIRE 21., DTU report, DOI: 10.11581/5c80b82a-445b-42f4-9f90-9616e831112b	Technical report
	Frykmer, T. & Johnson, V. (2025). Individual qualities for effective collective problem solving - report for FIRE21. https://lucris.lub.lu.se/ws/portalfiles/portal/206569992/Individual_qualities_for_effective_collective_problem_solving_-_report_for_FIRE21.pdf	Technical report
	Frykmer, T. (2025). Projekt FIRE21 - Key individual problem-solving qualities in the fire and rescue services: a survey in Norway. https://lucris.lub.lu.se/ws/portalfiles/portal/206568951/Projekt_FIRE21_-_Key_individual_problem-solving_qualities_in_the_fire_and_rescue_services_a_survey_in_Norway.pdf	Technical report
2024	Nordic Fire and Rescue Services in the 21st Century (FIRE21), M. McNamee, T. Frykmer, G. Gjøsund, L. Vylund, F. Markert, NFSD 2024, Lund	Conference abstract and presentation
	Fire and Rescue Service´s problem-solving – different municipalities – different problem-solving qualities, G. Gjøsund Gudveig, P. Almklov, T.K. Haavik, NFSD 2024, Lund	Conference abstract and presentation
	Present Risk Landscapes in the Scandinavian Countries, F. Markert, N. Johansson, O.A. Holmvaag, NFSD 2024, Lund	Conference abstract and presentation
	The importance of problem-solving networks in emergencies, L. Vylund, G. Gjøsund, F. Markert, NFSD 2024, Lund	Conference abstract and presentation

	Well connected? Important individual qualities for collective problem-solving in the fire and rescue services, T. Frykmer, V. Johnson, NFSD 2024, Lund	Conference abstract and presentation
	Theorizing rescue services as organizations, M. Grothe-Hammer, NFSD 2024, Lund	Conference abstract and presentation
	Antonsen, C. Brennende engasjement. En studie av deltidsbrannvesenets rolle i lokalsamfunns beredskap. Master thesis in sociology, NTNU. https://ntnuopen.ntnu.no/ntnu-xmlui/handle/11250/3167373	Master thesis
	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, 1-24. DOI: 10.1007/s10694-024-01582-0.	Journal article
	VYLUND, L., JACOBSON, J., FRYKMER, T. & ERIKSSON, K. 2024. Improving Complex Problem-Solving in Emergency Response: A Study of the Fire and Rescue Service in Sweden. Fire Technology, 15, 867-878. DOI: 10.1007/s13753-024-00603-4.	Journal article
	VYLUND, L. 2024. Solving complex problems in emergencies: A Fire and Rescue Service perspective. Licentiate, Lund University. https://portal.research.lu.se/en/publications/solving-complex-problems-in-emergencies-a-fire-and-rescue-service	Licentiate thesis
	Frykmer, T. (2024). Problems, problem-solving and problem-solving networks - a theoretical foundation for FIRE21, version 2. https://lucris.lub.lu.se/ws/portalfiles/portal/207314983/Problems_problem-solving_and_problem-solving_networks_-_a_theoretical_foundation_for_FIRE21_v2.pdf	Technical report
	Frykmer, T., Johnson, V. & Uhr, C. (2024). Individual qualities for collective problem-solving - Insights from an interview and literature study. https://lucris.lub.lu.se/ws/portalfiles/portal/206567944/Individual_qualities_for_collective_problem-solving_-_an_interview_and_literature_study.pdf	Technical report
	Frykmer, T. & Johnson, V. (2024). Projekt FIRE21 - Sammanställning workshops Räddningstjänsten Syd (Rsyd) och Malmö Stad https://lucris.lub.lu.se/ws/portalfiles/portal/206568342/Projekt_FIRE21_-_Sammanst_llning_Rsyd_och_Malm_stad.pdf	Technical report
	Frykmer, T. & Johnson, V. (2024). Projekt FIRE21 - Sammanställning workshop med Hovedstadens Beredskab. https://lucris.lub.lu.se/ws/portalfiles/portal/206568709/Projekt_FIRE21_-_Sammanst_llning_workshop_Hovedstadens_Beredskab.pdf	Technical report

	Frykmer, T. (2024). Key recommendations from project FIRE21. https://lucris.lub.lu.se/ws/portalfiles/portal/206569535/Key_recommendations_from_project_FIRE21.pdf	Technical report
	Iliopoulos, S. & Frykmer, T. (2024). Project FIRE21 - Internal workshop on recommendations. https://lucris.lub.lu.se/ws/portalfiles/portal/206567634/Project_FIRE21_-_Internal_workshop_on_recommendations.pdf	Technical report
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	Brandposten #62, https://www.ri.se/en/news/newsletter/subscribe-to-brandposten	Popular scientific article
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7 Risk landscape today and tomorrow

The aim of the work presented in this chapter was to investigate our understanding of the Nordic risk landscape today coupled to a projection of potential risk landscapes of the future. The focus was on risks specifically relevant for the FRS. As such, the various published risk reports in Norway, Sweden and Denmark by the relevant authorities were collected and reviewed (MSB, 2016; DSB, 2019b; a; Beredskabsstyrelse, 2022b; a).

The motivation for the work was as follows:

1. The rapidly changing risk landscape means that there is a need to follow trends to be able to adopt any preventive and operational measures that may be necessary.

2. The discourse about new challenges due to changing risk landscape in Europe appears primarily to be dominated by direct impacts due to climate changes as it is foreseen based on input from international assessments and foresight documents, e.g., from McKinsey Quarterly, Bloomberg, Boston Consulting and other reputable sources. Present climate descriptions and climate predictions will come from a combination of input from an ongoing project (Extreme-Index, MSB 2019-06053) run by the Lund University, analysis of various reports from Nordic meteorological institutes and findings from the International Panel on Climate Change (IPCC) (IPCC, 2014; 2023).

7.1 Mapping the present recognized risk in Denmark, Norway, and Sweden

Risks are part of our world. Over time, various strategies to prevent potential hazards and to mitigate the consequences that may arise from such risks have been developed. But the world's risks are not static as they are dynamically developing over time. Therefore, also preparedness needs to (and will) change over time.

The question is how to identify such altered risks and to prepare the emergency services to cope with these new challenges to prevent major consequences of incidents and catastrophes the best way possible? Historically, such risks and their impacts on society could not be predicted very well and the development of preparedness was more based on former experiences. More recently, a great number of tools as e.g., software to support risk management are available and it is now possible to make better foresight of risks.

Presently, one of the greatest challenges is climate change. This implies emergence of hazards due to various adverse weather conditions resulting in both dry and hot periods, heavy rain, and other conditions. All may lead to different adverse scenarios ranging from extended forest fires to flooding, landslides and avalanches.

Climate change will also lead to innovation in technologies and new solutions to mitigate climate change. Also, the solutions themselves may create new types of emergencies and have a certain potential to alter the risk picture of today, as well. The challenge is the rapid technological development, which is partly driven by a desire to mitigate climate change or to improve humanity, but which can have the opposite effect. As an example, the introduction of new systems of transport or energy carriers might result in different hazards in the urban area. Another example is the increased dependence on technical and digital systems and electricity that can make a society very vulnerable.

As part of this project, a report has been developed mapping the present risk landscape in Norway, Sweden and Denmark (Markert et al., 2023). This full report intends to describe today's recognized risk picture in the Nordic countries and how new risks are identified by the emergency services. Furthermore, the available event statistics for Denmark, Norway and Sweden are presented and analysed to find any new trends that may be leading to an altered risk picture. Finally, the possible future impacts of climate change to the risk picture in the Nordic countries are being identified and the results of a brainstorm exercise on the future emergency topics are reported.

As a starting point the respective national risk profiles/pictures developed by the Danish Emergency Management Agency (DEMA) (Beredskabsstyrelse, 2022b; a), Norwegian Directorate for Civil Protection (DSB) (DSB, 2019b; a), and Swedish Civil Contingencies Agency (MSB) (MSB, 2016) were evaluated and compared to each other. It is found that each country's selection of its main categories were compatible to the others, but the level of details within main categories were different, due to differences in the number and type of specific threats observed. Further, the three countries' procedures for establishing and updating their respective risk landscape appear similar, see Figure 11.

In addition, a common aligned European approach was also considered (EC, 2010; Union, 2011). The national reports on the recognized risks are intended to be used for strategic work and various related tasks and planning to prevent and to mitigated emergencies and increasing threads due to climate change. An important source of information was also emergency related statistics from each country. The present status of the statistics on climate change related emergencies as forest fires does not seem to change the statistical trend over the last decades. It is clearly seen that such accidents when taking place as in 2018 require huge resources. In 2018, an increased forest fire frequency is observed for Denmark, Norway, and Sweden. That year the main weather conditions were extremely warm and dry in all the three countries, in fact over the most of Europe. This observation across Europe is important, as it may negatively affect the potential for mutual resource sharing across the countries helping and supporting each other in large catastrophic emergency situations.

To predict the future emergencies and planning for proper dimensioning of the emergency services, a number of tools are available. The scientific knowledge in the field is increased in our century and better understanding of the phenomena leads to better predictions. Together with the high-performance computing facilities many types of predictions may be made. These range from weather forecast and "dryness indicators" to consequence models based on GIS systems to evaluate the consequences of, e.g., flooding and forest fire spread and others. Lastly, forecasting is made possible by these various models and using special programs to analyse the "big data" which is expected to impact on risk predictions in the future.

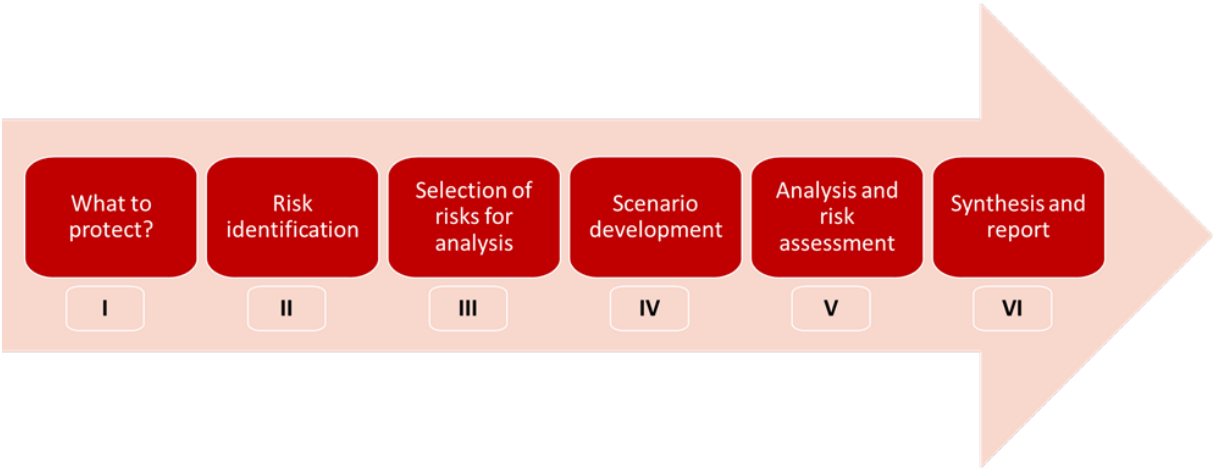

Figure 11: A general process to assess and report the national risk picture (MSB, 2011).

7.2 Important factors regarding emergency management

A workshop was conducted within the FIRE21 experts to identify the FIRE21 project view on climate change related emergencies and effects on the FRS in the three countries. A distinction was made between direct climate changed driven weather impacts, such as forest fires due to dry conditions, landslides due to heavy rain, and impact of technologies and socio-technologic changes made as part of climate adaptation (e.g., to minimize the carbon dioxide emissions by renewable fuelling systems). The results of the seminar were summarized in a map of important factors, see Figure 12.

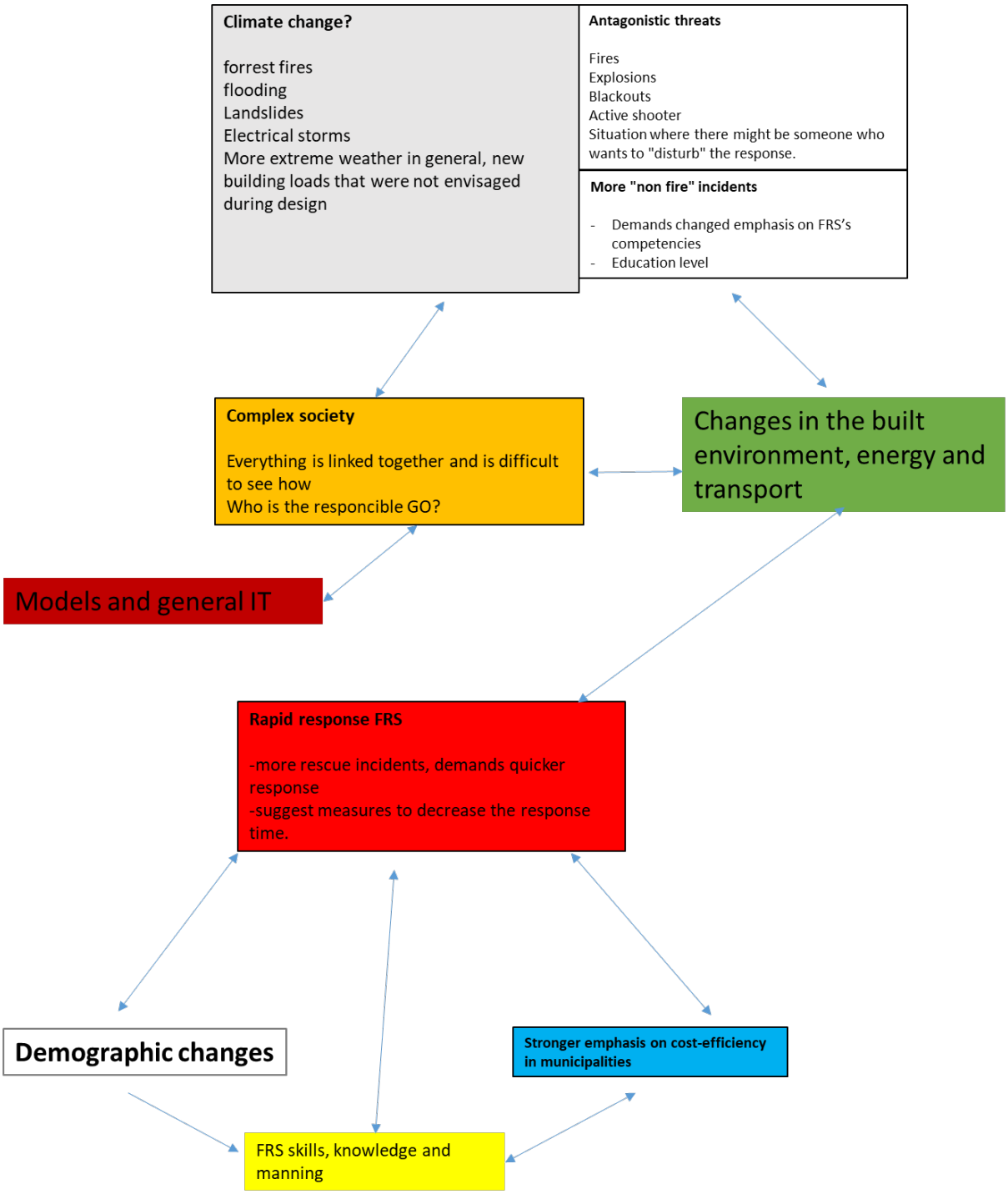

Figure 12: Main topics identified in workshop.

7.3 Recommendations from risk landscape overview

It was found that the national processes for identifying emerging risks are coordinated with the respective European guidelines but still are focussing on the situation and environment in each of the Nordic countries. These differences are based on differences in topography and geography but are also due to the population density, variety of national industries, historical events and the established (critical) infrastructures.

To predict future trends of potential emerging risks and, in turn, a proper future dimensioning of the emergency services, the national authorities continuously refine their respective pictures with periodic updates for Denmark e.g., in intervals of about 5 years, as national risk reports are established in 2013, 2017 and 2022.

The common basis for risk assessment appears to be climate change trends and the assumption that climate change will have a future major impact on the risk picture in the Nordic countries, i.e. it likely will provide:

- More extreme weather types with rapid change of conditions
- More storms and hurricanes
- Long periods of rain
- Long periods without rain are predicted.

These trends are still not clearly seen in the respective statistics but beginning trends may be seen when combining the present statistics with climate forecast models that predict future climate changes.

While the project admits that climate change is one of the greatest challenges of our time, towards the end of the project, the international geopolitical situation has seen a significant move towards increased concern about national security. It is proposed that in the new future, risks related to espionage and civil defence are likely to increase in importance.

8 Case studies

8.1 Overview

During the NVivo mapping of formal networks, it rapidly became clear that case studies would be a necessary tool to move from formal connections to an understanding of problem-solving networks. The first year of the project was spent identifying criteria for case study selection. It was agreed that all countries should try to select three case studies, that these should represent different types of FRS and that they should cover different types of incidents. The final selection of case studies is summarised in Table 2.

Table 2: Summary of case studies selected within the project.

Sweden	Norway	Denmark
Type of incident: Explosion in apartment building Type of FRS: Urban Location: Coastal city	Type of incident: General response Type of FRS: Rural Location: Mountainous location	Type of incident: Traffic accident Type of FRS: Rural Location: Coastal bridge
Type of incident: Flooding Type of FRS: small urban Location: Regional hub	Type of incident: Fire in parking garage Type of FRS: Urban Location: Coastal city	Type of incident: Wildfire Type of FRS: Rural Location: Forested region
Type of incident: Wildfire Type of FRS: Rural Location: Forested region	Type of incident: Landslide Type of FRS: Rural/part-time Location: Fjord location	Type of incident: Apartment building fire Type of FRS: Urban Location: Capital city

The aim of the case studies was to identify problem-solving networks both within and around the FRS. While identifying stakeholders other than the FRS, the focus was nonetheless on the FRS role in the interaction.

8.2 Norwegian case studies

Three case studies on different FRSs have been conducted from February 2022 to May 2023. The cases vary with regard to how the FRSs are organized, demographics and what kind of incidents that have been studied, and they all have their own local qualities. The presentation of the Norwegian cases will briefly describe each FRS, show some of the interesting findings and point out the analytical questions that arise from the cases.

Case 1 The mountain FRS

The first case study was carried out in a small rural Fire and Rescue Service (FRS) in the mountains of Norway. This FRS serves a large geographic area with few inhabitants. Except for the fire chief who works full time, there are only part-time firefighters. The lack of formal preparedness resources is compensated for by informal resources, such as different actors spending their leisure time and use their own equipment in order establish emergency maintenance. The strengths of this FRS are mainly informal, such as local knowledge, additional competence and volunteer efforts.

One small but interesting finding in this case was how the local FRS handled the national requirement saying that municipalities are obliged to have back-up systems in case of loss of critical infrastructure. Instead of investing in high tech drones or other expensive equipment, which can be vulnerable if the power grids fails and satellites are put out of action, they had established a collaboration with the local amateur radio community (Norwegian Radio Relay League). By reintroducing old technology in a new way, driven by voluntary radio amateurs, this local FRS have managed to establish independent redundancy in critical infrastructure functions. This solution shows how a local community maintains important obligations in a way that are informal and invisible in formal policies, in lack of formal resources and competence.

This case raises several interesting questions about the organization of futures FRSs. Some are about very local problems that have to be solved, e.g. how to have the right preparedness for fire extinguishing without enough access to water. Others are more of a general nature when it comes to the preparedness of local FRSs, e.g. the use of the competences and resource's part time fire fighters hold from their 'day jobs' and how local knowledge compensates for lack of resources in the small FRSs. This first case also raises questions about how to maintain local preparedness including informal competence and resources, when authorities signal movement towards bigger and more professionalized FRSs.

Case 2 The large multi-organized FRS

The second case study was conducted at a large FRS serving both a large city and several smaller surrounding municipalities. This FRS is of interest because of the specialization and centralization required by this organization. It shows how a large FRS works to create needed flexibility (in case of unpredictable situations) in an organisational form built up by stronger formal structures.

This FRS combines the qualities that follows with the size and specialisation that stems from operating in a big city, with the more rural organization and qualities in the surrounding communities (which are also a part of this FRS). Since the surrounding rural municipalities part of this FRS has to answer to a Fire Chief located in the big city, it also gives valuable insight to the centralization debate – How to maintain the strength in the commitment from part time fire fighters and other local actors who do not have their fire chief in geographical proximity.

In 2021, there was a large fire in a parking house connected to the local airport. Studying this incident has given insight into how the organization mobilizes problem-solving networks during a fire. A lot of actors not defined as a part of the problem-solving networks of the FRS were mobilized in the extinguishing phase. Most important was the collaboration between the FRS and AVINOR (the airport operator) and how they took advantage of each other's resources, knowledge and equipment. This case also gave valuable insight into how crisis management was practiced both at the sight and at the emergency center.

Another valuable insight this case gives us is about how 'Common Operational Picture' (COP) can be understood and used during an emergency situation. The use of the COP as a concept differs through the various phases in an operation and between locations/actors. E.g. the alarm central use it in a structured and formalized way, while it is a more adaptable and unformal way of using it at the scene of an incident.

Together with the first case, this case provides insight in different ways small/rural and large/urban FRSs operates in order to establish both the stability and the flexibility needed in order to be prepared for all sorts of incidents; The small by structuring the informal resources, and the big by trying to establish less static connections between formal actors.

Case 3 The part time FRS by the fjord

This last Norwegian case involved a rural FRS with part time fire fighters. It consists of two small rural FRSs that merged in 2020. It now has a fulltime fire chief, 4 fire stations and 40 part time fire fighters. These fire fighters bring with them broad competence gained through their regular day time jobs, as carpenters, mechanics, teachers, and so on.

In connection with one of the fire stations there is a gym. Several of the part time fire fighters use this gym, and by that it becomes an informal arena for networking. Here we see network building as an informal, yet strategic, endeavour in normal situation.

This FRS had recently handled a landslide incident where 6 people were involved; one person died, and the rest were injured with varies degrees of severity. Especially the rescue of a two-year-old girl trapped under furniture and masses from the landslide has been considered as a very dramatic and successful operation. With limited resources (compared to the big rural FRSs), and with skills they have developed through their day jobs, this rural FRS handled the critical situation impressively. The pivotal role of practical competence and skills, having nothing to do with FRS formal training, was the key to this operational success. The incident also gives some important insights into situated improvisation and decision making.

Based on this case study and earlier studies on rural fire and rescue services, we problematize what future position these small, rural FRS will play in Norwegian society. What qualities in the rural fire and rescue services might be lost when moving towards larger FRS constellations? What skills might be missed when the emphasis is on centralization and specialization?

8.3 Swedish case studies

Three case studies on three different emergencies where the FRSs have been involved have been conducted. The cases vary concerning how the FRSs were organized, demographics and what kind of incidents that have been studied, and they all have their own local qualities. The presentation of the Swedish cases will briefly describe each FRS, the specific cases studied and show some of the interesting findings from the cases.

Case 1 Building fire in urban area

The first case in Sweden involved building fire in Gothenburg. Gothenburg is the second largest city in Sweden and their FRS is a local federation which, in 2021, included six municipalities over the region surrounding Gothenburg. The area encompassed around 850 000 residents and had a total area of 3300 square kilometres, of which roughly 50 percent was land area. The personal from the FRS involved in the case was manly full-time personal included a lot of experience related to the case.

The study case included an explosion and fire which occurred in an apartment building in Gothenburg early in the morning of September 28, 2021. The apartment building in question is located in central Gothenburg, encompassing a mix of structures ranging from older buildings from the early 1900s to more modern constructions from the 1980s. The explosion was likely triggered by the ignition of evaporated flammable liquid. The resulting force of the explosion produced a pressure wave strong enough to displace fire-separating structures and the entrance door, which facilitated the spread of smoke throughout the building.

A significant number of Fire and Rescue Service (FRS) units responded to the scene. Upon arrival, they observed smoke emanating from windows and balcony doors of multiple apartments, with many people calling for help. During the initial two hours, approximately 60 apartments were evacuated from the courtyard side. The incident affected three stairwells and their associated apartments. One

individual died to injuries caused by the fire, and several others were transported to the hospital for observation. All injured persons were evacuated from the site using ambulances or buses. Non-injured evacuees were directed to a nearby church, where they received practical assistance, including support with insurance matters, social services, and sustenance.

This case provided valuable insight how the FRS solves complex problems by breaking them down to several sub-problems which are easier to understand and thus easier to solve. This case also gave important insight in how and why a problem-solving network is formed and developed during an incident.

Case 2 Wildfires in a rural area

This second study was performed in an area in the south-eastern Sweden. The area comprises three Swedish municipalities that at the time of the interviews consisted of two fire and rescue services with close cooperation. One of the fire and rescue services consists of only part-time firefighters while the other fire and rescue service also had career firefighters.

The area is one of the driest in the Nordic countries and is expected to become drier with climate change. Wildfires are common in the area and several small fires of a few hectares or less burn every year. The area also has experience of two major wildfires. The first major fire occurred in 1983 after 6 weeks of drought, sparks from a railroad ignited a fire, burning 670 hectares of forest and destroying several houses. In 2021 another large wildfire occurred in the area. This fire resulted in 100 hectares of forest burned. The fire would have threatened several homes had there been small differences in wind direction. Aerial resources deployed to the incident which contributed to the successful extinguishment of the fire despite a continuously difficult weather situation. In both incidents, both the fire and rescue service and volunteers were involved in the response.

This case together with case 1 provided valuable input to an increased understanding of what is needed to enhance complex problem-solving in emergencies. The research question which was studied was What key factors affect complex problem-solving in emergencies for the Swedish fire and rescue service?

Case 3 Flooding in semi-rural area

This study was the focus of one of the bachelor theses connected to this project (Karlsten and Sand, 2022). The third case focused on Gävle which is the capital of Gävleborg County. Gävleborg County (Swedish: Gävleborgs län) is a county on the Baltic Sea coast of Sweden. Gävleborg has a population of approximately 285 000 of which almost 80 000 reside in the County capital of Gävle.

In the summer of 2021, a massive rainfall occurred in Gävleborgs county, causing extreme flooding in the city of Gävle and surrounding area. The flooding contributed to an extremely high burden on the FRS in the region, when approximately 700 emergency calls were received in the space of just a few short days. The flood caused flooding in cellars, damage to infrastructure and problems moving through traffic. The high burden caused the inner Commanding Officer of the FRS to create a special staff support unit. Extra personnel were required, and the staff support unit was able to prioritize vital societal functions and critical infrastructure. Emergency calls, other than to prioritized areas, were put off for the time being, to be handled later when acute calls had been handled. Even though the burden on the FRS was too great and not everything could be handled directly, every address who made an emergency call was ultimately visited, although in some cases it took several days.

When natural catastrophes happen, they put high demands on the societal resources and the problem-solving capacity of the FRS. In response to the unusual burden due to the rainfall, and the inability of the FRS to adequately respond to the situation, an evaluation was made by the County Administration in Gävleborg. This report was analyzed together with response reports from the FRS reporting system. In addition, three semi-structured interviews were conducted with representatives of the Gävle FRS.

The conclusions show that preemptive measures are important in existing urban environments, but also during new construction or as part of urban development. The preemptive measures include routines for what needs to happen during large incidents such as the those investigated. While certain events are unusual, they can be predicted in traditional foresight activities and routines developed.

8.4 Danish case studies

Three case studies on three different emergencies that relate to various emergency situations in Denmark have been conducted and are described in more detailed in the following. They were also the basis for an interview campaign. Each incident is related in one way or another to the changing weather conditions which are predicted to become more frequent in the next decades, such as storms / heavy wind situations and drought.

Case 1 Train accident on the Big Belt Crossing

In 2019 (02.01.2019) a passenger fast train collided with a freight train's carrying a semi-trailer on a pocket wagon (Havarikommissionen, 2019). The semi-trailer was misplaced to reach across the tracks to compromise the passenger train driving in opposite direction on the parallel tracks. The misplacement was due to a combination of mechanical defects and a sidewards wind impact that forced the trailer out of the mechanics. The accident caused 8 fatalities, 4 passengers sustained serious injuries and 14 sustained minor injuries.

Figure 13: Map of the Big Belt Crossing (Vestbroen) – the collision point is marked in yellow (Havarikommissionen (2019), p9).

That day high water occurred, caused by a heavy storm with wind speeds of 20 -22 m/s from north perpendicular to the direction of the bridge. At the time of the accident, the bridge was closed for all road traffic. Due to the weather situation the emergency service had already prior to the accident been collected for the Staff Readiness (*Stabsberedskab*). Therefore, the response time was faster that day as the emergency services were pre-alerted. Nevertheless, one of the emergency services (ISL Sund) called to the location of the train accident experienced a delay as the closed bridge (road traffic) caused a heavy traffic jam. The Incident Commander from FRS Sund had therefore difficulties to reach the location of the rail collision, which was only reached after 36 min, while the emergency service (ISL Fyn) reached the location 7 min after the alarm. The first responders could enter the train at 08:05 mainly to provide first aid. The rail tracks must be entered from the road bridge after the high voltage powerlines were grounded and a transportable short bridge was installed to cover the gap of 1.35 m between the road bridge and the rail bridge. This meant that the passengers were instructed to wait on the damaged train. The evacuation started at 09:12 and was finalized 09:41.

The emergency responders experienced further problems with their radio communication between responders, which was a potential threat for the victims of the incident and safety of the responders. There was experienced “too much talk” on the frequencies and the sound was compromised because of the strong wind. Despite these problems, the evacuation conducted by the emergency services, and afterwards was judged exceptional satisfying and fully in accordance to the REFIL guidelines (Beredskapsstyrelse, 2023).

Case 2 Nature fire in Randbøll Hede (drought, rural situation)

In May 2018, a large outdoor fire started in an area called Randbøl Hede close to the towns Vejle and Billund in Jylland, Denmark. The fire lasted about 72 hours (25.5. to 29.05), but first 05.06.2018 the emergency service declared the fire being extinguished. The fire destroyed about 410 hectare forest and nature areas, which is about 2/3 of the Randbøl Hede area. The firefighting was successful to avoid damage to property and animals, but several properties were evacuated. During the fire 120 fire fighters were on duty.

The fire happened shortly after the municipal FRS were re-organised in 2016 to create the Trekant brand FRS, but the six individual FRS combined into the single Trekant brand still had not been fully coordinated using a common operational plan. Overall, the merger into a larger service was perceived as very positive. The fire pinpointed some improvements concerning how to manage such a large fire that are now implemented, e.g. a major event concept to cope with large and long-lasting events. The Randbøl Hede event revealed a very heavy load on the Incident Commander (IC), and the need for an extra Operational Chief was recognized. The Operation Chief’s role was to support the IC, to enable better handling of such events, e.g. tactical meetings at the accident place are possible.

Case 3 Large fire in a building block in Copenhagen (heavy wind, urban situation)

The fire started 25.03.2022 at 13:47 in a residential building block as a roof fire at Grøndals Parkvej 6A in Vandløse (see Figure 14) being a suburb to Copenhagen. Due to a faulty fire protection design of the roof and strong wind the fire spread extremely fast providing severe challenges for the fire services. As a consequence, the fire totally damaged the building blocks and a large number of people needed re-housing. The Copenhagen fire service was supported by FRS East, FRS 4K and the DEMA center in Næstved / Hedehusene. The main lesson learned was that faulty design, missing entrance roads and weather condition could lead to the major consequences even in an urban fire scenario with all the available resources.

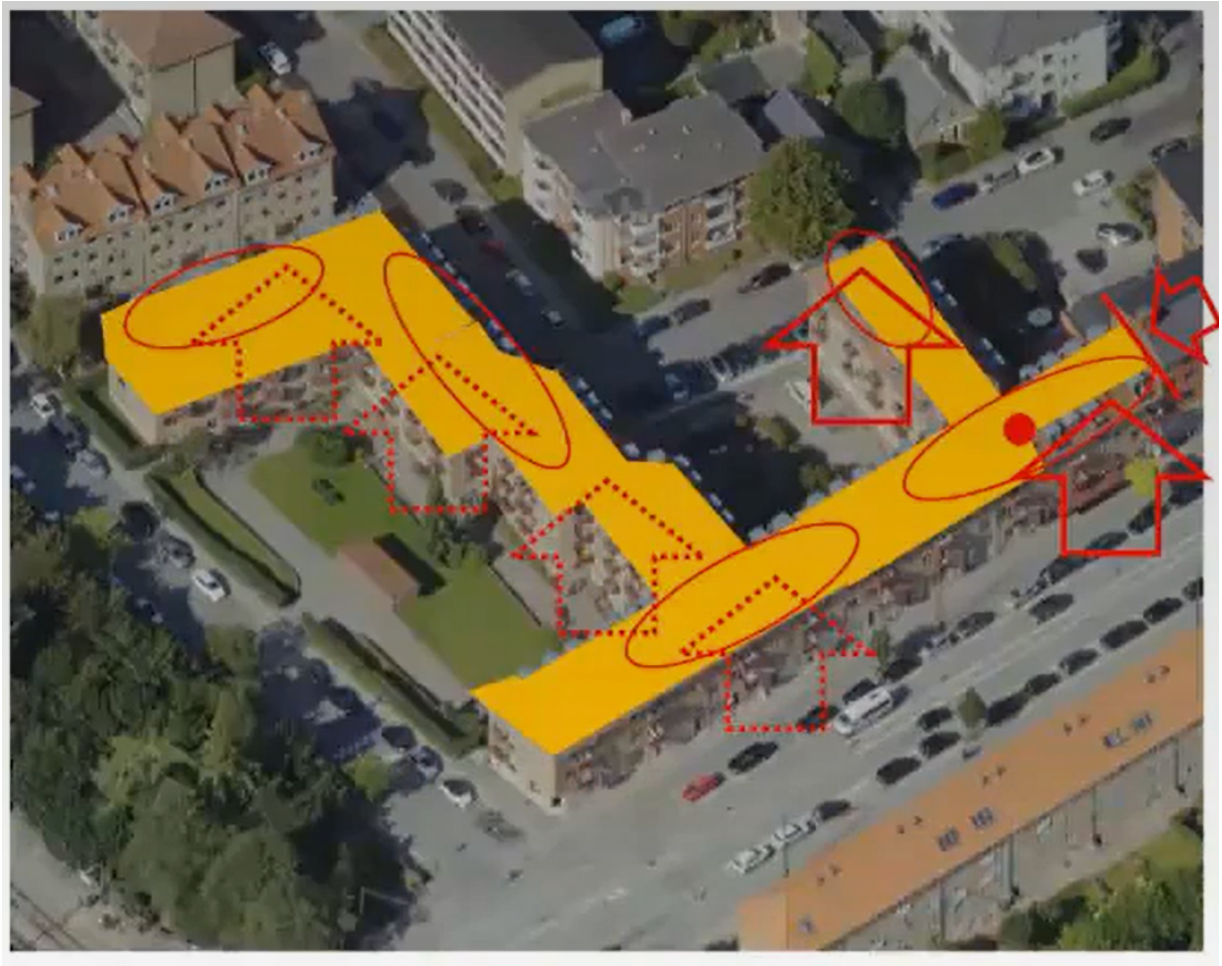

Figure 14. Fire at Grøndal Parkvej, Vandløse. The roof fire started at the upper left circle and spread fast over the yellow marked roofs (Photo: Hovedstadens Beredskab, Morten Malmqvist's presentation 8.11.2024 HBR, presentation Morten Malmqvist ved IDA Brandteknisk Selskab 08.11.2022; video: Tagbranden i Vanløse - IDA Play, last access:29-01-2025)

9 An empirically based framework for problem-solving competence in the FRS

Work package 4 investigated key individual qualities that are needed for efficient collective problem-solving in an FRS context. In the overall study, several sub-studies were performed. First, problem-solving scholars were interviewed and their suggestions of relevant problem-solving literature were reviewed. After this initial stage, two workshops were conducted with FRS professionals (Räddningstjänsten Syd, or Rsyd, in southern Sweden and Hovedstadens Beredskab, or HBR, in Copenhagen, Denmark). A workshop was also conducted with professional Emergency Managers in the city of Malmö, Sweden, due to their close collaboration in emergencies with Rsyd. Finally, a survey was conducted in Norway, involving FRS in Oslo and Bergen and including collaborating partners in the local context.

This chapter briefly summarizes the main findings of the work package. For more details, see overall reports and material on each respective sub-study (Frykmer and Johnson, 2024b; a; Frykmer, Johnson and Uhr, 2024; Frykmer, 2025; Frykmer and Johnson, 2025).

In all sub-studies, input on key individual qualities for efficient collective problem-solving was received. The broad term, "qualities", was chosen intentionally to capture all important aspects, rather than zooming in on only knowledge or skills or capabilities etc. The suggested qualities were first categorised as individual, interpersonal and group/organisational aspects for an overarching analysis. For the five data sources (interview + literature study, workshop with Rsyd, HBR and Malmö, Norwegian survey), a number of important conclusions can be drawn.

Overall, the suggested qualities are rather similar across the five data sources. There are many overlaps, but there are also some answers that are unique for single studies. There is a slight overweight for Rsyd and the Norwegian survey concerning the group aspects. This could be due to how questions were phrased in the survey or how the qualities were discussed. Overall, there are fewer suggestions from the interview + literature study. Following is a summary of the most important qualities:

- In all 5 studies, qualities concerning being flexible/adaptable, able to rethink, reassess, think out of the box, see the situation from the outside or similar, are mentioned. This appears to be of great importance to solve problems effectively in a group context. The collective aspect is stressed by three studies when mentioning the ability to see and use/involve others in the problem-solving, i.e. to look for and include other perspectives.
- All four studies involving professionals describe the importance of having the courage or ability to make decisions under uncertainty. Further, being without prestige and being able to withstand stress and be calm are described in four out of the five studies.
- Professional or technical knowledge as a firefighter or commander is described in three studies, and three studies mention being creative as central.
- On a more interpersonal or group level, having good communication and sharing of information between group members, is described in four studies, and having diversity in groups and an allowing (tillåtande) organisational culture is brought up in three studies, respectively.
- It can be noted that the workshop qualities fit with interview/literature study results when it comes to emphasising an understanding of perspectives (on problem, roles, solutions, other organisations etc). Here, qualities as being able to rethink, reassess, reframe, being adaptable and flexible illustrate this quality.
- In addition, the results mirror the well-established view that to manage emergencies, this requires predetermined structures/knowledge/relationships in combination with being adaptive/ flexible/improvise.

To categorise the qualities further, the concept of *competence,* including a sub-set of relevant components, was used. In brief, competence is viewed as including both individually situated characteristics, both innate and job-specific knowledge etc. In addition, it recognises that group/organisational prerequisites as well as the emerging situation and context impact both how the individual applies his/her competence in the situation and how individual competence can be developed. Last, the relationships or interaction between group members are also taken into consideration when investigating individual qualities for effective collective problem-solving.

Following components are used to categorise the *individual* aspects of competence:

- **Innate capacities or talents** a person possesses that enable them to perform tasks. Examples are cognitive capacity and physical features.
- **Traits**, meaning personal characteristics or attitudes that influences how a person executes a task. Motivation is often part of this sub-category.
- **Knowledge**, understood as the theoretical understanding and information a person has within a particular area. This can be acquired through education, training and reading
- **Experience**, meaning practical application of knowledge, skills and innate capacities/talents over time. This provides context and depth to a person's understanding and performance.
- **Skills**, i.e. a person's practical abilities to translate knowledge into action and to perform specific tasks.

To explore how the components of competence above could be used to categorise the individual qualities, an internal workshop with researchers in the project FIRE21 was performed. Here, 11 members of the FIRE21 project team conducted a workshop on how the individual qualities could be categorised, using competence as a starting point. Participants were: 5 women and 6 men, 4 represented NTNU Social Research in Trondheim, 3 represented DTU, 1 represented RISE Sweden and 3 represented LU.

Participants were given the five sub-categories of competence described above and all qualities from the interview and literature study and the three workshops, including interaction and group aspects. The reason for not including the Norwegian survey was because it was not completed at the time.

The members were asked to, in three groups consisting of 3-4 participants, sort the qualities into the competence sub-components. To not limit the participants when exploring categorisation of the data, they were also allowed to sort the qualities in any other preferred framework or categories. The aim was to jointly find suitable categories to further analyse the qualities.

Using the results from the project internal workshop but also adding the Norwegian survey results, Table 3 summarises how individual qualities could be categorised into the competence framework. In addition, Table 4 describes important group/organisational competence.

Table 3: Categorising the qualities into individual competence. Colours refer to: black = interview and literature study, green = Rsyd, blue = HBR, red = Malmö stad, grey = NO survey. When mentioned by several groups, the colours are added.

Innate capabilities or talents	**Knowledge**	**Experience**	**Traits (incl. attitude)**	**Skills**
Ability to withstand stress (also Malmö) Be calm/show calmness (also Malmö, NO survey) Working memory, metacognition Analytical capacity (also HBR) Be creative (also HBR, NO survey) Have common sense (also NO survey)	Knowledge about responsibilities, roles, structures, the organisation/group, other organisations (also NO survey) Having basic firefighting knowledge and training Professional knowledge at a high level, and being trained at it To know oneself Having knowledge in other fields (see skills). Have relationships from before	Experience of FRS response operations (also HBR, NO survey)	Be loyal to the mission Working within routines Being motivated Being thorough, systematic, structured Being smooth (smidig) Be open-minded Be curious (also Malmö) Be prestigeless (also Rsyd, HBR, Malmö) Willingness to share information (also NO survey) Willingness to rethink, reassess, reframe Willingness to learn Willingness to work Take initiative (also HBR) Have the courage to /be able to make decisions (under uncertainty) (also HBR, Malmö, NO survey) Be courageous Being a fellow human (visa medmänsklighet) and concern To be a group member/team player (also NO survey) Be a role model	Have a holistic understanding Navigate/understand perspectives (on problems, roles, solutions etc) Understanding of perspectives Be able to understand the problem Read the situation, create a situation understanding Have integrity and put the problem in focus Put the human in focus Ability to focus on most critical tasks, solve critical tasks quickly and effectively Be able to rethink, reassess, reframe problems Be able to rethink, out of the box Be able to see the situation "from outside" Knowing when to give up and change strategies Ability to question and evaluate information/the problem representation Be uncomfortable and question Be able to zoom in/out Be flexible, agile, adjust to the situation Be able to listen (inlyssnande) Listen to others' suggestions Ability to involve others and find good solutions together See strengths in the group Knowing and using competence in the group Ability to see dependencies Ability to set a common direction, communicate the direction clearly Be able to delegate Be able to evaluate and monitor towards the goal Not controlling the group too much Ability to work independently (in line with common direction)

				Having (knowledge and) skills in other fields, being a carpenter, electrician, plumber, mechanic, health worker, farmer etc. Being good with tools. Being a jack-of-all-trades, knowing much of everything. Having communication skills Be able to increase/decrease the speed of operations ("gasa/bromsa") Be able to separate person from profession Be proactive Be able to look forward in time Ability to learn and reflect Create room for sharing experience (during incidents) "Köpa sig ledningsrum" (during incidents) Think before you act, use your head Be able to connect with others (skapa kontakt) Call a friend Being/having a translator/boundary spanner between group members Good, clear communication and sharing of information (also HBR, Malmö, NO survey) Good collaboration

The following group aspects of competence are described in the study. Note that the interpersonal/interaction aspects are renamed to fit the group/organisation aspect.

Table 4: Group/organisational competence. Colours refer to: black = interview and literature study, green = Rsyd, blue = HBR, red = Malmö stad, grey = NO survey. When mentioned by several groups, the colours are added.

Group/organisational competence
Group composition: leader/no leader, ad hoc/mature
Diversity in group Different competencies in group Having different perspectives in group
Allowing (tillåtande) organisational culture (also HBR, Malmö)
Having a leader, who delegates
To have clear structure in the group/organisation: mandates, roles, hierarchy
To have a common understanding in the group (also NO survey) - of problem representation and needs to have a common goal
Allow several individuals to come with solutions
Have trust in the group (also NO survey) Have respect in the group
Avoid groupthink Have a devil's advocate in the group
Trust between group members
Good teamwork, not own goals first
Having the "same language"
Having enough resources and tools
Well organised and robust FRS
Training often, well trained staff
Having enough time (also seen as a contextual factor)
Having motivated staff
"Allowing for" group members able to connect with others (skapa kontakt) and Call a friend
Ensure relationships are created from before
Having a translator/boundary spanner between group members
Having good, clear communication and sharing of information (also HBR, Malmö, NO survey)
Having good collaboration

The categorisation above shows that most qualities are interpreted as skills, mirroring the internal workshop sentiment that skills are what is needed in the end. Other competence sub-components are nevertheless crucial, because without these basic competences, individuals will not be able to develop the desired skills.

When it comes to categorising qualities into components of competence, we want to raise the issue that the categorisation could depend on the *attribute preceding the suggested quality*. Attributes such as "ability to", "willingness to", "knowledge of/about", "experience of/in" or "showing/having/being" largely decide how we view and subsequently categorise the qualities. These attributes can also be used to show the "progression" of qualities into skills.

We use the example of understanding of perspectives (UoP) to illustrate this reasoning. First, it is important to have *knowledge of* different perspectives in emergencies, be it different organisations' responsibilities and roles, others'/different perspectives on needs and problems. Further, knowledge about why UoP is important is needed. Subsequently, an individual needs *experience in* applying different perspectives over time, in real emergencies. Having that, the individual can develop the skill of *being able to* understand perspectives. However, how successful the individual is at developing this skill, could depend on innate capacities/talents or traits/attitudes. For example, *having* analytical capabilities or a *willingness to* rethink or reassess information certainly impacts the skill development. Finally, the group/organisation also influences whether certain qualities are applied or not, such as setting up diverse groups to allow for different perspectives or to have an allowing culture where individuals are encouraged to discuss and question each other's perspectives.

This illustrates the multi-faceted characteristics of problem-solving competence in the FRS. Problem-solving needs to be understood in light of both individual and group/organisational aspects, as well as the interaction between individuals. Categorisation into competence sub-components depends on the given attribute. Individuals are (more or less) born with innate capacities/talents and traits, which are difficult to influence, but knowledge, experience and skills can be more easily developed. Skills are what is desired to reach in the end. Organisational preconditions are interpreted as being both difficult and easier to influence.

Figure 15 illustrates these characteristics and, together with Table 3 and Table 4, constitute an empirically based framework for problem-solving competence in the FRS.

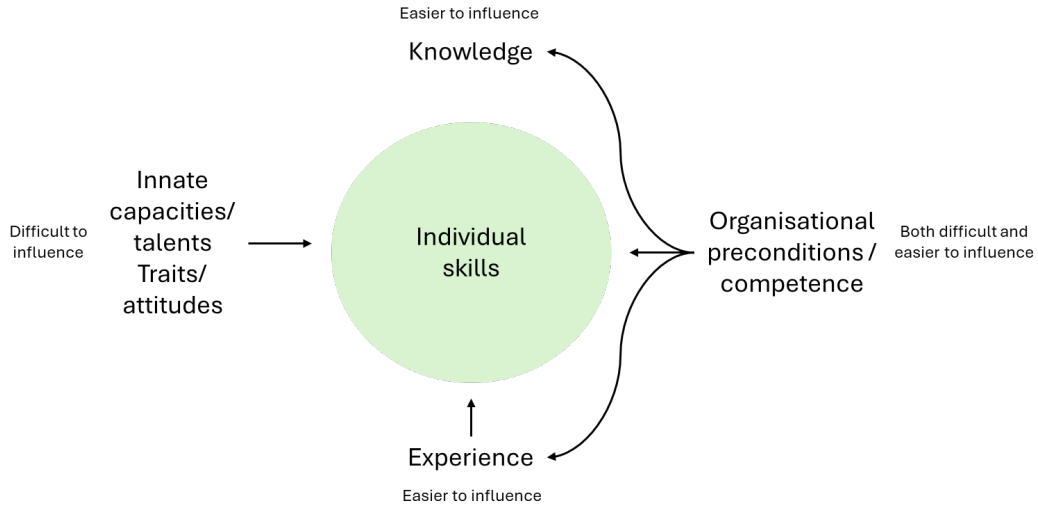

Figure 15: Problem-solving competence in the FRS.

The framework can be used by the FRS to develop problem-solving competence, both at the individual and group/organisational level. It can point to important skills that can be useful for the FRS when responding to emergencies. Here, it can be used to identify important knowledge, experience and/or innate capacities/talents or traits/attitudes that are informing/influencing an individual's set of skills.

10 Nordic Added Value

The project FIRE21 was a collaboration between Swedish, Norwegian and Danish partners. The focus has been on understanding problem-solving of large incidents from the perspective of the Fire and Rescue Services (FRS).

The **Nordic Added Value** of the FIRE21 project includes several key benefits that arise from cross-border collaboration among Sweden, Norway, and Denmark in understanding and improving problem-solving within Fire and Rescue Services (FRS).

Key Aspects of Nordic Added Value:

1. Harmonization of Terminology
    - One of the project's early challenges was the variation in terminology used across the three countries.
    - A significant outcome was the creation of a glossary of key terms, providing agreed definitions in English and translations into Swedish, Norwegian, and Danish.
2. Comparative Risk Mapping
    - The project mapped the current risk landscape across the three countries, identifying shared challenges such as climate change risks and geopolitical uncertainties.
    - This comparative approach helps improve emergency preparedness and response coordination across the Nordic region.
3. Knowledge Exchange and Case Study Comparisons
    - FIRE21 analyzed case studies from each country, revealing both similarities and differences in FRS structures, operational approaches, and response strategies.
    - These insights enhance mutual learning and best practice sharing across national borders.
4. Theoretical Contributions to Problem-Solving Networks
    - The project introduced the concept of "possibility space" as a theoretical tool to understand how FRS personnel adapt to complex emergencies.
    - This framework supports better incident learning and decision-making for future crises.
5. Strengthening Cross-Border Collaboration
    - The project highlights the importance of joint emergency response efforts, particularly for transboundary risks like wildfires, floods, and security threats.
    - Enhanced information sharing and cooperation among Nordic emergency services ensures a more resilient and adaptive FRS network.

By leveraging Nordic cooperation, FIRE21 has created a stronger foundation for problem-solving in the region’s fire and rescue services. The project's findings contribute to more effective, technology-driven, and well-coordinated emergency responses in an increasingly complex world.

11 Recommendations

This document summarises key recommendations from project FIRE21. The recommendations are based on results from 1) professionals through the workshop with FRS South (Rsyd, which included Bulöv, Eslöv, Kävlinge, Lund and Malmö municipalities) and the Norwegian survey (both in work package 4) and 2) acquired experiences and knowledge from project members. Details can be found in the full reports (Frykmer, 2024a; Frykmer and Johnson, 2024b; Iliopoulos and Frykmer, 2024; Frykmer, 2025).

11.1 Key recommendations from professionals

In the workshop with Rsyd and in the Norwegian survey, we posed the question of whether they thought that there will be a need for new qualities in the future, and, if so, which. Here, the answers are presented as recommendations on which qualities to prepare for and develop to meet future needs.

Rsyd described that they might have to handle a new generation where individualism may be more important than the collective, which could lead to less efficient collective problem-solving. Further, they mentioned a need to keep up to date on new knowledge and an ability to collaborate with "new" (as yet unidentified) organisations.

Table 5 contains a summary of suggestions of new qualities from the Norwegian survey (shortened in relation to the original table for this report).

Table 5: Summary of future qualities from the Norwegian survey.

New qualities needed in the future
Team competence
Communicative qualities, to better collaborate with other agencies and the public.
Leadership education, pedagogical and social competence.
Educating leaders
Future-looking / specific /building technical competence
Important to stay updated. There will be more electrical and hydrogen-based vehicles.
Competence on new energy carriers
More competence on artificial intelligence.
Battery fires and weather-related events will increase.
Increased competence with solar power and car/boat batteries.
Fighting extreme weather
Increased competence on natural events like flooding and landslides, will affect building collapses.
First aid when it comes to gunshot wounds and knife wounds.
Larger battery packs. High voltage in solar power. Larger events at sea.
Increased focus on collaboration, have a common goal. Maybe course on operative psychology and team building.
Increased collaboration between several FRS (focusing on the joint command system).
Society demands closer collaboration between agencies to reach a good level of preparedness in relation to future scenarios.
Focus on societal needs and not on what the FRS can and wants to do.
Increased focus on health, environment and safety to reduce risk for firefighters before and during incidents.

Need for more competence within health and mental problems.
Interdisciplinary competence in the team
Don't forget the team. If the team is built in peacetime, we can adjust to changes in the society.
More and better exercises focusing on communication.
Training on larger and more complicated events with many actors.
Assignments/course/exercises on how groups collaborate.
Need to use drones
Common situation understanding.
Control stress
Risk of qualified people choosing other professions, we will not get the best people like we do today, based on current changes in education (vocational school leading to less heterogenous groups. Competence within electricity/ventilation/plumbing/building construction/mechanics is needed.
Practical competence and practical understanding.

11.2 Key recommendations from project members

As part of the project, an internal workshop was organised to brainstorm on potential problems for the fire and rescue services, and recommendations on how to improve the handling of these problems. Table 6 summarises the recommendations, per so called problem cluster. Also, a potential organisation that could develop the recommendation is suggested.

Table 6: Summary of project recommendations.

Problem cluster	**Recommendations**	**Potential organisation to develop recommendations**
Understanding, identifying, solving problems	Developing taxonomies, validate/test with FRS. Develop checklists to be used in emergency call centres, e.g. on which actors to involve.	Research institution in collaboration with FRS FRS
Managing tunnel fires	Use the toll system to monitor type of fuel and cargo entering the tunnel.	National authorities (Authorities having jurisdiction, AHJ), Research institutions
Geographic scope	Develop information technology for early warning systems, and for planning/distributing resources Use drone technology for overview. Look into literature on distributed decision-making/problem-solving, situation awareness, common operational pictures. Develop individuals' communication skills. Test different ways to present information.	Research institutions, private companies, AHJ, FRS FRS Research institution in collaboration with FRS FRS Research institutions
Information problems	Look into IT tools/systems for collecting and presenting data, and AI tools for analysing data. Include education on ethical aspects of using such tools.	Research institution in collaboration with FRS

	Develop alternative analogue means for data handling to establish independent redundancy in case power grid fails or loss of satellites.	FRS in collaboration with volunteers/amateur radio groups
Antagonistic threats	Acquire knowledge of antagonistic threats. Develop capabilities for grasping and conceptualising antagonistic threats. Increased collaboration with the Police.	FRS, assisted by research institution and/or security agencies Research institution in collaboration with FRS FRS
Technological challenges	Increase knowledge and training on analogue or "low-tech" communication tools. Introduce "fire mode" in buildings to unlock doors, windows in case of fires. Have knowledge of cell phone coverage. Improve digital competence.	FRS in collaboration with volunteers/amateur radio groups AHJ, FRS FRS FRS
Structural problems	Closer cooperation between the FRS and city planning departments. Accessibility to building Information Modelling (BIM) and related software in operations. Co-location of response actors. More practice-oriented education for the FRS. Train for key scenarios. Use careful and bottom-up-oriented approach to structural changes. Use a practice-informed SWOT analysis for investigating effects of structural changes.	FRS and city planning departments Private companies, FRS and local authorities Relevant response actors FRS FRS National emergency management agencies (DSB, DEMA, MSB),
Working under "disturbed" conditions	Increase FRS knowledge and training on analogue or "low-tech" communication tools. Introduce nodes of experts/volunteers who can operate "low-tech" communication tools.	FRS in collaboration with volunteers/amateur radio groups FRS in collaboration with volunteers/amateur radio groups

Following aspects around these recommendations are noteworthy:

- Same typology of recommendations for different problems

Several typologies of recommendations were proposed to address problems of different nature, and, therefore, seem to hold potential. These are: IT solutions to address technological/information challenges, problems related to the geographical scope of events and managing tunnel fires. Education and training, for structural problems, working under disturbed conditions, technological challenges, and antagonistic threats. Knowledge enhancement is also seen as important.

- Solutions create sub-problems

A suggested solution may also create secondary problems, such as overreliance on IT solutions, or co-locating FRS and partner organisations.

- Conceptual vs technical skills

Both kinds of skills are important for the FRS, and ought to be developed in a balanced manner. Conceptual skills are necessary to address the problem cluster of “Understanding, identifying and solving problems”, but also to be able to visualise and understand problems related to the cluster of "Geographical scope". Technical skills are at the same time necessary to implement solutions. This type of knowledge is prevalent in the recommendations for different clusters, in relation to the need to enhance education.

- Negative ripple effects of structural changes

When restructuring top-down towards larger and more specialized fire and rescue services, the qualities in the rural fire and rescue services might be lost. Therefore, it is crucial to be aware of how to keep local knowledge and resources for emergency preparedness in small communities when restructuring fire and rescue services from above. Suggestion is to use a bottom-up analysis to investigate possible effects of such changes

11.2.1 Prioritising recommendations

Following recommendations were seen as most important by the two project participants who suggested how to prioritise recommendations:

Efficient sorting and validation of information as it is vital for improving how we identify, understand, and solve problems. IT and AI developments are useful for assisting in decision-making; however, validation and filtering is important to prevent misinformation or conflicting information.

A wider use of drones as a standardised equipment for FRS. FRS personnel can be further trained in the use of drones and in analysing data and imagery.

More training on “low tech” means of communication. New technologies allow for richer and more comprehensive data transfer; however, they are also more dependent on functioning power grid and satellite systems. These can both be subject to failure and a backup solution needs to be in place. Analogue communication back-up alternatives and relevant skill development can provide a safer means of communicating during the worst-case failure scenario.

The changing risk picture and the operational differences between urban and rural areas imply a difference in the way FRS respond to different types of incidents. An interactive actor map can help navigate a complex landscape of actors involved and the relevant responsibilities and tasks during an incident.

11.3 Considerations emerging from case studies

Also from the case studies, there are some important considerations that can be taken into account when designing the FRS of the future. These considerations are to some extent overlapping, as well as country- and case-specific. Nonetheless, considerations of the different requirements represented by greatly varying population density in different municipalities is particularly marked in Sweden and Norway and considerations rising in one country are largely valid for the other.

11.3.1 From Norwegian cases

Considerations emerging from the Norwegian cases are largely about structural conditions. Authorities aim for larger and more professionalized FRS. At the same time, they recognize the importance of maintaining the unique qualities rural FRSs offer, such as multiple competencies, local knowledge and informal relationships. This is because the density of professional competence, lack of special equipment in immediate proximity and long distances can and will never be compensated for in sparsely populated areas. The goal is to balance or merge these qualities into larger and more professionalized FRSs in order to have a good or better level of preparedness.

Our research indicates that careful thought must be given before expanding FRS. The key qualities that are vital for rural FRSs and their preparedness—such as local knowledge, the complementary skills fostered by tight-knit communities, a strong sense of commitment to the local area, and the intrinsic motivation to serve as a PTFF—are not guaranteed to persist in larger, centralized structures. Authorities need to be aware of which rural FRS qualities may be lost in this centralization process. Without compensatory measures, they may need to reconsider or even reverse certain restructuring plans until these measures are in place.

11.3.2 Swedish cases

Analysis of the Swedish cases indicates that by zooming in and out on different problems and sub-problems in an incident, organisations can identify important components and types of relationships needed to solve the problems and use this as an input to their learning process. The learning outcome from the urban explosion incident provides the following main lessons: breaking down a complex problem into more manageable sub-problems makes the problem clear and easier to identify which resources are needed to solve the problem in hand, although a downside of this approach is potentially the risk of losing the overall holistic understanding of the situation; informal contacts are important to be able to solve problems at the scene of an accident, exemplified by the support provided by locals close to the incident; understanding different roles and responsibilities facilitates rapid problem-solving; problem-solving is not only affected by the people and organisations involved in the incident, but artifacts and potentially technical systems.

Identifying relationships and components needed to solve problems, the FRS could plan and exercise for important components for problem-solving during emergencies. Using relevant division of problems into sub-problems helps to determine which aspects of incident response are related. This method of post-incident analysis can provide important insights for planning of future events. This approach could also assist the FRS in managing relationships, identify vital resources, and better comprehending the efficacy of different relationships in addressing emergency challenges.

Improved collaboration between various stakeholders with a vested interest in resolution of an incident is also a key finding in the case evaluations, despite the fact that the FRS was the focus for all evaluations.

11.3.3 Danish cases

The considerations emerging from the Danish cases are on one hand technology related and on the other hand related to the requirements of modern societies. The performed re-organisation to larger emergency services some years ago is perceived as very positive by the rescue services and has proven its value through the described cases already. Part of the learning was that large emergencies need the gathering of better information and best real time two-way communications between the various functions. Here, clearly technology is very useful to gather information and to make better decisions. More real-time information is important, but at the same time there might be a drawback in processing, reflecting and communicating the enormous amount of real data that will be provided and to filter out the important facts to make the right decisions.

The other consideration is about societal changes in the society. Related to the FRS, there are concerns and difficulties to motivate and have sufficient part-time fire fighters and volunteers showing up when an emergency occurs. This is related partly to the civil occupations and the demands the employers have. Hereunder one problem could be the employees increased mobility at work to serve customers within a wider radius compared to the past. From the interviews, the FRS are clear about this challenge and have different strategies to handle it.

The modern society becomes more complex with many new technological developments, e.g. sustainable building materials and sustainable transport to cope with climate change. This increases the requirement for some specialized knowledge within the FRS. Here, it got obvious that the situation for part time and full-time firefighters is different, because of the time spent for the FRS. This also relates not only to the more complex emergency situations, but also when operating advanced equipment and clearly it is a question of continuous training received.

12 Future Work

In the project, we have identified areas for future work. These areas build upon findings in the project or derive from limitations to the conducted work.

First, future work could concern new risks that were not identified in the project. Here, risks associated with the changing geopolitical situation could be explored, including the increased importance of civil defence and how this impacts information sharing and collective problem-solving. It is apparent that well-functioning joint problem-solving will be required to prepare for and respond to antagonistic threats to the Nordic countries, i.e. threats that transcend national borders. Associated with antagonistic threats, future research could investigate important individual qualities for the FRS to solve problems collectively in the context of war or heightened alert. Such qualities will be needed to build capabilities for civil defence. This could be explored in light of experiences from the war in Ukraine, and through empirical research in the Nordic FRS.

Second, the project has mainly studied the response part of the emergency management cycle. Future work could investigate problem-solving networks established and utilized when mitigating risks and preparing for emergencies. Also, future work could examine complex problem-solving from the perspectives of different first responders (and even other stakeholders).

Third, based on the project findings on individual qualities for collective problem-solving, future research could examine which are the most important qualities for the FRS. Such research could include expanding data collection to a broader segment of Nordic FRS, to validate qualities. It could also include testing of how relevant qualities really contribute to more effective problem-solving through, for example, experiments.

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