UiT The Arctic University of Norway

Faculty of Science and Technology

Communication and Technology in Wildfire Emergency Response in Norway: Current Methods, Improvement Potential, and Barriers

Anette Mauno Torbjørnsdatter

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Summary

In recent years, rising temperatures have contributed to the spread of wildfires globally, including in Norway. Record high temperatures and wildfires are placing increasing pressure on the country's fire and rescue services, highlighting the need for effective wildfire response strategies. This study explores how effective communication, and technological advancements can lead to a more successful wildfire response in Norway. It identifies key communication methods used during wildfire response, potential improvements, and barriers to implementing new technology.

The study is conducted as a qualitative case study, gathering empirical data through participant observation, document analysis, and interviews with key personnel in the fire and rescue services. Based on the discussion of three research questions, I have addressed the main research problem: *In what ways can communication be enhanced and how can technological advancements contribute to a more successful wildfire response operation in Norway?*

The study shows that current communication methods in wildfire management, such as direct and radio communication, are important but face challenges with multiple conversation groups and inter-organizational communication. Technical and Digital tools like drones and real-time information systems enhance information sharing but can lead to incorrect resource allocation and over-reliance on technology. Traditional methods, such as paper maps, are crucial backups but are slower and less efficient. Improved communication requires comprehensive training, standardization of equipment, increased use of digital tools, and better collaboration through joint exercises. Economic, technological, and organizational barriers must be addressed, additionally, increased funding and establishment of national wildfire teams for better response is recommended. This approach is supported by previous research emphasizing the importance of communication, collaboration, and technological innovation in emergency management.

Foreword

With this master's thesis, I conclude a five-year academic journey at the University of Tromsø, the Arctic University of Norway, in the field of societal safety within the Faculty of Science and Technology. I would like to thank Ole Anders Holmvåg for initiating this thesis, and for guiding me through the initial steps. Additionally, I extend my thanks to the team at RISE Fire Research for the engaging exercise in which I had the opportunity to participate, and for their guidance and close supervision. Thank you for entrusting me with the task of writing this thesis for you. Similar gratitude is extended to Tiril and Tord at Jotne. Thank you for your guidance and input along the way. I also would like to express my heartfelt gratitude to my two brilliant supervisors Maria Sydnes and Ragni Fjellgaard Mikalsen, for their excellent guidance and insightful discussions. This thesis is the result of your belief in me and your constant support. Thank you for your patience and warmth. I also wish to express my heartfelt appreciation to my beloved family, who have stood by me throughout this journey. Without your unwavering support, this thesis would not have been possible. Finally, I would like to extend a sincere thank you to all the informants who contributed to this thesis. Your insights and input have been invaluable, and I am grateful for the opportunity to learn from your perspectives.

Anette Mauno Torbjørnsdatter
Tromsø, June 2024.

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Glossary

An overview of the terms used in this study is provided in Table 1.

Table 1: Terms, definitions and abbreviations used in this study, with Norwegian translation.

Abbreviation/Terminology	English	Norwegian
TETRA	Terrestrial Trunk Radio (TETRA) is a secure digital radio system used for critical communication by emergency services and public safety organizations.	Det engelske begrepet brukes også i norsk tale. Det eksisterer per i dag ingen offisiell norsk oversettelse av dette begrepet. TETRA er et sikkert, digitalt radiosystem som brukes til kritisk kommunikasjon av nødetater og offentlige sikkerhetsorganisasjoner.
CIM	Crisis Information Management	Kriseinformasjonshåndtering
RAYVN	RAYVN is a digital platform used in the Norwegian crisis management context for handling emergencies and incidents.	RAYVN er en digital plattform brukt i norsk krisehåndtering for å håndtere nødsituasjoner og hendelser.
LOKUS	Local and Operational Mapping and Equipment System (LOKUS) is a digital mapping and planning system used for coordinating emergency responses.	Lokalt og Operativt Kart- og Utstyrssystem (LOKUS) er et digitalt kartleggings- og planleggingssystem som brukes for å koordinere nødsituasjoner.
ELS	Incident Command System	Enhetlig Ledelsessystem
DSB	Norwegian Directorate for Civil Protection (DSB) is responsible for maintaining public safety, emergency preparedness, and civil protection.	Direktoratet for samfunnssikkerhet og beredskap (DSB) er ansvarlig for å opprettholde offentlig sikkerhet, beredskap og samfunnsbeskyttelse.
BAPS	Fire, Ambulance, Police and Civil Defence	Brann, Ambulanse, Politi og Sivilforsvaret
ILKO	Incident Command Post	Innsatsleders kommandoplass

Leadership	Leadership in this study refers to the incident commander, sector commander, and area commander at the incident site, as well as leadership support and organizational leadership within the fire service.	Ledelse i denne studien refererer til innsatsleder, sektorleder og teigleder på skadestedet, samt lederstøtte og organisatorisk ledelse i brannvesenet.
Drone	Also termed UAV, or unmanned aerial vehicle. A technical tool operated without a human pilot on board. It is controlled either remotely by a human operator or autonomously by onboard computers.	Også kalt UAV, eller ubemannet luftfartøy. Et teknisk verktøy som opereres uten en menneskelig pilot ombord. Det styres enten eksternt av en menneskelig operatør eller autonomt av innebygde datamaskiner.

Attachment Overview

Table 2: Overview of attachments.

Attachment 1	Coding Frame - Communication and Technology for Wildfire Emergency Response in Norway: Current Methods, Improvement Potential, and Barriers.
Attachment 2	Preparing Questionnaire for Semi-structed Interviews.
Attachment 3	Focus Group Interview Guide.

1 Introduction

Recent years have seen a rise in extreme heatwaves, significantly contributing to the spread of wildfires. Research indicates a global trend where the climatic increase in temperature leads to increased wildfire incidents across the continents, with concurrent reports from South America, North America, Australia and Europe (San-Miguel-Ayanz et al., 2021). In the summer of 2022, the United Kingdom experienced record-breaking temperatures, with readings exceeding 40 degrees Celsius in London. The elevated temperatures resulted in a wildfire outbreak of such magnitude that it was reported fire crews had not encountered a comparable level of resource utilization since World War II. (CNBC, Weather and Natural Disasters, 2022, paragraph 1). Similarly in the summer of 2018, Norway faced a record-breaking total of 114 wildfires in a single day (Direktoratet for Samfunnssikkerhet og Beredskap, 2022), which is an exceptionally high number for the country. Since 2016, a total of 3,542 wildfires have been recorded in forests and uncultivated land in Norway (Brannstatistikk.no). The increase in wildfires significantly impacts the fire and rescue service in Norway, particularly challenging the response capacity and resources allocated to combat these fires (Meld. St. 16, (2023-2024)). These ongoing developments underscore the seriousness of the threat posed by wildfires and highlight the need for an increased focus and progress on appropriate wildfire prevention and prompt response when wildfires occur.

In addressing the growing pressure on response organizations, effective communication becomes crucial. Communication is the backbone of effective emergency management, playing a pivotal role in the coordination and execution of response efforts (Kapucu, 2006b). In the context of wildfires, the complexity and often rapidly changing nature of the situation make robust communication systems essential for success (Luokkala et al., 2017). Effective communication processes enable responders to perceive, generate, and disseminate critical information accurately and promptly (Luokkala et al., 2017), and a critical aspect of any communication process during a response operation is how information is shared among response personnel (Weick, 1993). Several factors can influence information sharing processes, such as inadequate equipment, training deficiencies, or organizational challenges (Engen et al., 2021, p. 365). The lack of effective information sharing among emergency responders can significantly undermine the effectiveness of the response (Engen et al., 2021, p. 365) or, in the worst-case scenario, contribute to the escalation of the incident (Weick, 1993).

To address information sharing challenges, and ensure clear and unambiguous communication, a unitary incident command system (ICS/ELS) was developed and published in 2011 in a cooperative effort by the Norwegian Directorate for Civil Protection (DSB), the Norwegian Coastal Administration and the Norwegian Climate and Pollution Agency (Klif) (DSB, 2011). The goal was to provide a standardized management framework that can handle incidents professionally, efficiently, and safely, regardless of their type or scale. This standardized approach is particularly crucial in large-scale incidents such as wildfires, where extensive distances necessitate reliable communication methods. In such scenarios, technical communication tools become indispensable.

Recent technological advancements in emergency communication enables the use of internet-based systems such as network communication and information-sharing platforms, and the technology holds significant potential for reducing costs, improving processes, and enabling faster information flow (Engen et al., 2021, p. 252). An application of such novel systems is real-time information sharing between different emergency services by situational reporting tools (Harrald, 2006). Concurrently, emergency services have approached these innovations cautiously, exhibiting resistance to technological advancements (Engen et al., 2021, pp. 253-254). One reason for this resistance may be cultural opposition within the organization, where personnel is reluctant to changing the established routines and practices, especially if they have experienced successful use of the existing routines in the past (Warrick, 2023). At the same time, technology may contribute to emergency response enhancement by providing real-time data, improving coordination, and facilitating better decision-making through advanced communication tools and predictive analytics. (Engen et al., 2021, p. 252).

Responding to wildfires is resource-intensive, requiring fire responders to make quick decisions in uncertain, time-sensitive situations, with the safety of critical infrastructure, natural environments, and human and wildlife populations at stake. Efficient decision making may be inhibited by ineffective communication and information sharing (Bui et al., 2000), especially when rapid data assimilation, processing, and accurate wildfire predictions are required. Irrespective of the extent of experience or preparation, individuals, when faced with complex and unpredictable events, encounter a cognitive saturation point where further information absorption becomes infeasible (Weick, 1993). Consequently, the capacity for effective and clear communication becomes impaired.

Given that wildfires can escalate into large-scale incidents with significant geographical, environmental, and infrastructural impacts, studying communication processes in wildfire response to gain insight on how to improve the response efficiency is essential. Therefore, this study aims to identify factors that influence effective communication during wildfire response, as well as the barriers preventing the adoption of new communication-enhancing technologies, and ultimately apply this information to suggest actionable improvement points. Understanding these elements is crucial, as it can significantly contribute to the success of wildfire response.

1.1 Previous Research

Systematic research on wildfire management gained traction in the United States with the establishment of the United States Forest Service in 1905 (Pyne, 1982). Historically, early research focused heavily on wildfire suppression, but by the mid-20th century, there was a shift toward an ecological perspective that emphasized the use of fire as a mitigating factor against wildfires (Donovan & Brown, 2007; Agee, 1993). Ongoing research opts for a more comprehensive approach to wildfire management that integrates biophysical and socio-political dimensions to address the growing complexity of wildfires (Essen et al., 2022). The need for adaptive strategies that extend beyond traditional fire suppression has become increasingly recognized. However, progress in the response phase is of great importance as this is where the actual firefighting takes place. Steelman and Nowell (2019) propose a cohesive strategy for wildfire management that emphasizes the importance of co-management across levels of operation. Their methodology includes network-based concepts to improve coordination and communication. The strategy's effectiveness heavily depends on the existing capacity and willingness of institutions to adopt adaptive measures, highlighting the need for more flexible and universally applicable solutions. Bodin and Nohrstedt (2016) examine the formation and performance of collaborative networks in managing wildfire responses in Sweden. Their research underscores the importance of inter-agency cooperation and the role of social networks in effective emergency management.

In the Norwegian context, wildfire research has gained traction over the past decade, aligning with global trends by primarily focusing on wildfire management from a mitigation and prevention viewpoint. Gjedrem and Metallinou (2023) approach wildfire management from a risk reduction and fire mitigation perspective. Their study focuses on the fire and rescue services' risk perception, tactical decisions, and lessons learned from dealing with

wildland-urban interface (WUI) fires in Norwegian coastal heathlands. The focus is on identifying effective measures to reduce fire hazards, improve preparedness, and enhance community resilience against future wildfires.

Several studies highlight the increased wildfire risk resulting from altered vegetation management practices and how mitigating measures can reduce this risk. Log and Gjedrem's (2022) case study of the Sotra fire examines how vegetation management in Norway, through regular burning cycles and livestock grazing, has resulted in an accumulation of biomass that increases wildfire risk. Additionally, they explore how climate change contributes to making the region more susceptible to wildfires. The study also observes how the Sotra fire exhibited intense and unpredictable behavior, highlighting the fire's ability to jump across fjords, which complicated the firefighting efforts. This research points to the growing challenges of managing wildfires in the coastal areas of Norway's WUI. It reveals gaps in current fire management practices and emphasizes the need for adaptive strategies that incorporate both immediate and long-term measures.

Metallinou (2020) explores the development, activities, and learning processes of a civic group in Norway that has taken up the practice of prescribed burning to manage landscapes, taking on a preventive approach to wildfire management. Log et al. (2020) focus in their study on the potential benefits of new tools and frameworks for fire disaster prevention in Norway and other regions. The study examines the increasing fire risks in WUI areas, particularly those involving wooden structures in Norway. It links this heightened risk to changes in climate, land use, and habitat management, and proposes the development of new dynamic and adaptive fire risk assessment and management tools. The authors emphasize the importance of interdisciplinary approaches, stakeholder involvement, and innovative research to mitigate fire disasters, with a focus on temporal changes in fire risk and the need for effective risk communication and management strategies.

In a more response-oriented approach, Sørensen et al., (2020) concludes that participation in wildland-fire collaboration exercises in Norway significantly enhances perceived learning among participants. However, it also highlights that this type of learning does not fully translate into perceived utility in real-life scenarios. The primary conclusion of the study is that effective collaboration is essential for emergency management and can significantly enhance response outcomes (Sørensen et al., 2020). Furthermore, Fernandez-Anez et al. (2021) focus on fire management strategies. The study highlights that there is

insufficient research on the effectiveness of different fire management strategies and their adaptation to changing climate and land use patterns (Fernandez-Anez et al., 2021).

Since this study examines the response from the fire service's perspective, a thorough search was conducted to find previous research on fire and rescue service responses to various events. Storesund et al. (2018) focus on the operational efficiency of fire and rescue services, highlighting the need for better coordination and clear regulatory definitions to improve response times. They argue that enhancing operational procedures and streamlining processes can significantly reduce response times, ultimately leading to more effective emergency response. Brændeland and Refsdal (2013) take a risk management approach, concentrating on the decision-making processes that occur during emergency responses. They stress that early-stage decisions are critical and that a lack of proper risk assessment can lead to increased dangers for both responders and civilians.

In the Norwegian context, recent studies have concentrated more on preventive measures and risk mitigation, and less on the operational response phase. However, there are a few articles that, in the context of fire services in the northern region, examine aspects of emergency response; Steelman and Nowell (2019) and Bodin and Nohrstedt (2016) underscore the critical role of effective communication, coordination, and institutional adaptability in managing wildfires. The communication aspect is particularly relevant to this study, as it focuses on how effective communication can enhance wildfire response and improve management strategies. However, the practical application of these strategies depends on the readiness and capacity of institutions, emphasizing the need for research that explores how to enhance communication and technological integration within fire service response efforts. This undertaking would address existing gaps, such as the lack of integrated communication systems (Essen et al, 2023), or how advances in technology could better support firefighting efforts (McLennan et al., 2005), by providing concrete strategies to improve wildfire response in Norway.

1.2 Research Purpose

The premise of this thesis is that the risk of wildfires is increasing in tandem with climate change. This presents new challenges for the Norwegian fire service and the current national wildfire response strategy, as we face fires with new characteristics and greater intensity than those previously encountered in Norway. The aim of this thesis is therefore to investigate how the fire service communicates during wildfire response and how to optimize

communication processes within this context. Furthermore, it will be crucial to examine which technology that are currently in use, and to identify potential for implementing new technology to improve the overall response on wildfires. This thesis intends to contribute to our knowledge in these areas of study.

1.2.1 Problem Statement and Research Questions

Building upon the preceding discussion, I hereby propose the following problem statement for consideration:
"In what ways can communication be enhanced and how can technological advancements contribute to a more successful wildfire response operation in Norway?"

To answer the problem statement, the following research questions are posed:

1. *Which specific communication methods and tools are utilized in the response to wildfires, and how do they facilitate information sharing?*
    - The research question aims to examine which specific communication methods and tools are currently utilized in the response to wildfires in Norway, and how they facilitate information sharing.
2. *What specific elements of communication in wildfire management operations can be improved, and which strategies or technological tools can be employed to enhance these elements?*
    - The research question aims to examine which specific elements of communication in wildfire management operations can be improved, and which strategies or technological tools can be employed to enhance these elements. Referred to as improvement potentials.
3. *What are the key barriers to the successful implementation and adoption of new technology for enhancing response in wildfire management?*
    - The research question aims to examine what the key barriers are to the successful implementation and adoption of new technology for enhancing response in wildfire management, and how these barriers can be addressed.

1.2.2 Limitations

The thesis examines how various communication systems and technologies impact the effectiveness of wildfire response. The theoretical framework does not theorize this context but presents the organization and processes of the fire service during wildfire response in the

context chapter. The framework is based on the emergency management cycle, which includes prevention, preparedness, response, and recovery phases (Haddow et al., 2008; Waugh, 2015). The focus is primarily on the response phase, though elements from other phases are included to provide a comprehensive understanding of emergency management.

This focus is justified by the study's aim to explore general improvements in wildfire response rather than specific incidents (Bumgarner, 2008; Canton, 2019). The theoretical framework primarily examines how technology and communication can enhance the emergency plans foundational to the fire service's response efforts, excluding an in-depth analysis of social and psychological aspects. The technological tools used in wildfire response are complex and context-dependent, making it difficult to define the conditions and factors affecting their effectiveness (Kapucu & Garayev, 2013).

The interdependency of the emergency management phases makes it challenging to isolate the response phase from the others (Ramsay et al., 2020). While it may seem paradoxical to limit the focus primarily to the response phase, the intent is not to cover the entire emergency management cycle. Instead, the emphasis is on addressing the most urgent needs in modern wildfire response, particularly technological integration and effective communication (Kapucu & Garayev, 2013; Pine, 2017). The goal is to investigate whether the fire service possesses the communication and technological tools necessary to improve response effectiveness during wildfires.

The introduction of new technology can introduce vulnerabilities into systems, adding layers of complexity and potential points of failure (Engen et al., 2021, p. 243). This study does not conduct an in-depth analysis on these vulnerabilities but discusses them briefly as limitations. Incorporating new technologies can expose emergency response operations to risks such as system malfunctions, cyber-attacks, and over-reliance on automated processes, which might reduce responders' ability to make critical decisions independently (Pine, 2017; Kapucu & Garayev, 2013). Recognizing these potential issues is crucial for a comprehensive understanding of technology integration in emergency management.

1.3 Structure of the Thesis

In chapter two, I present the context of the thesis, focusing on the organization and processes of the fire service during wildfire response. Chapter three outlines the theoretical framework of the study, which includes Emergency Management and Response,

Communication, Information Sharing, and Technology. Chapter four details the methodological choices and considerations made throughout the research. Chapter five presents the empirical findings of the study. In Chapter fix, these findings are discussed and linked to the theoretical framework and previous research. Finally, Chapter seven offers the conclusion, reflections, and suggestions for future research.

2 Context of the Thesis

To understand the communication processes within the Norwegian fire service and the context in which this study examines wildfire response, it is necessary to present this information in a dedicated chapter. This chapter will provide insight into the TREEADS research project before it shifts focus to the organization and command structures of the fire service, detailing how they typically operate during a response.

2.1 Research and Innovation Project TREEADS

This study is part of the TREEADS research project. The TREEADS project is a European research endeavor that commenced on December 1, 2021, with a planned duration of 3.5 years. This collaborative initiative encompasses the participation of 13 European countries and Taiwan, with the primary aim of establishing a comprehensive fire management platform for addressing wildfires. The overarching objective of the project is to integrate the ternary phases of wildfire management—namely, prevention and preparedness, detection and response, and restoration and adaptation—under a unified framework. I have been granted the opportunity to undertake my master's thesis as part of the TREEADS project through my affiliation with RISE Fire Research, which is a part of RISE Research Institutes of Sweden. One of my academic mentors is affiliated with RISE Fire Research, providing me with access to the European wildfire research community and associated innovation companies, who are integral project partners. My master's thesis will be fully integrated into the project, allowing me access to the data resources that will underpin my research. Moreover, I will have the privilege of validating my research findings in collaboration with the esteemed scientists at RISE Fire Research.

As part of this collaborative European initiative, a Norwegian pilot program is currently underway. The Norwegian pilot focuses on understanding the characteristics of Norwegian wildfires on the wildland-urban interface, and on streamlining rescue and logistical processes through standardization of data from devices and sensors, in accordance

with pertinent ISO standards. My research project will facilitate this streamlining, with knowledge and understanding of the role of communication and the potential use of new technologies in the context of fire services' response to large and intricate wildfires. This endeavor presents an opportunity to explore the potential contributions of emergent technologies within the domain of wildfire management, and how technology is utilized in communication and information sharing processes.

2.2 Organization of Fire Service Response in Norway

In Norway, the organization of the fire and rescue services differs from the police and ambulance services in that they are not state operated but are organized under the municipalities to which they belong (St. Meld. 16 (2023-2024)). Fire services across the nation operate under the same fundamental principles, but their structuring and resourcing are tailored to local economies and aims to address specific municipal challenges.

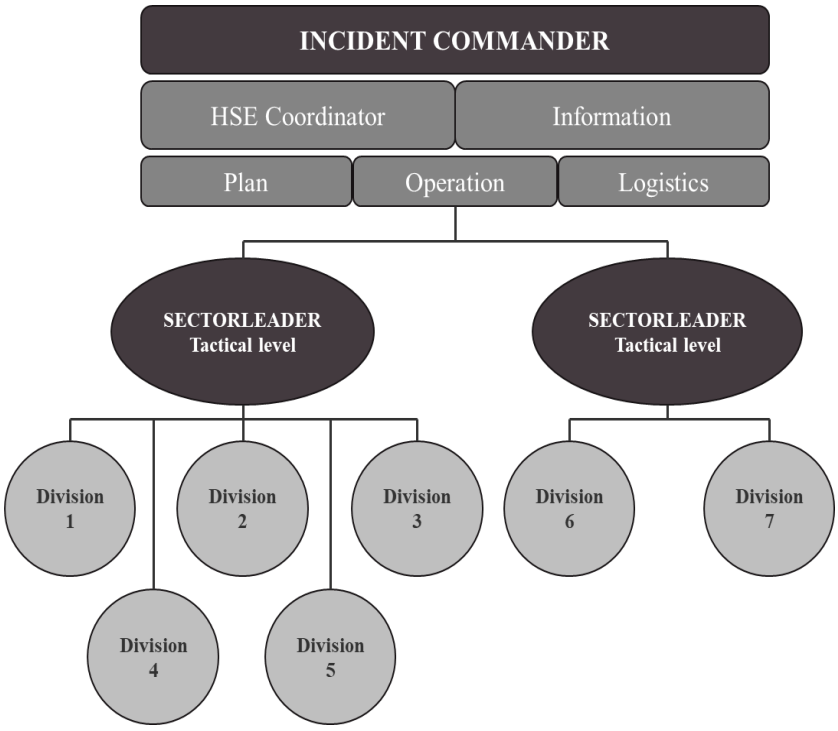

Figure 1: Illustration of the fire service's organization at the tactical level during an incident, created by the author with inspiration from the book Enhetlig Ledelsessystem (Norsk brannvernforening, 2021, p. 47).

All wildfire responses are organized according to the Unified Command System (Enhetlig Ledelsessystem, ELS) (Norsk Brannvernforening, 2021). The ELS ensures efficient leadership by providing a consistent organizational structure, saving time during the response phase. This consistent structure is designed to optimize the response (Norsk

Brannvernforening, 2021, p. 15). Figure 1 illustrates the fire service's operational framework within the incident area.

The ELS adheres to a set of fundamental principles designed to ensure the system functions optimally as a uniform and cohesive organizational model (Norsk Brannvernforening, 2021, p. 40). These principles include the requirement for a uniform level of basic competence across all levels, providing a foundation for a shared understanding of the organizational model's functioning. The terminology used within the system must be clear, common, and easily understandable, ensuring consistency across all levels of operation. Furthermore, the ELS mandates a single incident organization for the entire incident area, with one leader operating a single command line, which ensures effective coordination and safety of the response personnel (Norsk Brannvernforening, 2021, pp. 40-41). The incident organization must be established for each incident following the same pattern, enabling response personnel and leadership to recognize and seamlessly integrate into the organization (Norsk Brannvernforening, 2021, pp. 42).

Geographical and functional sectorization is another key principle, where multiple divisions (each with their own division leaders) can constitute a single geographical sector, led by one sector leader. Functional sectors involve activities outside the primary firefighting efforts, such as supply, transport, catering, camp operations, and smoke diver depot management (Norsk Brannvernforening, 2021, pp. 43-44). The principle of control span limits the number of direct subordinates a leader can have, which should be no fewer than three and no more than eight (Norsk Brannvernforening, 2021, pp. 44-46). Each sector must have a single leader, a principle deemed the most critical in ELS, as having multiple leaders within a sector is considered hazardous (Norsk Brannvernforening, 2021, p. 47). Uniformity in escalation, both in line and for leadership support, dictates that the same organizational patterns and rules apply during an escalation (Norsk Brannvernforening, 2021, pp. 49-51). Lastly, every operation must have clearly defined objectives, and the means to achieve these objectives, they must be outlined in an operational plan (Norsk Brannvernforening, 2021, pp.

52-54). The ELS posits that a successful response is contingent upon five established key elements, as illustrated in Figure 2.

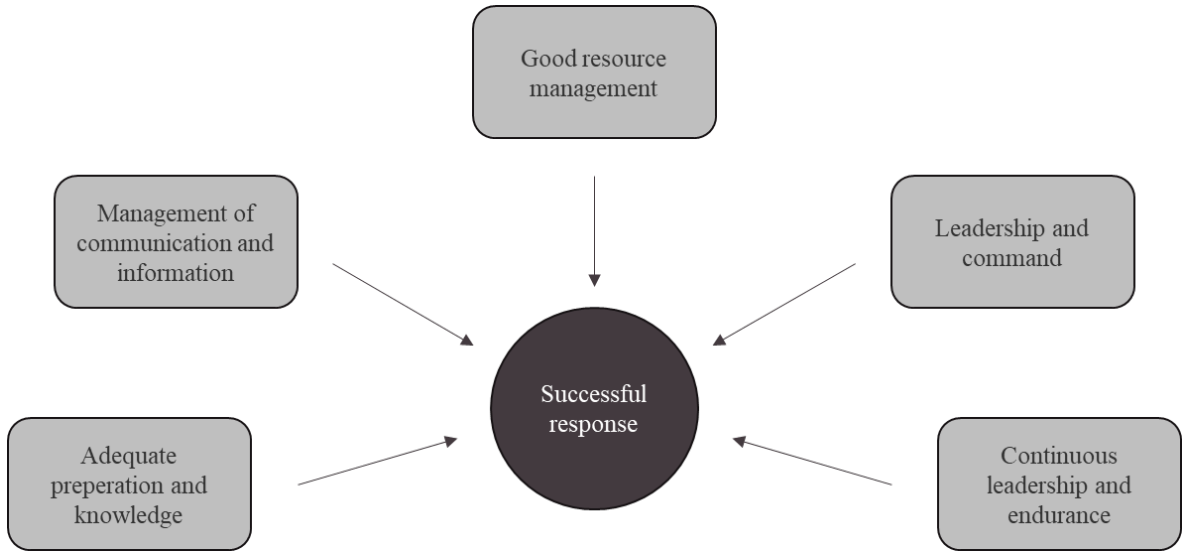

Figure 2: Five elements for a successful response, created by the author with inspiration from the book "Enhetlig Ledelsessystem" (Norsk brannvernforening, 2021, p. 30).

To meet these prerequisites during a large-scale wildfire incident, it is necessary to engage multiple organizations in the response. A non-exhaustive list of involved parties includes emergency services, rescue helicopters and air ambulances, the Civil Defense, forest fire helicopters, local industrial safety units, airport fire and rescue services, specialized competence centers, maritime resources with firefighting capabilities, and the armed forces (Nasjonal veileder for planverk og samvirke i redningstjenesten, 2018, p. 73). According to Section 12 of the Fire and Explosion Protection Act, the fire service always leads the firefighting efforts and assumes incident command until the police take over (2002). Consequently, it is the fire service's responsibility to assess the need for resources to combat the fire (Nasjonal veileder for planverk og samvirke i redningstjenesten, 2018, p. 74).

The legal framework mandates that fire and rescue personnel must possess the necessary qualifications to perform their duties safely and effectively (Fire and Explosion Protection Act, Section 18-a, 2002). There are also requirements for equipping the fire and rescue service, ensuring that equipment aligns with updated risk and vulnerability analyses that impact organization, staffing, and equipment (Fire and Rescue Service Regulations, Section 6, 2022). Specifically, the preparedness analysis must identify and assess the

necessary resources, such as equipment, personnel, and expertise, required to manage significant incidents satisfactorily (Fire and Rescue Service Regulations, Section 9, 2022).

Table 3: List of factors considered when reporting a forest fire (National Guidelines for Planning and Cooperation in Rescue Services, 2018)

Situation	A description of the situation from the caller.
Position	Address / municipality, place name, GPS position/map reference, terrain, and elevation.
Number of people involved.	People in the area, injured/missing.
Communication	Caller's phone number, battery status.
Fire/Smoke	What is burning, direction and color of the smoke, distance to buildings.
Initiate measures	Resources on site, ongoing actions, and risk of spread.
Access routes	Accessibility / conditions.
Weather conditions	Wind direction and speed, visibility, precipitation, temperature.
Safety	Hazards for involved individuals and emergency personnel.

Based on the information gathered through critical factors (See Table 3) in the initial phase, the fire service's response is established and scaled accordingly (Nasjonal veileder for planverk og samvirke i redningstjenesten, 2018, p. 74). This insight into the fire service's response objectives, organization, and chain of command should provide the reader with a solid understanding for how the Norwegian Fire Service will operate during wildfire response.

2.2.1 Levels of Operation

The Norwegian fire service will only operate at the overarching operational and tactical levels[1] during a response (Engen et al., 2021, p. 353). Therefore, their response

[1] The levels of emergency operation in Norway are structured differently than the international levels of operation, resulting in variations in how they operate across these levels (Lunde, 2022, p. 86).

organization does not engage in the strategic level. This implies that within the overarching levels of operation, the fire service has its own hierarchical system, as illustrated in Figure 3.

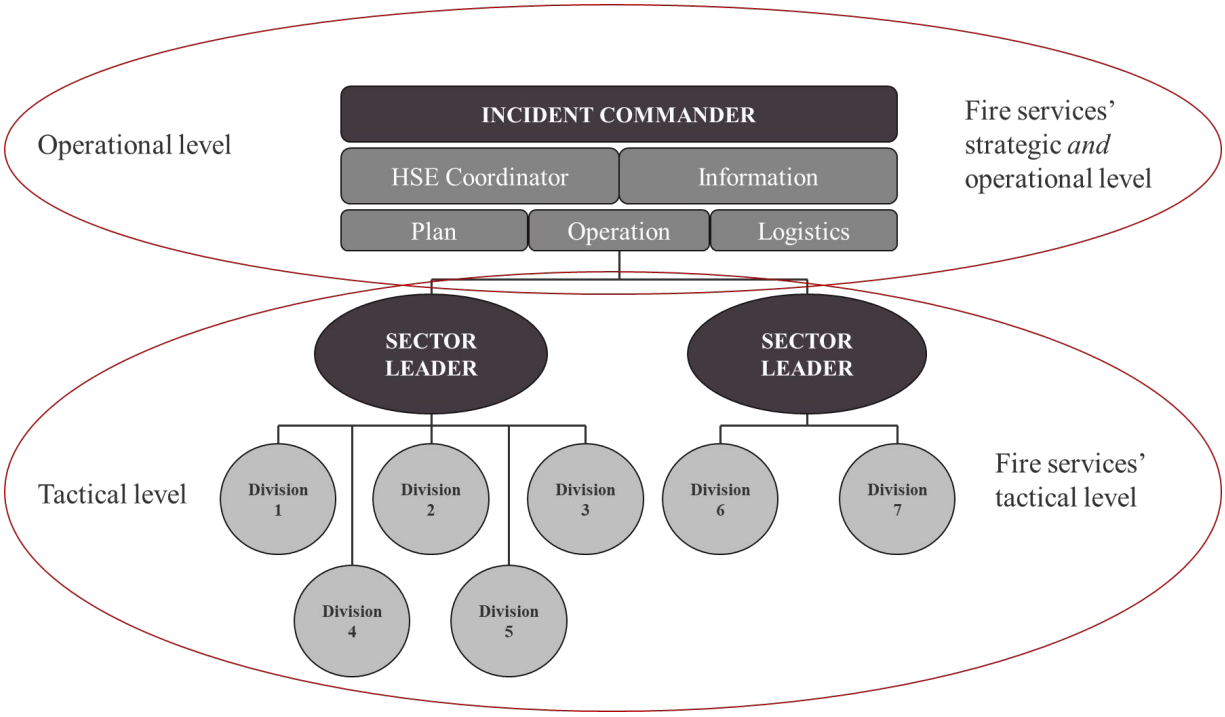

Figure 3: Illustration of the fire services' levels of operation (to the right), within the overarching levels of operation (to the left). Illustrated by the author.

3 Theoretical Framework

In the theory chapter, I present and argue the analytical framework within which I seek to answer the main research questions. This chapter starts with the introduction of emergency management as a process, followed by a presentation of the response as a phase within this process. I then discuss the response phase in three sub-phases to examine the specific activities that occur in each, highlighting the crucial role of communication and information. Subsequently, I describe how this study views communication as an overarching process in which information is shared among actors. I further focus on information sharing as a concept. Finally, I introduce technology as a tool for information sharing. To enhance understanding, I use visual aids such as figures to illustrate the theories.

3.1 Emergency Management

An emergency is a situation posing an immediate risk to health, life, property, or the environment (Haddow et al., 2008, p. 27). Emergency management involves managing risk so societies can live with environmental hazards and handle the disasters they cause (Waugh,

2015, p. 3). In the context of wildfires, which can embody risk, hazard, and disaster (Moritz, 2014; Saban, 2014, p. 17), this study focuses on incidents requiring inter-organizational solutions per the principle of cooperation [2]. This is relevant in Norway, where severe wildfires have historically been rare (Gjerdrem and Metallinou, 2023), limiting experiential knowledge. Climate and ecological changes increase the potential for more severe scenarios, making response enhancement imperative (Moritz, 2014; Saban, 2014, p. 17).

A wildfire necessitates prompt intervention from fire and rescue services (Thompson et al., 2019) to prevent damage to lives, infrastructure, and the environment. Emergency management is a complex process, with response being one of its four critical phases, see Figure 4 (Bumgarner, 2008, p. 32).

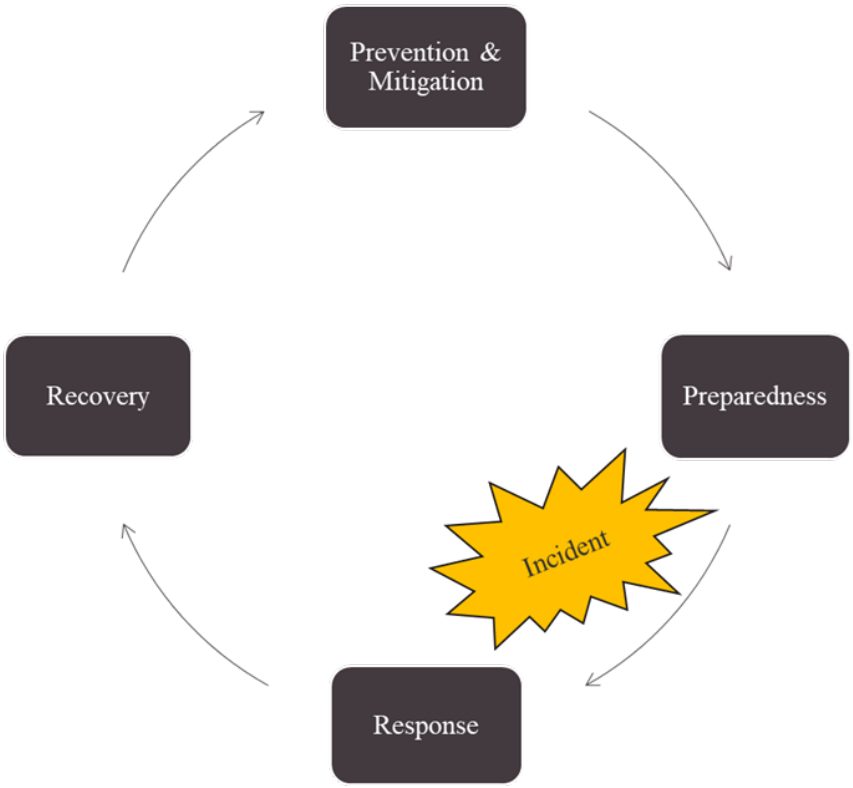

Figure 4: Illustration of the emergency management process, made by the author, inspired by Bumgarner's "Emergency Management", 2008 & Pursiainen's "Crisis Management Cycle", 2017.

The success of emergency management depends on effectively integrating all phases (Ramsay et al., 2020, p. 121). Prevention and mitigation involve proactive measures to prevent incidents or minimize their effects (Waugh, 2015, p. 6). Preparedness includes actions

[2] *Nasjonal veileder for planverk og samvirke i redningstjenesten* (2018), Published by the Ministry of Justice and Public Security, which provides a comprehensive description of the four principles of emergency preparedness.

like conducting risk assessments, informing the public about evacuation procedures, and updating emergency plans (Bumgarner, 2008, p. 34). The response phase, directly associated with the incident, is the ultimate test of prior phases, focusing on preserving life, protecting the environment, and safeguarding infrastructure (Canton, 2019, p. 247; Ramsay et al., 2020, p. 136). Recovery centers on reconstructing society to its pre-incident state or improving conditions (Bumgarner, 2008, p. 44). All phases are interconnected: the response relies on preparation, which depends on effective prevention and mitigation. Following an emergency, recovery underscores the cyclical nature of emergency management. This study aims to enhance response effectiveness, thus focusing primarily on the response phase.

3.2 Emergency Response

Bumgarner (2008, p. 43) presents emergency response as a process, and delineates the response phase into three primary stages, visualized in Figure 5. This segmentation reflects on the complexity of the response process and aims to facilitate a more manageable approach to the diverse activities required within the response phase.

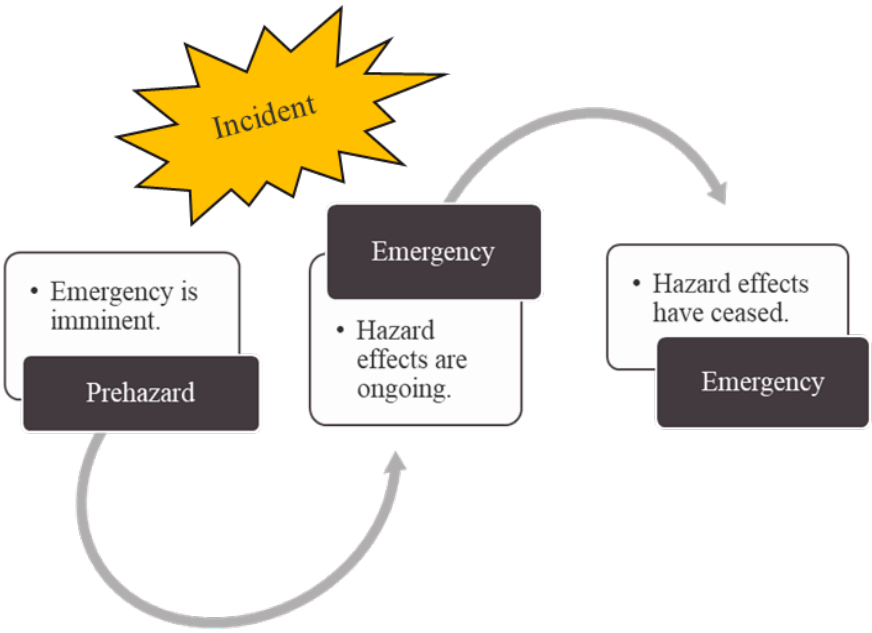

Figure 5: Illustration of the three primary stages in the response phase, made by the author, inspired by Bumgarner (2008, p. 43).

3.2.1 Prehazard Stage

The prehazard stage is defined as the phase in which an incident is imminent but has not yet occurred (Bumgarner, 2008, p. 43). In the context of wildfire response, this stage represents the critical moment when emergency personnel are alerted, relevant information about the incident is gathered, and necessary resources are allocated to manage the situation (Madigan, 2017, p. 34). Effective *communication* is essential at this stage to ensure that emergency personnel have a comprehensive understanding of the situation they will encounter at the incident site (Adams & Singh, 2018). This stage demands prompt dissemination of *information* and strategic allocation of resources to preemptively mitigate the potential impact of the wildfire.

3.2.2 Emergency Phase – Ongoing Hazard Effects

The onset of an emergency incident may often be characterized by uncertainty and sometimes even chaos (Canton, 2019, p. 315), making the task of gaining oversight and control particularly challenging (Moritz et al., 2014; Duane et al., 2015). At the incident site, assessments must be made regarding the allocation of emergency resources, which, in the case of large fires, will involve multiple locations (Kendell et al., 2023). Effective planning of the response is therefore critical, necessitating strong leadership (Canton, 2019, p. 279). In this phase, the primary focus is on bringing the situation under control, with leadership responsible for developing and effectively communicating a plan to the frontline emergency personnel (Canton, 2019, p. 279). Concurrently, leadership relies on frontline personnel to efficiently and accurately communicate their needs for resources and to provide updates on the status in the field (Coleman, 2020, p. 72). This phase is characterized by dynamic decision-making processes dependent on *effective communication* and requires continuous adaptation to the evolving conditions of the wildfire.

3.2.3 Emergency Phase – Ceased Hazard Effects

Once the incident is under control and the immediate danger has subsided, response activities continue (Bumgarner, 2009, p. 43). In the context of wildfires, emergency personnel focus on mop-up operations to ensure the fire does not reignite (Kendell et al., 2023). This process can be time-consuming and requires significant endurance from the crew (Kendell et al., 2023). The incident is considered ongoing until emergency personnel can safely cease their activities at the scene, allowing recovery efforts to commence (Bumgarner, 2009, p. 43).

During this stage, the focus shifts to ensuring that all hotspots are extinguished, and potential reignition points are thoroughly checked, to prevent any resurgence of the wildfire (Kendell et al., 2023). Effective coordination and communication remain critical to ensure that recovery operations are seamlessly integrated with the concluding response activities, thereby facilitating a smooth transition to the recovery phase (Bumgarner, 2009, p. 43).

In summary, the prehazard stage focuses on proactive measures and resource allocation, the ongoing incident stage emphasizes real-time response and situational control, and the post-incident stage involves thorough mop-up operations and preparation for recovery. Each stage is interconnected, necessitating continuous communication, strong leadership, and strategic planning to manage wildfires effectively from the initial alert to the final resolution (Bumgarner, 2009, p. 43). These stages collectively contribute to a comprehensive wildfire response strategy, ensuring preparedness, effective response activities, and robust recovery within the response phase.

3.2.4 Cross-Organizational Collaboration Within the Response Phase

Emergency response is a complex task that necessitates a cross-organizational solution (Quarantelli, 1986, p. 15; Hall et al., 1977; Kapucu, 2006a, 2008). This requirement is addressed in Norway's four societal principles for emergency preparedness [3]. The principle of cooperation mandates that all relevant actors have an independent responsibility to ensure mutual collaboration to achieve comprehensive and effective emergency management (Engen et al., 2021, p. 324). Effective collaboration, which is at the heart of emergency management, relies on several key factors, including trust and established relationships between different organizations. However, the literature often highlights communication as one of the most crucial prerequisites for successful collaboration (Wankhade and Patnaik, 2019). Although emergency services are often grouped together under the same umbrella globally, there are significant differences in how they are individually organized, and how they operate and function (Wankhade and Patnaik, 2019).

In Norway, a primary rule is that the police will always hold the official role as the incident command organization if human life and health are threatened. However, in the event of fire incidents, the fire service assumes the role of the premise setter for the response, leveraging their specific field of expertise (Engen et al., 2021, p. 349) This means that the fire

[3] See footnote, page 14.

service will establish the operational conditions and determine the actions to be undertaken. They will also overtake the role of incident command if human life and health are not threatened. This is established in the principle of responsibility, which states that the entity responsible for a service or function on a daily basis also has the responsibility to manage emergency situations related to that service or function (Engen et al., 2021, p. 324). The coordination of such incidents necessitates that collaboration is supported by effective communication among the involved organizations. Effective emergency management and planning are unattainable without communication (Carreras-Coch et al., 2022). Therefore, this study emphasizes communication as the primary factor for a successful response.

3.3 Communication

During an incident, communication will flow bidirectionally, and communication occurs within a predetermined and established hierarchy known as the Command-and-Control chain (Coleman, 2023, p. 72). This chain designates a top leader at the strategic level responsible for setting the overall strategy for the response. The information is then transmitted to the operational level, which handles the implementation of strategic decisions and directives. If there is a need for logistical support and resource allocation, these tasks are carried out through the operational level. Close coordination within and between all levels of operation is extremely important to ensure a unified effort and communication along the chain of command (Oh and Lee, 2020). Frontline leaders at the tactical level, will execute the measures determined by the operational level, and communicates with the operational level to report status and needs (Engen et al., 2021, p. 353). The hierarchical design of this communication process means that personnel receive and execute commands from those "above them", hence the term "Command and Control" (Coleman, 2023, p. 72).

3.3.1 Formal and Informal Communication

The Command and Control-structure reflects on the *formal* communication lines of the emergency organization. Formal communication involves official and documented information exchange that follows established channels and procedures. It ensures that shared information is recorded, traceable, and can be evaluated for accountability and coordination (Kapucu, 2006b). On the other hand, *informal* communication lines are more spontaneous and unstructured. They include conversations over the phone, informal messages, informal meetings, and verbal discussions (Engen et al., 2021, pp. 365-375). This type of communication is crucial in emergency management as it allows for quick information

sharing, relationship building, and efficient problem-solving (Kraut et al., 1990). On the other hand, Kraut et al., also emphasizes that informal communication has a spontaneous and unstructured nature, and in lacking the structured channels of formal communication, can make it difficult to ensure that critical information is accurately and consistently shared (1990). This can further lead to discrepancies and misunderstandings in emergency response situations (Kraut et al., 1990). However, it is important to recognize that formal and informal dimensions are integral and inseparable parts of organizational life. According to Selznick (1948), organizations integrate both formal structures and informal processes to form a cohesive system.

The complexity of wildfire response involves multiple organizations, and coordinating communication across these entities to ensure a unified response is according to Quarantelli (1988) “inherently challenging”. Nonetheless, both formal and informal communication practices are needed during an emergency event, and both are seen as important to ensure effective communication and a successful emergency response (Quarantelli, 1988; Kraut et al., 1990; Kapucu, 2006a).

3.3.2 Inter- and Intra-Organizational Communication

Wildfires often necessitate inter-municipal cooperation, and fire services from different municipalities are treated as distinct organizations, despite belonging to the same professional group. This is due to the varying challenges and organizational structures faced by fire services in different municipalities, as highlighted in the context section of this thesis. However, the fire service is not the sole organization involved in managing an incident. In most cases, police, ambulance services, and volunteer organizations also participate in the response, involving multiple different organizations that communicate with each other (Eide et al., 2013).

Inter-organizational communication has often been highlighted in literature as particularly problematic due to a lack of prior familiarity, trust in each other's practices, and decision-making capabilities (Wankhade and Patnaik, 2019). Quarantelli (1988) highlights that communication challenges arise both within and between organizations, emphasizing that difficulties are not limited to inter-organizational communication but also include intra-organizational issues. The explanations for this include miscommunication or lack of communication due to organizational silos and differing priorities and protocols within

organizations (Quarantelli, 1988). Kapucu (2006b) explains that within organizations, there may be differences in cultures, goals, and communication styles.

Considering the organizational structure of the Norwegian Fire Services, and the fact that a wildfire response effort will demand a cross-organizational collaboration, this study does not aim to divide between inter- and intra-organizational communication but aims the focus on the communication happening among all actors during the response phase, which consequently will be both inter- and intra-organizational. However, the study will have an intra-organizational dimension, as it will focus on the fire department's communication and response at the operational and tactical levels of operation.

3.4 Information Sharing

Communication builds on information sharing (Seeger & Sellnow, 2013). Information sharing is an essential part of crisis management, and a central component of the response phase, where effective handling and accurate decision-making are fundamental factors for success (Bharosa & Janssen, 2009; Rebmann et al., 2008). Information sharing constitutes a premise for comprehending the circumstances individuals encounter, facilitating the identification and processing of pivotal information regarding the event (Kedia et al., 2020). Information has been conceptualized in different ways over the years (McCreadie & Rice, 1999), and to be able to concretize it in the context of this study, some reflections on different concepts must be made. Information can be defined as a controllable *resource* (Arrow, 1979; Bates, 1988; Hirschleifer & Riley, 1992). This perspective takes a somewhat idealistic approach and assumes that information can be transmitted from a sender to a receiver where both will have the same interpretation (McCreadie & Rice, 1999). This conceptualization of information implies that the meaning lies in the message being sent and that the meaning cannot be influenced by external factors.

On the other hand, information can be conceptualized as part of *communication* processes (Atwood & Dervin, 1982). Here, it is assumed that information is something that only gains meaning when interpreted by humans (McCreadie & Rice, 1999). Between these extremes, various other perspectives on information exist. One such perspective views information as *recorded* knowledge (Lievrouw, 1998), positing that knowledge must be documented and archived to be considered information (Salles, 2015). From this viewpoint, information is deemed objective and unaltered only when it has been recorded. On the exact opposite, information can be seen as something everyone continuously *absorbs simply by*

existing in an environment (Shan-Ju et al., 1993), meaning that in a wildfire response context, information is constantly gathered by all who take part in the response.

Buckland (1991) delineates three primary functions of information: facilitating the process of becoming informed, reducing ignorance, and diminishing *uncertainty*. In emergency management and response, uncertainty is a constant challenge for emergency responders (Xia et al., 2012). Therefore, information in this study is defined as a resource for reducing uncertainty, and information is shared through communication, documentation, and the impressions, needs and experiences encountered by response personnel. Information can thusly be visual in the form of body language, pictures, video, or text (McComb and Kennedy, 2020), it can be verbal in the form of speech or sounds, or it can be a combination of both visual and verbal in the form of experiences or combining information sharing techniques (Xia et al., 2012; Jimenez and Morreale, 2015). Furthermore, the study will examine how information is acquired. Going onwards, it will be pertinent to identify the communication tools utilized for disseminating information between the involved response organizations.

3.5 Technology

A part of his study examines the utilization of technology to enhance wildfire response, with a particular focus on the use of technology for information sharing and communication. Information sharing necessitates the use of a medium for communication. Information does not arise spontaneously; it is generated through the interpretation of observations and experiences, which are then conveyed to others (McCreadie & Rice, 1999). Communication constitutes the transmission of information from one location to another (Fischer et al., 2016).

The manner in which this transmission occurs significantly influences the speed at which information is delivered and the clarity with which it is understood by the recipient (McCreadie & Rice, 1999). Depending on the scale of the incident, physical distances often arise between response personnel, resulting in the frequent reliance on technological tools for communication (Damaševičius et al., 2022). The concept of technology encompasses a wide range of tools and systems, but for the purposes of this study, technology is defined as a designed, material means to achieve a goal (Agar, 2020). Communication technology has been shown to significantly enhance the efficiency of emergency management (Reddy et al., 2008; Kapucu and Garayev, 2013). A notable example is the Apollo 13 mission, where the

use of a Digital Twin on the ground enabled responders to analyze and manage the situation effectively, resulting in the safe return of all astronauts despite the critical incident involving an exploding oxygen tank (Zio & Miqeles, 2024).

The use of technology can also introduce increased risks and potentially exacerbate the response to incidents (Cheng et al., 2019). Engen et al. (2021, p. 255) refer to this as the crisis management dilemma. The identified problems relate to the stability of technological solutions and their impact on response effectiveness if failures occur. Additionally, there is concern that emergency personnel may become overly reliant on technological solutions, leading to a diminished capacity for independent thinking and reduced decision-making abilities (Engen et al., 2021, p. 255). At the core of the problem is the fear that technology standardizes responses, which does not align with the inherent uncertainty and unpredictability associated with emergencies, known in the literature as the unknown unknowns (Marcot, 2020, p. 4). This concern necessitates the adaptation of technology to address these uncertainties, and it is highlighted in the literature that technology must be user-friendly and accessible at all levels of the response effort (Pine, 2017, p. 6). Therefore, this study focuses on the design, usability, and accessibility of technology to examine how it contributes to an enhanced response.

3.6 Analytical Implications

The theoretical framework presented in this chapter forms the foundation for the research questions guiding this study. Previous studies have demonstrated that successful emergency response depends on effective communication among response personnel (Fischer et al., 2016), and that information can be shared more efficiently through new technology (Kapucu and Garayev, 2013). This suggests that new technology can enhance wildfire response by optimizing communication processes.

The framework highlights the necessity of both intra- and inter-organizational communication during emergency management, particularly in wildfire response scenarios (Heide & Simonsson, 2019, p. 38; Wal et al., 2021). It also suggests that effective communication is essential for the success of emergency management and highlights potential barriers such as lack of trust, message interpretation, logistical barriers and information quality (Bui & Subba., 2009; Bharosa et al., 2010). I will use this as the basis for research question 1, aiming to identify any communication challenges or limitations experienced by emergency personnel. This evaluation will help determine how well current methods facilitate

information sharing and manage the flow of critical information during wildfire response (Coleman, 2023, p. 72).

Regarding research question 2, the framework emphasizes the importance of continuous communication and the potential for technological enhancements to improve information sharing (Carreras-Coch et al., 2022; Kapucu and Garayev, 2013). It further highlights the role of technology in emergency management, including both its benefits and potential drawbacks (Engen et al., 2021; Pine, 2017). By focusing on the use of technology in current information sharing processes, I will try to identify gaps or inefficiencies in communication that could be addressed through technological innovation. I will also explore the potential of utilizing specific technological solutions that could enhance communication processes, such as advanced sensors, drones/unmanned aerial vehicles (UAV), automated data analysis tools, and unified communication platforms. I will then discuss how these technologies can improve communication processes (Kapucu and Garayev, 2013).

The framework highlights potential barriers to effective communication and the challenges posed by the introduction of new technologies (Bharosa and Janssen, 2010; Engen et al., 2021) In the study, this will be used to identify key challenges associated with new technologies. It is further emphasized the need for user-friendly and accessible technology that can address the inherent uncertainties of emergency situations (Pine, 2017). This will be addressed in research question 3 by assessing how barriers impact the adoption and effective use of technological solutions in the context of wildfire response (Marcot, 2020, p. 4; Pine, 2017, p. 6)

4 Methodology

In this study, I have chosen a qualitative approach to understand how people perceive situations and what factors influence their decisions, particularly in identifying communication practices and the role of communication and technological tools in enhancing wildfire response in Norway. This method allows for deep exploration and interpretation, capturing the meaning and value perceived by individuals (Brinkmann & Tanggaard, 2012, p. 11). This chapter explains the rationale for the chosen methodology, the case study design, the data collection process, data analysis techniques, and discusses the ethical considerations, strengths, and weaknesses of the method.

4.1 Research Strategy

A qualitative approach allows for a comprehensive understanding of the subject matter (Neuman, 2011), and this choice inherently affects the methodological techniques employed, as a qualitative strategy necessitates specific methods for data collection and analysis (Silverman, 2005). For studies exploring under-researched themes, qualitative methods are especially appropriate (Thagaard, 2013), which is relevant for this study as it addresses a topic that has been minimally researched in the Norwegian context.

The development of the theme and problem statement for this study was conducted in collaboration with researchers at RISE Fire Research and Jotne, both of which are participating entities in the TREEADS project. Based on the problem statement and overarching theme, three research questions were formulated to provide detailed answers to the problem statement. The choice of a qualitative research strategy determined the logical procedures and perspectives employed to address the research questions (Blaikie and Priest, 2019) and the overarching theme and problem statement guided the development of the theoretical framework (Merriam et al., 2016, p. 20). The theoretical framework of a study significantly influences what is considered relevant data (Silverman, 2005). As this study is part of a larger research project, the stakeholders of the research project played a significant role in shaping the theoretical framework. The theoretical framework was developed, revised, and finalized through collaboration between me and the stakeholders, ensuring it aligned with their objectives for the overarching research project.

4.2 Exploratory Case Study

Given the aim to identify factors of successful wildfire response, it was crucial to adopt a research design that allowed for an in-depth exploration. The goal was to gain a comprehensive understanding of wildfire response in Norway and examine variations among fire stations and differing perceptions of response effectiveness (Jacobsen, 2005, p. 89). A case study is suitable when focusing on a phenomenon within its real-life context (Yin, 1994, p. 1). In this study, the fire and rescue service's response to wildfires guided the choice of a case study research design. Case studies effectively capture nuances, patterns, and latent elements in the data (Lune and Berg, 2012, p. 327) and are particularly suited to uncovering why or how situations unfold (Gerring, 2016, p. 60).

Exploratory case studies are conducted to investigate new phenomena, generate hypotheses, or gain initial insights into a research topic (Silverman, 2013, p. 126). For this study, the phenomenon was not new, but rather under-researched, which meant that the choice of a case study allowed me to gain initial insights into the topic. The focus is on understanding the context and dynamics of the phenomenon being studied. Researchers collect data using various methods such as interviews, observations, surveys, or literature reviews to explore different aspects of the phenomenon (Gerring, 2016, p. 62). For this study, I used several different sources of data, which I will present further down in this chapter. The analysis involves identifying patterns, themes, or emerging concepts from the data to develop preliminary insights or hypotheses about the phenomenon (Gerring, 2016, p. 62).

In case study research, the focus is on a specific case from which extensive data is extracted from a limited number of units (Johannessen et al., 2016, p. 80). The case represents a particular context, such as the response to wildfires, with research units that can include individuals, groups, or organizations (Thagaard, 2018, p. 51). For this study, the case is the fire and rescue services' approach to wildfire response, and the unit of analysis is the fire and rescue service organization, encompassing various subunits within the organization. Case studies are particularly well-suited for achieving an in-depth understanding of the phenomenon due to their capacity to explore multiple analytical units (Thagaard, 2018, p. 51).

4.3 Sample and Data Collection Techniques

When conducting a case study, researchers typically rely on both primary and secondary data sources (Alexandrov, 2004). For this study, methods were chosen for their ability to generate rich information relevant to wildfire responses in Norway (Yin, 1994, p. 44). Public documents in Norway often incorporate international experiences, requiring input from local actors with direct wildfire response experience. The increasing prominence of wildfires in Norway and the scarcity of specific resources highlight the need for context-specific data. ***Primary*** data collection occurred in three stages: participating in a wildfire exercise to observe events and select interview subjects, conducting nine semi-structured interviews, and conducting a focus group interview based on themes from the semi-structured interviews.

Secondary data refers to information that is already available, such as academic articles, government reports, and statistical data (Blaikie and Priest, 2019, p. 15). In the case of this study, the secondary data consist of three different documents: "Stortingsmelding 16,

(2023-2024)", "the Fire and Rescue Services Regulations", and "the Fire and Explosion Protection Act". Both primary and secondary data are important for gaining a comprehensive understanding of the nuances within the context of Norwegian wildfire response.

To enhance the robustness of the dataset, this study employs triangulation. Triangulation uses diverse sources of information and focuses on different sources, such as documents, observations, and interviews (Fusch et al., 2018, p. 22). I utilized data triangulation to achieve the goals of qualitative research, which is to provide rich and detailed insights into the subject matter being explored (Creswell & Miller, 2000).

4.3.1 Documents

The textual material serves as both background and supplementary data for this study (Blaikie & Priest, 2019, p. 15). The document analysis aimed to use these documents as a foundation for further investigations and to gain a comprehensive understanding of the field (Thagaard, 2018, p. 119). These documents provided background data, helping me contextualize the research topic and develop a broader understanding of the subject matter (Blaikie & Priest, 2019, p. 15). Incorporating documents into empirical studies complements the primary data, enhancing the robustness of research findings (Lynggaard, 2012, p. 153). For this study, I utilized three public secondary data sources, listed in Table 4 below.

Table 4: Document overview.

Document	Origin	Published
Stortingsmelding 16, (2023-2024) Fire and Rescue Services, Proximity, Local Knowledge and Rapid Response Nationwide	Ministry of Justice & Public Security	2024
Regulations on the Organization, Staffing, and Equipment of the Fire and Rescue Services and the Emergency Reporting Centers (the Fire and Rescue Services Regulations)	Ministry of Justice & Public Security	2022
Act on Protection Against Fire, Explosion and Accidents Involving Dangerous Substances and, on the Fire and rescue service's Rescue Tasks (Fire and Explosion Protection Act)	Ministry of Justice & Public Security	2002

The Stortingsmelding is a national initiative aimed at enhancing the fire and rescue service, providing an overview of its status and development. It addresses challenges from both historical and future perspectives and examines specific areas of emergency management, including ongoing research both nationally and internationally. Particularly relevant to this study are sections on wildfires in Norway (Meld. St. 16 (2023-2024), pp. 54-57) and technology and innovation (Meld. St. 16 (2023-2024), p. 71). The Stortingsmelding has provided valuable insights into wildfire response challenges in Norway.

Additionally, the legislative texts have acquainted me with the requirements for fire response and the structuring of the fire and rescue service. This has allowed me to compare primary data with legislative texts to determine if current wildfire responses meet legal requirements. These texts are highly relevant to the research questions, offering valuable comparative data (Lynggaard, 2012, p. 153).

4.3.2 Observation

As part of data collection, I observed a large-scale wildfire exercise involving over 200 personnel from 13 fire stations across Western Norway. Observation, a recognized qualitative research method, involves systematically studying and recording participants' actions (Thagaard, 2018, p. 63). It is useful for understanding interactions and social dynamics (Merriam and Tisdell, 2016). During the exercise, I observed interactions between operational and tactical levels, mimicking a real incident. I also engaged directly with participants, gaining a deeper understanding of the processes. Thus, I became part of the social setting while studying participants in their work environment, an important aspect of field observation (Thagaard, 2018, p. 63). My participation aimed to observe and establish contact with emergency personnel who could be potential interview subjects. Together with my associate at RISE Fire Research, I approached incident commanders, operational leaders, and sector leaders during the exercise. Making initial face-to-face contact enhances trust and fosters a more personal relationship in subsequent conversations (Kamberelis and Dimitriadis, 2013, p. 63).

However, it is important to be aware of the disadvantages of field observation. Interacting with participants while they work can distract them and alter their behavior, a phenomenon known as the Hawthorne effect (Sedgwick & Greenwood, 2015). To avoid becoming a distraction, I adjusted my approach to the participants based on their level of activity in the response. Conversations with the participants took place during calm periods,

and if the situation escalated, I withdrew and then re-engaged with them once things had settled down again.

4.3.3 Semi-Structured Interviews

To understand what works well and what is less effective in wildfire responses in Norway, semi-structured one-on-one interviews were conducted, aiming to assess current practices and identify problem areas, as highlighted by Tjora (2021, p. 127). The interviews allowed for a detailed analysis of informants' experiences during wildfire response operations (Brinkmann & Tanggaard, 2012). I conducted nine interviews with personnel from various fire stations and rescue services, selecting informants based on two selection criteria, as highlighted by Creswell (2013).

The first criterion was that they needed to have direct experience or extensive knowledge of the research topic. The second criterion was that they could provide in-depth and detailed information to adequately address the research questions. Three informants were employed at part-time fire services, while the rest worked at full-time fire services. Furthermore, all participants held various roles and experience related to actual wildfire incidents. All informants who met the selection criteria happened to be male, likely due to the predominance of male representation in the profession (Danbold & Bendersky, 2019). Table 5 shows an overview of the informants who participated in this study.

Table 5: Overview of the study's' informants.

Informant	Type of Fire Service	Experience with Wildfire Response	Experience with Wildfire Drills	Interview or Focusgroup	Male or Female
I1	Part-time	No	Yes	Interview	Male
I2	Full-time	Yes	Yes	Interview	Male
I3	Full-time	Yes	Yes	Interview	Male
I4	Part-time	Yes	Yes	Interview	Male
I5	Full-time	Yes	Yes	Interview	Male
I6	Full-time	Yes	Yes	Interview	Male
I7	Part-time	Yes	Yes	Interview	Male
I8	Full-time	Yes	Yes	Interview	Male
I9	Full-time	Yes	Yes	Interview	Male
I10	Full-time	Yes	Yes	Focus group	Male
I11	Full-time	Yes	Yes	Focus group	Male
I12	Full-time	Yes	Yes	Focus group	Male

The value of the interviews lies in their ability to provide information on how the response to wildfires is experienced by sharp end personnel and which factors influence perceptions of the response's quality, as highlighted by Thagaard, (2018, p. 89). I acquired knowledge about where the most significant problems are and what could be done to improve specific aspects of the response. The varying locations and conditions of the informants mean that the empirical knowledge about the effectiveness of wildfire response is based on diverse experiences and perspectives, as highlighted by Silverman (2013, p. 285).

Arrangements for interviewing informants were made during the exercise in early May 2023. The interviews were conducted over one and a half weeks, starting the week after the exercise. Conducted digitally via Teams due to the distances between participants and me, each interview was initially set for 45 minutes but lasted around an hour. There are some aspects with digital interviews that I had to be aware of. Firstly, they can suffer from technical issues, consuming time and diverting focus (Bertrand et al., 2023). Secondly, physical closeness and certain visual communication aspects are also lost. However, digital interviews offer enhanced accessibility, allowing researchers to engage participants from diverse locations and facilitating broader sample representation (Krueger & Casey, 2015; Parker & Tritter, 2007). Participants in familiar settings, like their own offices, feel more relaxed and secure, contributing to a more open and productive discussion (Kamberelis and Dimitriadis, 2013, p. 67). This was clearly evident in the interviews conducted in this study, as the participants appeared very relaxed and actively engaged in an open discussion on the topic.

4.3.4 Focus Group Interview

A focus group is conducted with a specified number of participants engaging in an interactive discussion on one or more topics (Tjora, 2021, p. 137) to gather substantial empirical data quickly (Kamberelis & Dimitradis, 2013, p. 3). After the semi-structured interviews, recurring themes emerged that required further exploration. To gain a comprehensive perspective, a focus group interview was organized in collaboration with the TREEADS team. The selection criteria for informants required them to have high competence in leading wildfire responses and to work in areas of Norway frequently experiencing wildfires. Participant selection is crucial, balancing relevant experiences with the need for diversity to capture a range of perspectives (Sugden & Moulson, 2015). This thoughtful approach creates a participant pool that fosters productive discussions while providing a comprehensive understanding (Puchta & Potter, 2011). We presented the criteria to a contact

at the Directorate for Civil Protection (DSB), who provided names of potential candidates. We invited five individuals, where three accepted the invitation.

An ideal focus group typically consists of six to eight participants, though there is no strict rule regarding the number of participants (Hennink et al., 2020, p. 151). At the last moment, one of the informants had to be replaced due to illness. The informant who fell ill found a replacement who possessed the same qualifications as him, ensuring that the selection criteria for interview participants were still met. Consequently, the focus group interview was conducted with three participants, which is considered a small group. Smaller groups allow each informant more time to discuss, which can be challenging in larger groups (Johannessen et al., 2016, p. 115). However, the drawback of smaller groups is the potential difficulty in obtaining a wide diversity of opinions and perspectives (Hennink et al., 2020, p. 151). This limitation is acknowledged as a potential weakness of the study.

An unplanned but beneficial aspect of the interview was that all participants were already acquainted. This familiarity positively influenced group dynamics and facilitated a quick start to the discussion (Kamberelis and Dimitriadis, 2013, p. 64). The data was derived not only from participants' statements but also from their interactions (Johannessen et al., 2016, p. 146; Tjora, 2021, p. 138). The group's synergy was evident as participants sought clarification, elaborated on each other’s points, and allowed for thorough discussion. However, it is important to recognize that familiarity can lead to participants providing socially acceptable responses rather than their true thoughts, potentially skewing data (Krueger & Casey, 2015).

Focus groups allows researchers to gather in-depth insights into the perspectives, attitudes, and behaviors of a target population (Asbury, 1995). This strategy encourages shared reflection on experiences and insights, helping participants understand the case (Jacobsen, 2005, p. 154). During the interview, predetermined topics were discussed by participants who shared a common basis for the discussion. This allowed me to determine whether there were variations in opinions within the group (Thagaard, 2018, p. 92). Additionally, focus groups are ideal for gathering diverse data (Asbury, 1995), allowing me to clarify uncertainties and uncover new aspects. Participants led the discussion, with my interventions limited to follow-up questions or transitions to new topics. This approach kept the group focused on predetermined topics while enabling open reflection, leading to new perspectives that might not have emerged in a more structured setting. The interview followed

a guide[4] sent to respondents in advance, allowing for thoughtful and comprehensive responses (Patton, 2015). Given the limited research in the Norwegian context, it was crucial to ensure the interview questions were relevant yet flexible to accommodate new topics introduced by participants (Kamberelis and Dimitriadis, 2013, p. 69).

4.4 Data Analysis Method

The data were analyzed with a qualitative content analysis approach, adhering to the step-by-step guidelines outlined by Schreier (2012) and Mayring (2021). I found these guidelines to be extremely helpful throughout the analysis process, particularly during the initial coding phase, as they kept me focused and prevented me from getting lost in the data. (Schreier, 2012, p. 58). The method of content analysis involves systematically analyzing and interpreting the content of qualitative data, such as interviews, focus groups, or documents (Mayring, 2021, p. 58). It is used for systematically describing the meaning of qualitative material, done by assigning successive parts of the material to the categories of a coding frame, which is the central analytical tool of the method (Schreier, 2012, p. 1).

I first familiarized myself with the data through transcription of the interviews. While transcribing I noted initial impressions and emerging themes for creation of categories based on the three research questions, as highlighted by Mayring, (2021, p. 58) and (Schreier, 2012, p. 126). Segments of the text was then coded into subcategories and related to the overarching themes of the research questions (Thagaard, 2018, p. 153). This work resulted in the main categories of what constitutes my coding frame[5] (Schreier, 2012, p. 60). One of the advantages of Qualitative Content Analysis (QCA) is the adherence to strict guidelines, which helps avoid confusion due to the volume of data (Schreier, 2012, p. 59). Many respondents were very willing to share information, some of which was more relevant to my research questions than others. Therefore, it was crucial for me to initially establish main categories which I then had to adhere to during the process. An example of this could be I5 who highlighted statements about drone technology. These were assigned the code “Digital and Technical Tools” which again was related to the category “Communication Methods” which reflected research question 1.

I continued with grouping together the categories into overarching themes, and refined the codes and categories by combining those that were similar or splitting those that

[4] See attachment 2.
[5] See attachment 1.

encompassed multiple concepts (Mayring, 2021, p. 58). Until this point, my research employed a deductive approach, establishing the main categories based on prior research, the theoretical framework, and the study's research questions (Schreier, 2012, p. 85). From these established categories, I proceeded to create sub-categories in a data-driven manner, primarily using an inductive approach (Schreier, 2012, p. 88). At this stage of the process, the main categories were well-aligned with the research questions, allowing me to adopt a data-driven approach for the subsequent phases. Combining concept-driven and data-driven strategies is a common approach in Qualitative Content Analysis (QCA), and it is rare to find purely one or the other (Schreier, 2012, p. 89). This blended approach allows researchers to leverage the strengths of both methodologies, ensuring a comprehensive analysis that is both theoretically informed and empirically grounded (Schreier, 2012, p. 59).

Continuing, I determined how different sub-categories related to each other and to the research questions. An example of this was “Organizational Aspects” and “Training and Expertise”, which was connected under the theme “Identified Barriers”, which in turn was related to research question 3. I then proceeded to develop core categories by defining them by name, describing their features, and providing examples in form of direct quotes from the data (Schreier, 2012, p. 100). Here, I relied exclusively on quotes from the transcripts, which resulted in some examples being too narrow to accurately represent the categories. Upon revisiting the coding, I recognized this issue and reformulated some of the examples to be more illustrative and descriptive of the categories (Schreier, 2012, p. 101). This adjustment ensured that the examples were more comprehensively defined and better aligned with the categories.

In the next phase, I conducted what Schreier (2012, p. 148) defines as a pilot phase. During this phase, I selected a diverse sample of both my sub-categories and main categories and tested them on the data I had collected. This process was conducted in two rounds with a short interval in between, as I was the sole researcher on this project. The rationale for this approach is to ensure that fresh perspectives are applied to the data during the second round of testing. An alternative approach could have been to include another coder to conduct the second round of testing (Schreier, 2012, p. 84). The objective of this phase was to ensure that the results could be compared, overlapping categories could be identified, and difficult-to-use categories could be refined. Subsequently, a few necessary adjustments were made to the coding frame (Schreier, 2012, p. 150). The completion of the coding frame led me to the

phase of main analysis, where I could form a coherent narrative around each research question.

4.5 Validity

Validity in qualitative research refers to the extent to which the research findings accurately and reliably reflect the phenomena they are intended to study (Mayring, 2021, p. 174) and concerns the credibility of the findings (Silverman, 2013, p. 285). For this thesis, I have employed data triangulation. By utilizing interviews, observations, and documents as different data sources, and drawing parallels between the findings from these sources, I enhance the credibility of the study's findings (Silverman, 2013, p. 288).

The selection of informants has been deliberate and strategic. All informants have experience with, and in-depth knowledge of the phenomenon being studied (Jacobsen, 2005, p. 217). The value of the respondents lies in their proximity to the phenomenon under investigation, which can enhance the validity of the study by increasing the likelihood that the data collected is closely related to the research questions the study aims to answer (Silverman, 2013, p. 280). I have utilized informant validation of the findings, meaning I have received feedback from the informants to confirm whether the findings align with their experiences and perspectives (Jacobsen, 2005, p. 214). The feedback I received indicated that the findings accurately reflected the real world as they perceived it.

By participating as an observer in the exercise, I gained a thorough understanding of the context and acquired in-depth knowledge that I would not have otherwise obtained (Perry-Parrish & Dogdge, 2010). The analyzed documents provided me with a comprehensive understanding of the framework within which the fire services operate and the requirements that must be met during wildfire response (Silverman, 2013, p. 290-291). Throughout the process, I have meticulously documented everything I have done to remain aware of the methodological choices made along the way. Methodological awareness involves the researcher's intention to reveal as much of the research process as possible. Through detailed descriptions in the methodology chapter, I have strived to keep the procedures transparent, thereby ensuring the study's internal validity (Silverman, 2013, p. 284).

External validity concerns the generalizability or transferability of the findings, and qualitative research, achieving full external validity is often seen as challenging (Silverman, 2020, pp. 36-37). However, measures can be taken to enhance external validity by

generalizing data from the empirical level to a theoretical level (Jacobsen, 2005, p. 222). Therefore, I ensured that I interviewed informants from various municipalities and counties, with affiliations to stations of different sizes, and who had diverse experiences and knowledge about wildfire response.

4.6 Reliability

Reliability in qualitative studies refers to the degree of transferability or reproducibility of the research findings (Mayring, 2021, p. 174). This means that other researchers, by following the same procedures in a different context or with different participants, should be able to achieve similar results (Yin, 2018, p. 46). Although achieving external reliability in qualitative studies is challenging due to the unique and context-dependent nature of qualitative data, there are measures that can enhance this form of reliability (Mayring, 2021, pp. 174-178).

Within the constraints of qualitative research, I have made significant efforts to increase the level of external reliability. I ensured variation in the informant group by interviewing individuals from different locations in the country and with different experiences related to wildfire response. Additionally, I provided a detailed account of the recruitment process, describing how the informants were contacted and the informed consent process prior to the interviews. I outlined the selection criteria for the informant group, highlighting the requirements for experience with wildfire response and their roles within the fire service. I thoroughly detailed the data collection methods and the purpose of triangulating various data sources. I also meticulously described the analysis process and included examples from the data. Throughout the study, I have consistently highlighted my own reflections on the choices I made.

Internal reliability refers to the consistency of the analysis process. A researcher can ensure a degree of internal reliability by explicitly detailing their steps (Yin, 2018, p. 46). This was attempted by identifying the analysis method used and describing step-by-step how I arrived at my results. The generalizability of the results is limited by the specific context of the Norwegian fire service and the focus on wildfire response. The reliance on self-reported information from informants may introduce bias and affect the reliability of the data. Additionally, due to the lack of data on the long-term implementation of new technologies, the results cannot confirm the sustained effectiveness of these tools in varied emergency scenarios. The methodological choices were constrained by the availability of respondents

and the specific incidents they experienced. Despite these limitations, the results provide valuable insights into the current communication practices and potential areas for improvement in the Norwegian fire service's wildfire response. Based on this, I argue that I have taken the necessary measures to enhance the study's reliability as much as possible within the framework of qualitative research.

4.7 Ethical Reflections

During the interview process, personal data was collected from the informants, including their names, positions, affiliations, and experience. This was done to distinguish between the various respondents. The handling of personal data falls under the Personal Data Act, necessitating the registration of the project with the Norwegian Centre for Research Data (NSD). The application was approved prior to conducting the interviews. Data management was also overseen by the TREEADS research project, which has its own procedures that extend beyond this study. I adhered to the guidelines provided for master's thesis writing at the Arctic University of Norway (UiT). All informants received an invitation to participate in the project, along with a written consent form, prior to the interviews. The invitation included the background of the overall project, the purpose of the thesis, the informants' rights, how the data would be handled, contact information for any questions, and their right to withdraw from the study at any time without providing a reason.

The information sought aimed to uncover the current shortcomings in wildfire response. This could be considered sensitive information, as confirmed by several informants who emphasized the importance of anonymity in their responses. The promise of anonymity was clearly stated in the consent form, and I verbally reiterated this before starting each interview. The interviews were conducted via Teams, and the platform was used for audio and video recording, which were temporarily stored in UiT's[6] internal systems. The audio files were then transcribed into text format, with respondents being anonymized and coded with numbers. All recordings were deleted after the transcription was completed.

5 Empirical Findings

This chapter presents the empirical findings of this study. First, I present the communication methods currently utilized in wildfire response, focusing on how these methods facilitate information sharing among responders. The analysis identified four key

[6] University of Tromsoe – The Arctic University of Norway

communication methods: direct communication, radio communication, technical and digital tools, and traditional methods. Furthermore, the chapter highlights potential improvements in communication processes and identifies key barriers to implementing new technology in wildfire management operations. The findings are summarized in tables at the end of each section to provide a clear overview of the key points and informants' insights.

5.1 Research Question 1: Communication Methods in Wildfire Response

This theme addresses the various communication methods currently utilized in the response to wildfires, focusing on how these methods facilitate information sharing among responders. Analysis of the collected data identified four different methods for communication, currently used by the fire service today. At the end of this subchapter, Table 6 presents the findings related to research question 1, summarized in key points.

5.1.1 Physical Communication

Direct, face-to-face interactions are often used for immediate coordination at the sharp end. During the initial phase of the response, the incident commander establishes a command post where leaders from the police, fire, and health services collaborate on coordinating the response. At this stage, verbal and direct communication at the leadership level drives the operation. As one informant noted, *"We connect with the leadership of the police and preferably health services, so we constantly have contact between the leaders on the scene [...] This involves direct communication. It is not through radio communication."* (I2). The practice of having leaders physically gathered at the same location is considered a success factor for planning the response. Another informant highlighted:

> *"The last time we had an incident here, both the police and civil defense were present and located in separate rooms within the same building, so they could walk and talk to each other. This was likely a success factor, as they were gathered together and not sitting in separate operations rooms far from each other, communicating only through radios."* (I9).

The importance of direct communication among the leadership is affirmed by all informants, who emphasize the responsibility that lies with the leaders of the response. For instance, I2 stated, *"The leadership system is a cornerstone,"* while I3 elaborated, *"This is a type of incident where leadership is crucial [...] We are axe throwers, we go straight in to*

work, and the leaders have to ensure we are doing it correctly." Informant 11 pointed out that communication and leadership together are important, and over time, their relative weighting has shifted. *"The first edition of the tactics book*[7] *was supposed to be 80 percent leadership and 20 percent communication. When it was implemented, they quickly realized that this was not the case. It is 80 percent communication and 20 percent leadership."* (I11). Despite the change in the weighting of communication and leadership, it shows that both factors together are emphasized to achieve a successful response.

Direct communication is also crucial with other key contributors during the response. One informant highlighted an important lesson from a wildfire exercise:

> *"The Civil Defense was not included in the leadership, and they were the ones who started deploying equipment. Their leader was brought in too late. We could have received answers earlier about what equipment was available if he had been included in the leadership from the start."* (I4).

Additionally, the importance of involving local experts with knowledge of the wildfire area in the leadership is emphasized: *"Often these individuals become key personnel. It is very important that they are in the command post or where the leadership is coordinating the situation."* (I5). Local experts have an overview of available resources in the area, which can significantly improve the response, knowledge that the fire service might otherwise not have access to (I1, I2, I5, I8, I9).

This crucial integration of local expertise underscores the broader significance of strong leadership in wildfire responses. Good leadership is viewed as a key factor for effective communication processes (I2, I5, I6, I7, I9, I10, I11) and is thus critical for successful wildfire responses. Failures at this level can lead to cascading issues throughout the response effort, as underscored by informant 8: *"The greatest potential for improvement is generally at the leadership level. If the crew does not follow the plan, it is because it has not been communicated well enough."*

[7] "The tactics book" is translated from the Norwegian "Taktikkboka" and refers to a book which describes how rescue- and firefighting efforts are organized using a scenario-based decision model.
Authors: Magnus Mattsson, Linus Eriksson. Translator: Lars Brenden. *The Tactics Book - A Handbook in Systematic Management of Firefighting Efforts Against Building Fires*. Publication Year: 2017. Publisher: Norwegian Fire Protection Association

5.1.2 Radio Communication

Radio communication is a cornerstone of wildfire response, particularly when coordinating efforts over large areas or among multiple teams. One informant emphasized, *"The most effective means of verbal communication we have is the TETRA[8] radio system. It ensures that we can sit anywhere in Norway and verbally interact with each other."* (I10). One of the most crucial aspects of radio communication is the real-time sharing of information and situational developments.

> *"The most important thing is perhaps the radio system, so we can give warnings if dangerous situations arise. During a previous fire, someone over the radio said, 'this house is about to go up,' and we needed to clarify which house it was and where the person was located."* (I9).

The use of TETRA allows for the creation of various talk groups: *"In a significant incident, we use TETRA, and we have one talk group; if it gets larger, we split it into several talk groups based on sectors and areas."* (I12). However, the effectiveness of communication through TETRA heavily depends on the responders' familiarity with the system and training: *"I don't think we are very good nationwide at handling these larger incidents. It's easy for there to be confusion in the talk groups when we sectorize and create more subgroups and new talk groups."* (I12).

This challenge is further compounded when cooperating with other agencies. As one respondent noted: *"The rescue services (redningstjenesten) don't have TETRA, so we face a challenge when collaborating with them."* (I3). This issue is confirmed by several respondents, such as informant 6, who stated:

> *"When it comes to other agencies in relation to wildfires, it can actually be a bit challenging [...] they are entirely dependent on getting radios from us. So there have been some communication challenges there."* (I6).

Another limitation with TETRA is related to the type of information that can be shared via the system: *"A major limitation with the TETRA system today is that we cannot share pictures or data through the emergency network."* (I10). This highlights a need for integration of visual communication tools in wildfire response.

[8] See Glossary.

Some informants noted that the development of radio communication with other emergency services has improved significantly over the years: *"Overall, it has gotten much better, especially communication between us and other emergency services."* (I2). However, informant 2 pointed out that this improvement is general and not specific to wildfires. When it comes to wildfires, the respondent was more uncertain: *"Regarding wildfires... I am a bit unsure there... I think it is good Yes, it is good."*

Other informants perceive radio communication with other agencies as entirely unproblematic:

> *"It works very well. The police handle intelligence, we manage the operation, the Civil Defense is great to have with us, the ambulance service is involved in case we get injured, inhale smoke, suffer burns, and so on, so all emergency services contribute. No, it works excellently."* (I5).

5.1.3 Technical and Digital Tools

The integration of technical tools, such as drones, has significantly enhanced real-time information sharing. Nearly all informants highlight drone technology as revolutionary for how the fire service responds to wildfires. One informant noted, *"The drone technology that has come now is very good. We were early adopters, and it is a fantastic resource"* (I5). The use of drones provides easier and faster situational awareness, allowing for better planning and management of the fire. *"You get a completely different overview, and you can plan and manage the fire,"* said one informant (I1). This is achieved through visual information sharing via image and video transmission, and another informant described it as *"an incredibly good tool that provides excellent overview and great images"* (I9).

Drones can also provide very accurate information about where the fire is burning in the terrain and ground temperature using thermal imaging cameras (I5, I10). An informant elaborated, *"The drones available today have thermal cameras, and a fire can appear extinguished when it is not. Drones, along with helicopters, can find hot spots, preventing the fire from flaring up again."* (I3).

Despite the advantages of drones, such as providing an aerial view of the incident and detailed information about the highest temperatures in the terrain (I3, I4), it is noted that improper use without adequate knowledge and strategy can lead to ineffective resource allocation.

"When we first started using drones, the helicopter tended to fly to the hottest spots. Is it sensible? Maybe, maybe not. We need to use the resources understanding that if the fire is where it burns most intensely on the top, it doesn't matter; the energy will calm down and die out because it is on top. But if the fire spreads fifteen meters to the right, it will have all the energy up the hillside again," (I10).

This sentiment was echoed by another informant, who pointed out that this approach is in need of a focus change: *"Sending the drone up to extinguish the hottest spot is something we've done with house fires for many years. We spend a lot of resources on what is already destroyed. We need a change in focus in our training"* (I11).

It is therefore crucial to have the competence to use the information provided by drones effectively and sensibly (I10). The informants leave no doubt that drone technology, when used correctly, is revolutionary for the fire service. One informant stated, *"When I am in the field and get the aerial images from the drone, combined with the electronic mapping from DSB, you can get everything out of it"* (I6). Another informant summed it up well, noting, *"There is a before and after drone; it has an incredible impact on performance"* (I3). Additionally, new digital mapping systems have recently been adopted for planning operations:

"The system is called LOKUS, and it is essentially a mapping system where you can plan operations. You can add water lines, fire hydrants… Only your imagination limits it. It is a map you can draw and plan on" (I1).

Besides planning operations, LOKUS can also be used for logging and sharing image and video data from both drones and helicopters to the incident command (I11). There are high expectations that this will be a valuable tool for wildfire response. One informant mentioned:

"I spoke with someone who conducts training at the fire and rescue school. He recently attended a course to see what the tool entails, and he said it was fantastic. He believed it would become an essential tool for us in making decisions or assisting in decision-making" (I11).

Digital tools are also used when the scale of the operation requires leadership support. *"Many people work with leadership support on Teams[9]. Effective leadership support is crucial for good collaboration"* (I3). Private phones are also used to gain an overview of the incident and the fire's development.

> *"We are super 'googlers'. We quickly check local media around where the fire has occurred to see if we can find any images showing how the fire is behaving, what terrain it is in, and what the smoke looks like"* (I10).

Information gathered from local media is used not only to assess the current status but also to see the potential for development. *"...so we go straight to Google and the local newspapers to get close to the area and gain insight into the potential of this"* (I12). Private phones are also used to communicate between response personnel when needed. *"Private phones are still used to make calls. It can be faster. You call and call over the radio but get no response. So, you call with your private phone instead"* (I5).

Finally, CIM is a tool used for logging both in everyday operation and during incidents. *"We have a common platform called CIM, where we log all the equipment we have and its condition"* (I8). During an incident, CIM is used to keep track of what is happening (I2), and it can also be used as a mapping service (I8). CIM is in the process of being replaced by a new program. *"We also have RAYVN, which is now being integrated into the municipalities' crisis management systems, offering a completely different approach and possibilities for information sharing than we currently have in the fire service"* (I10).

5.1.4 Traditional Methods

Despite advancements in technology, traditional methods such as paper maps and written logs remain in use, particularly in areas where digital tools are unavailable or unreliable. One respondent noted, *"We have had a lot of technology here that is great and fine, but we very often go back to pencil and paper"* (I3). These methods are seen as reliable backups to more modern systems, as another respondent explained, *"If I need to draw new things, it is easiest to draw them on paper"* (I9). However, paper has its drawbacks, such as wear and tear over time. As one informant observed, *"Having something to draw on is great,*

[9] Teams is a collaboration and communication platform developed by Microsoft, designed to facilitate teamwork and productivity in both professional and educational settings. It integrates various features such as chat, video conferencing, file sharing, and application integration, allowing users to work together in real-time from different locations.

but a paper map that gets folded a lot becomes worn out eventually. I would still look at a picture on my phone and use both" (I9). Whiteboards are also used to visualize response plans. One respondent described the process*: "…a command board where we begin to visually write down the main goals, draw a sketch of the area, and organize ourselves"* (I10). The whiteboard is also used to create a common situational understanding and assign tasks to individuals (I2).

5.1.5 Summary

Direct communication, primarily at the leadership level, is crucial for ensuring a coordinated response without creating downstream errors within the organization. Radio communication is regarded by all informants as the most commonly used tool for communication during incidents. However, challenges arise with radio communication when there are numerous talk groups, particularly if inexperienced leaders struggle to manage multiple groups simultaneously. Another challenge is inter-organizational communication. Radio communication facilitates real-time information sharing among emergency responders. Additionally, digital tools such as drones, LOKUS, and CIM are used for real-time sharing of images, video, mapping services, and logging. Private phones are used for direct communication and gathering local information. In the context of verbal communication methods, drawing on whiteboards and paper is frequently employed to visualize and create a common understanding of the response plan. The role of leadership and the importance of competence and effective management are highlighted by the informants as key factors for a successful response.

Table 6: Findings research question 1, summarized in key points.

Method	Key Points	Informants
Direct Communication	• Immediate coordination through face-to-face interactions. • Leaders from police, fire, and health services collaborate. • Gathering leaders physically improves planning	I9, I10, I11, I12
Radio Communication	• TETRA radio system ensures real-time verbal interactions. • Used for warnings and situational updates. • Challenges with talk group management and inter-agency communication.	I1, I3, I4, I6, I9, I10, I11, I12

Digital Tools	• Drones provide real-time visual information and thermal imaging. • Tools like LOKUS for mapping and planning. • Use of private phones for rapid information gathering. • Use of CIM for logging.	I1, I3, I5, I8, I9, I10, I11, I12
Traditional Methods	• Reliance on paper maps and written logs. • Whiteboards for visualizing plans. • Used as backups when digital tools are unavailable.	I1, I4, I8, I10, I11, I12

5.2 Research Question 2: Potential Improvements in Communication Processes

This theme explores areas where communication processes in wildfire management operations could be enhanced and the potential benefits of such improvements. At the end of this subchapter, Table 7 presents the findings related to research question 2, summarized in key points.

5.2.1 Training and Familiarity

The data reveals that enhancing training that focuses on how to use communication tools and protocols is essential for improving the overall communication process. One informant emphasized that basic training and familiarity with specialized language can significantly reduce misunderstandings: *"If everyone has undergone basic training and knows the technical language, it becomes much easier than having to start training on-site, which can quickly lead to misunderstandings"* (I1). Another informant stressed the importance of ensuring that all personnel in the fire service understand the communication systems in use*: "...it's crucial in terms of competence that everyone in the fire service understands what this is"* (I10). Several informants noted room for improvement in training, highlighting dissatisfaction with current training levels*:*

> *"In that area, I have been dissatisfied, and it has been seen that we have not been good enough"* (I2). One informant added, *"Communication is one of the most difficult things in all incidents, I think. Sometimes it goes very well, and sometimes it does not go well, and it almost always boils down to communication, and then things go wrong"* (I8).

A lack of understanding of each other's work, both within the fire service and in collaboration with external agencies, was highlighted. One respondent said, *"It's not poor communication, but perhaps... It's not a poor tone, but it's a bit... Yes. I don't want to use the word poor. I think it's a lack of understanding of each other's work"* (I7).

This gap in understanding underscores the need for improvement on multiple levels. According to informant I1: *"In that area, it could have been much better... there is a significant backlog in education both at the firefighter level and the incident commander level"* (I1). Another informant added: *"The greatest potential for improvement is mostly at the leadership level"* (I8). Another pointed out that there is a lack of competence among leaders in Norway to interpret the information needed to handle major climate incidents today:

> *"Are we capable of analyzing and making the right decisions based on the data we have? And my answer to that is currently 'No.' Only a few people in Norway are able to think outside the box and have some understanding of what this is"* (I10).

5.2.2 Standardization

Currently, there is no standardized terminology that unifies the fire services and fire helicopters. As one informant noted, *"...the zone terminology that some fire services operated with […] did not exist in the pilot's mind; they operate based on flanks"* (I4). Additionally, the communication process between pilots and ground personnel has been highlighted as an area for improvement. One informant explained:

> *"...perhaps the person in the field should communicate directly with the pilot. Otherwise, there is a delay, and the pilot might have already flown past the area they should have targeted. Last year, the field personnel reported to their support leader, who then communicated with the incident commander, who finally relayed the message to the pilot. This process involved three stages from the initial message to the pilot receiving it, leading to inaccurate drops"* (I7).

Reflecting on the use of terminology in collaboration with helicopter pilots, one informant suggested, *"Maybe we should have a standardized grid for wildfires in Norway? That should be a goal, so everyone is aware that, for example, one grid is 500 meters"* (I4). There are, in addition, differences in terminology between fire services, with the informant stating, *"And I can say that I haven't heard about the colored zones"* (I4).

Another improvement point mentioned by several informants is the current incompatibility of equipment among different fire services. One informant noted, *"The equipment is not entirely compatible; there are differences"* (I3). Another specified, *"We found out that we have different hose couplings. We have snap couplings, while some still have screw couplings. So the hoses... can't be combined"* (I6). The incompatibility of equipment, such as different hose couplings, directly impacts the efficiency of the operation, and by extent the communication. When fire departments have incompatible equipment, it complicates the coordination and execution of tasks during an emergency, creating a need for more detailed and frequent communication to overcome these issues.

One informant highlighted that incompatible equipment can have a critically negative impact on the incident:

> *"One critical issue is that the hose couplings are not the same. The couplings from different fire departments do not match. If you grab the wrong hose and lack 25 meters, and it can't be connected to another hose, it can become critical. Uniform equipment on different fire trucks is important... It can be challenging. Having identical equipment when collaborating is important"* (I4).

Thus, standardized equipment is emphasized as a crucial point that should be implemented. As long as this is not in place, *"It's easier when you're alone, but as soon as more fire departments are involved, it can become a bit more difficult"* (I2).

5.2.3 Integration of Technology

Several informants highlight real-time tracking of both equipment and personnel as areas where integrating technology can improve information sharing and communication during wildfire response. One informant noted:

> *"If each fire department had marked their hose equipment with QR codes, the same with nozzles and such, the equipment would have its own identity. We can mark it and find it more easily. We can see that this equipment is not in use. Those in the command center would know we have available equipment and could move it. You could get an incredibly good overview of where you have equipment in the terrain. Otherwise, you don't have that"* (I9).

Tracking personnel is also emphasized as a way to make work safer for the crews and to streamline planning. Another informant stated, *"Tracking where we could see where we have people in the field. I could easily see that when we had sectorized and sent a person or a team into the field, we could see where they were at any time"* (I2). Another informant agrees that GPS tracking of personnel can be valuable but points out that it might only be useful if the personnel go off course or if teams are split up. Real-time tracking of all personnel at all times could create unnecessary noise for the incident commander (I3). According to the informants, the integration of technology through real-time tracking and data sharing platforms may offer substantial improvements in efficiency and safety. However, it may require careful implementation to avoid potential issues, such as information overload.

Furthermore, it is pointed out that visual communication is limited by the current emergency network. Example given as previously mentioned: *"A major limitation with today's digital emergency network is that we do not have good procedures for sharing pictures or data through it"* (I10). This limitation leads to alternative and time-consuming ways of handling visual communication:

> *"Otherwise, information must be explained and communicated out in the field. Here, you need communication, and you are in different places; one person must explain, and the other must draw... It is never the same. If there is a change in the area, you can take a picture in the command center and send it to the sector leaders. This way, they get updated. Again, it depends on having a phone with you. You can't send a message on our radios. They look almost analog. You rely on people having a mobile phone so they can see it"* (I9).

There are visual communication platforms available today, but they are rarely used due to outdated systems and low user-friendliness:

> *"The DSB also has a mapping solution that allows us to log in collectively and place things on the map, making it visible to all parties regarding where the fire is, where sectorization, containment lines, and the fire's development are. It could have been an excellent platform for information sharing. But it is used far too little, primarily because the system's functionality is outdated, poor, and not user-friendly. So that's a negative thing"* (I10).

However, it seems that this issue is being addressed, as new tools are being implemented:

"We will achieve better information flow when the current logging tool is replaced with the new LOKUS tool. There, both log sharing, regardless of where you are in the country, will be possible, in addition to digital photo sharing and streaming from both aircraft and drones. Things are underway, and it will be a national platform that we can use as a tool" (I11).

5.2.4 Collaboration with Other Agencies

Enhancing collaboration with other emergency services and incorporating feedback from all stakeholders can lead to a more cohesive and effective response. Several informants highlight the potential for improvement in collaboration both with other fire departments and other agencies*: "It has been less than satisfactory because we haven't planned for major incidents together before we are there handling them. We haven't practiced for major incidents, and that has led to the cooperation being less than satisfactory"* (I2).

A prerequisite for good cooperation, as pointed out by several informants, is strong leadership: *"What determines whether the collaboration is good or bad is solely leadership"* (I3). Informant 6 adds, *"Personal chemistry will always be crucial, especially at the leadership level."* An established regional collaboration is seen as a significant factor for success:

"For many years, the cooperation climate was frankly poor. But we have greatly strengthened it by establishing cooperation in the region, which makes us work more closely together. The foundation of success is knowing each other. We are not strangers to each other. So, it is much easier to set up operations" (I6).

A positive consequence of being a united region is that response personnel meet and establish relationships outside of incidents: *"I believe part of the success factor here is that we have established this fire and rescue region, which means we meet occasionally, and it is a success factor that we come together, have some collaboration, and meet each other"* (I9). Established relationships are emphasized as an important factor for good cooperation and effective problem-solving*: "Good relationships make cooperation good. The absence of this can lead to the opposite. Knowing each other means you can solve things you don't have a plan for as well. It is more challenging if you don't know each other"* (I2).

This collaboration extends to working with other agencies, where frequent interactions during incidents help establish good interagency cooperation. One informant highlight*, "We*

have very good contact with the police and health services through BAPS; we work together several times a week, so it works perfectly" (I6). Informant 1 concurs, saying, *"I would say there is good communication between the fire services and other emergency services like the police and health services,"* but also notes, *"It is good, but it can be improved"* (I1). Informant 6 points out that while the communication is generally good, *"When it comes to other emergency services in connection with wildfires, it can actually be a bit challenging. So, I wouldn't give a very high rating, to be honest"* (I6).

According to the informants, interagency cooperation has several areas for improvement. Informant 7 emphasizes different operational methods among various actors: *"Regarding the wildfire helicopter, the pilots need to tell us how they want things done. Last year, the fire services did it in a way that the pilot wasn't on board with, and it wasn't communicated at the incident site"* (I7).

The Civil Defense is also highlighted as an important actor: *"The Civil Defense is very good to have. They have a lot of equipment and bring many people"* (I5). Despite this, it is noted that the fire service could *"perhaps have better cooperation, especially with the Civil Defense"* (I7). According to Informant 2, this involves *"having good relationships with each other in in between incidents and preferably having some common overarching plans and meeting points."* An example of a meeting point, as highlighted by Informant 10, is common management platforms: *"We lack national coordination on which tools we should actually work on [...] there are numerous platforms, and the fire service isn't even invited to all of them to be able to view the information"* (I10).

5.2.5 Summary

During the data analysis, four points of potential improvement in communication processes were discovered. Firstly, there is room for improvement when it comes to *training and familiarity* with communication systems. Thorough training can prevent misunderstandings and streamline operations. Furthermore, *standardization* of equipment and procedures may ensure that responders operate cohesively, improving coordination and communication efficiency. Third point of improvement is *integration of technology*. There was a unified group of informants who agreed that a common platform for information sharing, and communication would enable more precise and timely decision-making based on real-time data from the field. Lastly, *collaboration with other agencies* is highlighted with a major potential of improvement.

Table 7: Findings research question 2, summarized in key points.

Improvement Area	Key Points	Informants
Training and Familiarity	• Basic training reduces misunderstandings. • Need for understanding communication systems. • Improved training at all levels, especially leadership.	I1, I2, I7, I8, I10, I11, I12
Standardization	• Need for standardized terminology and procedures. • Compatibility of equipment (e.g., hose couplings). • Unified equipment for better coordination.	I2, I3, I4, I6, I7
Integration of Technology	• Use of GPS tracking, weather measurement tools and real-time data sharing. • Overcoming limitations of current emergency networks. • Integrating tools CIM systems on mobile platforms for streamlining communication and reducing delays.	I2, I3, I9, I10, I11
Collaboration with Other Agencies	• Joint training exercises to improve coordination. • Strong leadership for effective collaboration. • Established regional cooperation enhances response.	I1, I2, I3, I5, I6, I7, I9, I10, I11, I12

5.3 Research Question 3: Barriers to Implementing New Technology

These findings identify key barriers to the successful implementation and adoption of new technology for enhancing wildfire response. At the end of this subchapter, Table 8 presents the findings related to research question 3, summarized in key points.

5.3.1 Financial Constraints

Budget limitations are a significant barrier to acquiring and implementing advanced new technologies. The cost of equipment and the ongoing expenses associated with training and maintenance can be prohibitive, especially for smaller municipalities. One informant noted:

"We are fortunate to work in a large corp. We have economic muscle due to regional cooperation. Clearly, a small municipality would have more wishes that do not get funded. You have small municipalities with poor economies, and then you have large municipalities that secure funding" (I6).

Informant 7 emphasizes that this issue is as much about the municipality's priorities as it is about financial resources: *"The biggest obstacle is the economy. And, of course, perhaps a municipal leadership that needs to see the need. I believe that most fire services see the need, but perhaps not those who control the purse strings"* (I7). Informant 8 adds that while there is already a lot of new and exciting equipment in fire and rescue, this does not automatically mean that fire services have the opportunity to renew themselves*: "There has been a lot of great equipment, but it comes down to economics […] we can't afford to renew as much as we would like"* (I8).

A specific example given by Informant 8 highlights this issue:

"I can mention one thing that I know exists and is patented and used by the Red Cross, but not by the fire service. Again, it is about money. And that is tagging personnel with a GPS transmitter that you then get up on an active map, so you see where the personnel are in real time. This would ensure that those who are in operation and planning know exactly who is where at any given time. It could provide a better picture of the entire effort" (I8).

In addition to the cost of the equipment itself, the financial challenge includes the cost of freeing up fire personnel to become proficient with the equipment: *"It's not just money for equipment, but to free people up to become good at what they need to do in an operation. Training is crucial here; the more you train, the better you become"* (I4). Informant 3 underscores the importance of knowledge and competence: *"The biggest obstacle to improving the equipment and technology used is perhaps knowledge? Knowledge and competence"* (I3).

This perspective is confirmed by Informant 2, who points out that while they have good conditions due to the regional cooperation they belong to, they still need someone interested in driving the field forward: *"We need someone who is interested in it, who holds the ball and advances the field. I would like to have a dedicated subject matter expert in this field"* (I2).

There appears to be a near-unanimous agreement among the informants that one of the biggest obstacles to implementing new technology lies in the economy and the prioritization of spending in municipalities. This is well summarized by Informant 1:

> *"It's the economy, there's no denying it. Even if you have numerous risk analyses and have adopted various plans, it always comes down to the economy. There's also a difference between municipalities. It depends on who is in the municipal council. If they are interested in preparedness, it goes smoothly, but if they are more interested in other things, then you don't have as much to go on. It has a lot to say. You see it in most fire stations in Norway; there is a backlog, and it costs a lot of money… And it eats into the municipal budget, so maybe the state should contribute more there"* (I1).

Finally, it is pointed out how economic priorities can be misguided when it comes to wildfire preparedness: *"When you look at the costs of a large forest fire, it often costs much more than the cost you would have spent on the equipment to extinguish it early"* (I7).

5.3.2 Technological Integration

Technologies must be compatible with current practices and intuitive enough for responders to use them effectively under pressure.
The knowledge currently possessed by the fire service is not sufficient to fully utilize the technology available today. One informant expressed concern: *"I worry that we might suddenly face a fire, make wrong decisions, and potentially endanger personnel or the public because we did not understand what was happening"* (I10).

This concern is echoed by several informants. For example, one noted, *"The biggest obstacle to improving the equipment and technology used is perhaps knowledge"* (I3). The lack of competence within the fire service is seen as a barrier to implementing new technology, highlighting the need for training and skill development in technology use. *"It must also be such that those who are going to use the technology are competent with it"* (I10).

The need for education is especially emphasized at the leadership level. One informant pointed out, *"Leadership training in Norway is unfortunately not very widespread. We are good at training skills on a technical level, but we have been very poor at training leaders"* (I11). Informant 10 suggests a specific solution:

"I think we need a separate training subject called sector leader. Those who are to enter the sector leader role should have a sector leader course that teaches them about the mechanisms they will be responsible for when handling such climate events."

Moreover, it is crucial that existing technology can be integrated with new technology to create a holistic platform. *"It is a fact that we make the first decisions based on little information and few facts. Implementing good information tools allows us to make decisions on a much more thorough basis"* (I11). Currently, there are numerous different information tools for crisis management; some are outdated, some are not available to the fire service, and several of the tools are not interoperable (I10).

5.3.3 Training and Familiarity

Ensuring that personnel are adequately trained to use new technologies is essential for their effective deployment. This includes both initial training and ongoing practice to maintain proficiency. Some informants directly point to the lack of knowledge as a major barrier to the effective use of new technologies. One informant stated, *"There is not enough knowledge"* (I11). Without adequate understanding, even the best technology will be difficult to utilize to its full potential.

Furthermore, the effective implementation of new technology requires strong leadership to guide and support the transition. One informant highlighted that the lack of leadership training may result in leaders not being equipped to manage the adoption and implementation of new technologies*: "Leadership training in Norway is unfortunately not very widespread. We are good at training skills on a technical level, but we have been very poor at training leaders"* (I11).

Despite having access to new technologies, the lack of practical training and comfort with these tools often results in a fallback to traditional methods. One informant remarked, *"We have had a lot of technology here that is great and fine, but we very often go back to pencil and paper"* (I1).

5.3.4 Organizational Aspects

The fragmented nature of emergency services in Norway complicates the adoption of standardized technologies and procedures. Differences in funding, resources, and priorities among municipalities can lead to inconsistencies in response capabilities. This issue is

highlighted by one informant, who points out the obstacles to implementing new technology due to the overall organization of the fire service:

> *"It makes us a bit vulnerable, the way we are organized [...] we are either dependent on coming under the umbrella of a sponsor municipality, or we are somewhat squeezed when it comes to RAYVN and previously CIM, which are the municipalities' crisis management and logging tools"* (I11).

Municipal organization is seen as a major hindrance to inter-organizational cooperation:

> *"A great platform[10] is now being rolled out, where fire and rescue are not included, even though we are an important search and rescue actor, both with personnel, drones, boats, you name it. So we don't have access to the platform at all because we are municipal. No one is taking responsibility for getting the municipalities involved in the project"* (I10).

This also creates problems for cooperation between fire services in different municipalities: *"If everyone hadn't kept to themselves with their small budget, and cooperation could be improved, we would have had better equipment"* (I8). Informant 7 also points this out and sees local organization as an obstacle to comprehensive cooperation: *"It's not just the local fire stations sitting in their own corners keeping things in order, but rather that we need a holistic collaboration"* (I7). Several informants question whether the organization should be different, exemplified by informant one's statement: *"Perhaps the fire service should be state-run? Then we would have a more unified approach, like the police and ambulance services"* (I1). Informant 8 believes a shared wildfire preparedness plan could be the solution:

> *"We can quickly help each other. Shared wildfire preparedness, I think, would make a big difference. Perhaps it would improve the economy, better economy = better equipment. Then the snowball starts rolling. With shared equipment, we need joint exercises, leading to a unified platform, which I believe would help"* (I8).

Informant 5 points out that differences between municipalities are a factor: *"A small municipality has fewer resources than a large one, and that certainly has an impact."* Informant 6 states: *"It's no coincidence; it's due to municipal finances. Being municipally run*

[10] The informant did not specify the name of the platform in question.

means there are differences." It is clear that all informants agree that both inter- and intra-organizational cooperation[11] have significant room for improvement. This need is summarized concisely by Informant 2: *"We need help when something big happens, and we are not large enough on our own."* Informant 10 adds: *"We lose a lot of momentum in terms of development, research, or new digital solutions because it's not centralized or done on a national level"* (I10). The need for a professional, national wildfire team to handle future wildfires underscores that the municipal organization of the fire service is itself a barrier to implementing new technology: *"It confirms the need for professional teams, because in addition to everything else we in the fire service have to handle, we also have to deal with the changes we see in wildfire contexts. And there isn't enough collective knowledge and competence"* (I11).

5.3.5 Summary

After analyzing the data, four barriers have been identified regarding the implementation of new technology in wildfire response. Financial constraints hinder the acquisition and implementation of advanced technologies. Smaller municipalities struggle to afford new equipment and the ongoing expenses for training and maintenance. Financial prioritization often overlooks the necessity for updated firefighting tools and technologies. The second barrier, regarding technological integration, highlights the current difficulty with integrating new technologies with existing systems and ensuring they are user-friendly. Insufficient training and expertise, as the third barrier, hinder the fire service's ability to effectively utilize new technology. Lastly, the organizational structure is regarded as a major barrier due to the fire services' fragmented nature, which complicates the adoption of standardized technologies and procedures.

Table 8: Findings research question 3, summarized in key points.

Barriers	Key Points	Informants
Financial Constraints	• High cost of equipment and training. • Smaller municipalities struggle with funding. • Prioritization of spending by municipal leadership.	I1, I2, I3, I4, I5, I6, I7, I8, I9, I10, I11, I12
Technological Integration	• Need for user-friendly and compatible technology.	I4, I5 I8, I10, I11, I12

[11] See page 47 & 48.

	• Training and competence crucial for effective use. • Holistic integration of existing and new tools.	
Training and Expertise	• Lack of knowledge hinders technology use. • Need for leadership training. • Regular practice to maintain proficiency with new technologies.	I1, I2, I3, I5, I6, I10, I11, I12
Organizational Structure	• Fragmented nature of emergency services complicates standardization. • Differences in funding and resources among municipalities. • Calls for a state-run unified approach.	I3, I7, I10, I11, I12

6 Discussion

In this chapter, the empirical findings are discussed against the theoretical framework, and previous research. The chapter is structured according to the three research questions, mirroring the structure of the empirical chapter. I begin by discussing the communication methods currently used in wildfire response and how the informants perceive their effectiveness. Subsequently, I reflect on the potential improvements that exist in relation to communication. Finally, I identify the barriers associated with the implementation of new technology.

6.1 Research Question 1

Which specific communication methods and tools are currently utilized in the response to wildfires, and how do they facilitate information sharing?

6.1.1 Physical Communication: Face-to-face Interaction

Physical communication involves the direct, face-to-face interaction between individuals, enabling the exchange of information through both verbal and nonverbal cues such as body language, facial expressions, and eye contact (McComb and Kennedy, 2020). The findings of this study demonstrates that physical communication is crucial during wildfire response to ensure clarity and immediacy in decision-making. Previous research highlights the importance of face-to-face interactions in emergency situations to mitigate delays and misunderstandings (Dunn et al., 2002). Empirical findings from informants in this

study reinforce the significance of face-to-face communication, noting that the physical presence of leaders from various emergency services (police, fire, health) at a single command post significantly enhances coordination and planning. This strategy has consistently been a success factor in past incidents.

This physical presence and proximity of leaders facilitates effective decision-making, and informants indicate that, in the initial phase of the response, physical communication is the preferred communication method for information sharing. The findings of this study are in line with the previous research by Steelman and Nowell (2019), that highlights the importance of co-management in improving coordination and communication. The practice of physical co-managament enables direct interaction, fostering a common situational understanding among the decision-makers. In such practice, local experts are also incorporated as vital participants. An important finding in this study is that the knowledge possessed by local experts is crucial for quickly orienting themselves to the landscape of the incident and understanding the availability of local resources. Integrating local experts with in-depth knowledge of the wildfire area into the leadership team has proven critical for effective resource allocation and strategic planning.

The primary objective of integrating leadership from various stakeholders in a wildfire incident is to consolidate their presence, enabling direct and effective communication. The emphasis on direct communication as a critical success factor demonstrates that the visual component of direct communication, such as body language, plays a crucial role, supporting the findings of previous studies that point at the importance of body language and visual communication for enhanced situational understanding (McComb and Kennedy, 2020). This suggests that direct communication not only conveys information but also builds trust and understanding among actors, which according to (Nowell & Steelman (2015) is essential for effective coordination and communication during wildfire response. Previous studies are warning that despite its effectiveness, direct communication can be hampered by logistical issues in large-scale incidents (Rebmann et al., 2008). Future strategies should consider enhancing the flexibility and reach of direct communication methods through changing the practice where leader support is solely offered digitally, and rather facilitate for the physical presence of leadership support personnel.

6.1.2 Radio Communication: Real-time Information Sharing

Advancements in communication technology have been pivotal in enhancing real-time communication among emergency responders, significantly improving the efficiency and effectiveness of their operations. The findings of this study show that real-time information sharing, and situational updates are crucial in emergency response. Radio communication facilitates the rapid exchange of situational updates and alerts regarding changes in the event progression. Additionally, radios are used to communicate resource needs and allocate resources where they are required.

One important finding of this study is that TETRA's effectiveness of communication largely depends on users' familiarity with the system and their training in handling large incidents. TETRA can facilitate real-time information sharing, but this capability is only fully realized when users are well-trained and competent in using the system efficiently. In addition, one informant highlighted the fire services' challenges in handling talk groups when sectorizing during larger incidents. This finding is in line with previous findings in TREEADS. In the Roan case study, the fire service's evaluation after the incident pointed to confusion with talk groups upon sectorizing (Kemal et al., 2023). The importance of well-trained and competent personnel is highlighted in the research of Kapucu and Garayev (2013), who emphasize the critical role of communication technology in enhancing emergency management efficiency, underscoring the need for comprehensive training and system familiarization.

In line with the previous research my data reveals that technology has its limitations. The TETRA system particularly is limited in its inability to share visual information such as images and videos. Visual information has been highlighted in the literature as crucial in communication processes, as it enhances understanding of environmental conditions and enables quicker identification of potential risks (Xia et al., 2012). This drawback is critical because visual data are essential for providing a complete understanding of on-ground response operations, as highlighted by Jimenez and Morreale (2015). Therefore, while TETRA is an efficient tool for real-time information sharing, its full potential is hindered by its inability to transmit visual information, a gap that must be addressed to optimize wildfire response efforts.

6.1.3 Technical and Digital Tools: Visual Information

The findings of this study show that the CIM system is a commonly used tool for logging, checklists, document handling, and community updates on wildfire incidents. However, this system is being phased out and will be replaced by a system called RAYVN, which is currently in its pilot period. Other new systems, such as LOKUS, which enable the planning and logging of operations as well as the sharing of images and videos from drones and helicopters to the command post, are expected to become valuable tools for wildfire response in the future.

The continuous technological innovation and adaptation to meet the dynamic challenges that wildfires present, is highlighted by Bharosa & Janssen (2010) as important to overcome these challenges and enhance wildfire response success. The same study by Bharosa & Janssen emphasizes the role of information and operational information systems in facilitating inter-agency communications during emergency operations. These considerations support the notion that novel systems like LOKUS is likely to have an important role in the enhancement of wildfire response through improved information sharing and coordination. Furthermore, the integration of technical tools, such as drones, has significantly improved visual real-time information sharing. Nearly all informants emphasize drone technology as revolutionary for the fire service's response to wildfires. Drones provide easier and faster situational awareness through visual information sharing via image and video streaming. Additionally, the use of thermal cameras on drones makes it possible to identify hot spots in the terrain that might otherwise be hidden, improving the accuracy and effectiveness of the response.

Conversely, it has been observed that the use of drones can result in the misallocation of resources, a problem evidenced in previous incidents. An instance highlighted by an informant reveals that firefighting decisions were based on drone data indicating the hottest areas of the terrain, rather than focusing on regions with the highest risk of fire spread. This scenario may reflect either a knowledge gap among decision-makers or insufficient or inaccurate information being provided to them. The assertion is in line with the crisis management dilemma[12] as presented by Engen et al. (2021, p. 255).

[12] See page 22.

Engen et al., (2021, p. 255) further pose the dilemma of what would happen if the dependence on technology reduces operational experience, and personnel suddenly and unexpectedly find themselves in a situation where technological information tools or systems fail. The findings of this study indicate that such a scenario is highly realistic, as evidenced by an incident in which a drone malfunctioned, crashed, and was completely destroyed during a fire event. The resolution to this issue was to procure a new drone as quickly as possible; however, the immediate absence of the drone at the scene likely delayed the acquisition of desired information. This incident highlights the potential significance of redundancy in future technological implementations within the fire service, ensuring continuous operational capacity despite equipment failure ((Kapucu & Garayev, 2013; McLennan et al., 2005; Pine, 2017).

6.1.4 Traditional Methods: Pen and Paper

The findings of this study indicate that traditional methods, such as paper maps and written logs, remain essential in emergency management, particularly in situations where digital tools are unavailable or unreliable. Despite significant technological advances, these tools provide a critical safety net in situations where digital solutions may fail. Research by Bharosa and Janssen (2009) indicates that while digital tools enhance information sharing and coordination, they are not infallible. Technical issues, such as connectivity problems and system failures, can impede the effectiveness of digital tools, making traditional methods indispensable in ensuring continuity and reliability in emergency responses.

My data suggest that traditional methods offer significant advantages in visualizing and planning emergency responses. Paper maps provide a tangible, broad overview of the terrain, which can be crucial for strategizing in dynamic environments. Paper maps are currently the only visual aid available to frontline personnel for orienting themselves in the terrain. Written logs ensure that all critical information is documented and accessible, regardless of technological disruptions. These methods support the findings of Cheng et al. (2019), who emphasize the importance of having reliable, low-tech options available during emergencies.

However, the literature also highlights that continuous reliance on traditional methods is not without challenges. The primary disadvantage is the potential for slower information dissemination and updating compared to digital systems. Real-time data sharing, a significant advantage of digital tools, is harder to achieve with paper-based methods. This limitation is

highlighted by Damaševičius et al., (2022), who point out that digital communication channels can significantly enhance the speed and accuracy of information sharing during emergencies.

The integration of both traditional and digital approaches can mitigate the limitations of each, ensuring more robust and flexible response strategies. Empirical findings in this study reinforce the significance of maintaining traditional methods as backups, noting that in areas with unreliable digital infrastructure, these methods ensure continuous operation. This balanced approach aligns with the research of Dunn et al. (2002), who advocate for a hybrid communication strategy in emergency management to enhance resilience and adaptability.

Traditional methods serve as reliable backups and are particularly useful in visualizing response plans. The balanced use of both traditional and modern methods, as advocated by Quarantelli (1988), may enhance the overall success and resilience of emergency response strategies.

6.1.5 Summary

Research Question 1 explores which specific communication methods and tools that are utilized in the response to wildfires in Norway, and how they facilitate information sharing. Physical communication, involving direct, face-to-face interaction, is crucial for clarity and immediacy in decision-making, fostering trust and coordination among emergency responders, especially at the leadership level. This method is particularly effective in the initial stages of response, supported by the presence and expertise of local leaders, although it faces logistical challenges in large-scale incidents. Complementing this, radio communication, particularly through the TETRA system, facilitates real-time information sharing and resource allocation. However, its effectiveness depends on user training and familiarity, and it lacks the capability to share visual information, which is critical for understanding environmental conditions.

Digital tools, including systems like CIM, RAYVN, and LOKUS, enhance information logging, planning, and real-time visual sharing via drones. These technologies improve situational awareness but also pose risks such as misallocation of resources and over-reliance on technology, which can undermine decision-making. The integration of drones has greatly enhanced real-time visual information sharing in wildfire response. Nearly all informants view drone technology as revolutionary, providing faster situational awareness

and the ability to identify hidden hot spots with thermal cameras, thereby improving response accuracy and effectiveness. However, drones can also lead to resource misallocation, as decisions may be based on drone data highlighting the hottest areas rather than those at the highest risk of fire spread. Traditional methods, such as paper maps and written logs, serve as reliable backups when digital tools fail. They are essential for visualizing response plans and ensuring continuous documentation of critical information, despite being slower and less dynamic than digital systems.

6.2 Research Question 2

What specific elements of communication in wildfire management operations can be optimized, and what strategies or technological tools can be utilized to enhance these elements?

6.2.1 Training and Familiarity: Knowledge Enhancement, especially at the Leadership Level

Improving training on communication systems and protocols is crucial for enhancing overall communication (Steelman & Nowell, 2019). Many informants stressed the importance of foundational training and understanding specialized terminology to reduce misunderstandings. A solid foundational knowledge level allows for more effective on-site training and reduces the risk of miscommunication. It is also crucial for all personnel to understand the communication systems in use.

The findings of this study show that there is general dissatisfaction with current training levels, highlighting the need for more comprehensive training programs. This aligns with the study of Log and Gjedrem (2022) who emphasizes the necessity for adaptive strategies and the importance of training in managing fire risks. Their study indicates that current training practices may not be adequately preparing fire service personnel to handle the complexities and unpredictability of wildfire incidents. This study also shows that there is a lack of understanding of tasks and responsibilities both within the fire services and in collaboration with external agencies. This aligns with the study of Sørensen et al. (2020), who found that while collaboration exercises enhance learning, they do not fully translate into practical utility, indicating a lack of understanding and coordination among different agencies. The study also reveals a significant backlog in education at both the firefighter and incident commander levels, with the greatest potential for improvement at the leadership level.

Additionally, the competency of leaders to interpret and act on information needed to manage larger climate events is a concern.

The need for specific leadership training is supported by the research of Boin and Hart (2014), who discuss the critical role of leadership competency in emergency management. They emphasize that targeted training programs are essential for developing the necessary skills for emergency management roles, thereby enhancing the overall capability to respond to emergencies. The findings regarding inter-organizational issues align with the research of Bodin and Nohrstedt (2016), who highlight the role of social networks in effective emergency management, suggesting that familiarity and training can enhance these networks. Steelman and Nowell (2019) also emphasize the need for coordinated training to improve communication and coordination during emergency management.

The findings indicate that the knowledge required to effectively handle wildfire response is not at the level it should be. Challenges include the lack of skills to manage multiple talk groups and collaborating with other agencies that do not use TETRA, which can create fragmentation in communication. The lack of adequate knowledge can directly impact the efficiency and effectiveness of response operations. If responders are not fully trained, it can lead to poor decision-making and delayed responses, ultimately exacerbating the impact of wildfires (Weick, 1993). This is supported by Kapucu (2006b) who points out that well-informed and well-trained personnel are crucial for effective emergency management.

The findings emphasize that continuous training and exercises are crucial to maintain proficiency in the use of technical and digital communication systems, aligning with Sørensen et al. (2020), who found that participation in communication exercises enhances learning and may improve emergency response capabilities. This underscores the need for ongoing training to ensure that emergency responders are capable of effective use of communication tools during wildfires.

6.2.2 Standardization: Matching Equipment and Common Language

The standardization of equipment and procedures, in example by ensuring that all responders use compatible gear and follow uniform protocols, is an effective way of reducing misunderstandings and delay (Bodin and Nohrstedt, 2016). Currently, there is no standardized terminology uniting fire services and fire helicopters, an issue commonly leading to confusion. This lack of standardization extends to the equipment used by different fire

services, such as different hose couplings, additionally complicating coordination, and task execution during emergencies, consequently impairing effective communication. Informants noted that incompatible equipment could have a critically negative impact on wildfire management. Standardized equipment and terminology are therefore key points that need to be implemented to facilitate seamless operations and communication during emergencies.

My study aligns with several previous studies and reinforce the importance of standardized procedures and equipment in emergency management. Kapucu (2006b) supports the need for formal communication and standardized procedures to ensure effective information management during emergencies. This approach aligns with the empirical findings highlighting the necessity of standardized terminology both within and across organizations. Steelman and Nowell (2019) propose a cohesive strategy for wildfire management that emphasizes co-management and improved coordination and communication across different operational levels and agencies. Additionally, Bodin and Nohrstedt (2016) examine collaborative networks in managing wildfire responses, underscoring the importance of inter-agency cooperation and the role of social connections across agencies, supporting the idea that standardized protocols can enhance coordination and response efficiency.

Storesund et al. (2018) focus on the operational efficiency of fire and rescue services, emphasizing the need for better coordination and clear regulatory definitions to improve response times. This aligns with the empirical findings in this study, which suggest that standardized equipment can streamline operations and reduce delays. Engen et al. (2021) discuss the critical role of effective communication, coordination, and institutional adaptability in managing wildfires, which is relevant to the need for standardized procedures and equipment as highlighted in the empirical findings.

Some studies emphasize different aspects of emergency management that may indirectly challenge the focus on standardization. Fernandez-Anez et al. (2021) highlight the need for adaptive fire management strategies tailored to changing climate. Although their research does not directly contradict standardization, they imply that a one-size-fits-all approach may not be suitable for all scenarios, emphasizing the need for adaptive and flexible strategies. Brændeland and Refsdal (2013) concentrate on decision-making processes during emergency management, suggesting that early decisions are critical. While they do not oppose standardization, their focus on decision-making processes indicates that flexibility and adaptability are also crucial, which can sometimes conflict with rigid standardization.

Considering that my findings specify the need for standardized terminology and technical equipment, the potential standardization of these elements will not directly affect decision-making processes as highlighted by Brændeland and Refsdal (2013). Instead, it will influence communication and logistics, which may have a positive impact on communication during response efforts.

The findings underscore the critical need for standardizing equipment and terminology to improve collaboration and response efficiency during emergencies. This implies that standardization can significantly enhance coordination among different fire services, ensuring seamless operations and communication during emergencies, which is crucial for effective incident management and timely response (Steelman and Nowell, 2019; Kapucu, 2006b).

Delays caused by incompatible tools can be avoided with standardized equipment, thus improving overall efficiency and response during emergencies (Storesund et al., 2018). Standardized terminology increases the likelihood that all responders comprehend the shared information, which reduces the risk of misunderstandings and errors (Engen et al. (2021). Standardized equipment and procedures also simplify training programs, as all personnel are trained on the same tools and protocols, ensuring uniformity in skills and knowledge (Sørensen et al., 2020).

6.2.3 Integration of Technology: Time Efficiency and Visual Data Sharing

Expanding the application of digital tools, such as GPS tracking and real-time data sharing platforms, can enable more precise and timely decisions based on real-time data from the field (Bharosa & Janssen, 2009).

My data show that real-time tracking of equipment and personnel has significant potential to enhance information sharing and safety during wildfire response. This aligns with the research of Bharosa & Janssen, (2009) who emphasize how communication technology can improve the efficiency of emergency management. Furthermore, findings in this study suggest that tagging hose equipment with QR codes can improve logistics management by providing a clear overview of available resources. Log and Gjedrem's (2022) study explore the use of innovative tools and frameworks in fire disaster prevention, highlighting how technology, such as QR codes for equipment tracking, can enhance resource management and improve logistics. Personnel tracking can streamline planning and increase operational safety, although it must be implemented carefully to avoid information overload, aligning with the study of Bharosa & Janssen (2009).

Current emergency networks limit visual communication, leading to time-consuming alternative methods. Although visual communication platforms exist, they are rarely used due to outdated systems and low usability. However, new tools like LOKUS are being implemented to improve information flow, allowing digital images and videos from drones to be shared with the command post. This finding aligns with the studies of Eide et al. (2012) and Reddy et al. (2008) who highlights that the use of communication technologies such as electronic messaging tools and wearable sensors can mitigate communication challenges by ensuring that relevant information is shared promptly and accurately.

The findings in this study suggest that digital tools can promote better collaboration and information sharing. Bodin and Nohrstedt (2016) study the collaborative networks in managing wildfire responses, emphasizing the importance of inter-agency cooperation and the role of social connections across agencies, which supports the idea that technology integration can improve coordination. Log et al. (2020) explore the benefits of new tools and frameworks for fire disaster prevention in Norway and other regions, and their focus on innovative research methods to reduce fire risk also aligns with the empirical findings of this study. Furthermore, the use of Inter-Organizational Information-Sharing Systems (IOISS) can enable better coordination and sharing of disaster-related information, ultimately improving response times and decision-making processes (Reddy et al., 2008).

The empirical findings emphasize the need for technology integration to enhance communication and coordination during wildfire response. The use of digital tools such as GPS tracking, real-time data platforms and visual communication tools like LOKUS can significantly improve response times and decision-making. This is supported by McLennan et al., (2005), who highlight the transformative potential of technology in emergency management. Their work indicates that advanced technological tools can enhance situational awareness and facilitate better decision-making in emergencies. Kapucu and Garayev (2011) also discuss the benefits of technology for improving emergency response efficiency through enhanced communication. However, Pine (2017) points out potential drawbacks of over-reliance on technology, such as the risk of information overload and the challenges of integrating new technology into existing frameworks. While the findings of his study highlight technology integration as a mean to improve wildfire response, we need to be aware of over-reliance on technology and the lack of sufficient research on the effectiveness on technology integration, as highlighted by Engen et al., (2021) & Fernandez-Anez et al., (2021).

6.2.4 Collaboration with Other Agencies: Improving Operational Methods and Communication

The empirical findings of this study underscore the significance of effective collaboration and strong leadership in enhancing wildfire management response. Joint exercises and shared protocols are highlighted as ways to enhance understanding and coordination among agencies. The findings aligns with Waugh (2015), who points out that effective crisis management depends on cooperation and mutual understanding between different agencies. Waugh's work supports the idea that joint exercises and established relationships are vital for effective collaboration.

My findings demonstrate that strong leadership is a key factor for effective collaboration, with established regional partnerships being a significant success factor. These regional collaborations between multiple fire stations facilitate resource sharing, standardized procedures, and unified response strategies, which may significantly enhance communication processes and collaboration during wildfires. Similarly, Engen et al. (2021) emphasize the need for integrated emergency strategies that rely on strong leadership and clear communication channels.

Previous research aligns with the importance of these regional partnerships. Bodin and Nohrstedt (2016) highlight the role of social networks in effective emergency management, suggesting that familiarity and training within these networks enhance coordination and response capabilities. The success of regional collaborations also aligns with Kapucu's (2006b) findings, which emphasize that pre-established relationships and clear communication channels are essential for effective emergency response. Storesund et al. (2018) further emphasize that better coordination and clear regulatory definitions, facilitated by regional partnerships, improve response times and operational efficiency.

While there is broad consensus in my data on the importance of collaboration, research by Fernandez-Anez et al. (2021) suggests that practical implementation of such collaborative efforts can be hindered by bureaucratic barriers and differences in organizational culture. This points to a potential conflict between the ideal collaborative framework and the reality of its execution, indicating that even though the empirical findings are robust, their implementation may face practical challenges. Additionally, Steelman and Nowell (2019), suggest that inter-agency cooperation can be impeded by differing priorities and operational

procedures. This indicates a potential area of conflict where ideal collaboration strategies may clash with the practical realities of different agencies' protocols.

The findings of this study show that inter-agency collaboration is crucial but has several areas for improvement, such as differing operational methods and communication challenges during wildfires. This is consistent with Quarantelli's (1986) findings, which underscore the complexity and necessity of inter-agency collaboration in crisis management. Quarantelli points out that effective disaster response relies on pre-established relationships and clear communication channels between different agencies. Similarly, Kapucu (2006b) emphasizes the importance of trust and familiarity between agencies for successful collaboration during emergencies.

6.2.5 Summary

Data analysis identified four main areas for enhancing communication in wildfire management operations. First, comprehensive training on communication systems and protocols is necessary to reduce misunderstandings and improve efficiency. This includes specialized training in technical language and system operation. Second, standardizing equipment and procedures across fire services and agencies can streamline operations and improve communication by using compatible equipment and uniform terminology. Third, expanding the use of digital tools, such as GPS tracking and real-time data sharing, can improve coordination and response times by enabling precise and timely decisions based on real-time field data. However, careful implementation is required to avoid information overload. Fourth, improved collaboration through joint exercises, permanent regional collaboration structures, and shared protocols can lead to more cohesive and effective responses. Established relationships and strong leadership are essential for successful collaboration and problem-solving.

These findings suggest that enhancing training, standardization, technology integration, and inter-agency collaboration can significantly improve communication processes in wildfire management, aligning with previous research emphasizing the importance of these elements in emergency management.

6.3 Research Question 3

What are the primary barriers to the successful implementation and adoption of new technology to improve wildfire management response?

6.3.1 Economic Constraints: The Need for Prioritized Funding

In this study, financial constraints constitute one of the major barriers in implementing new technology for improved wildfire response. Budget limitations hinder the acquisition and use of advanced technologies. This finding is consistent with the research by McLennan et al., (2005), which found that financial resources play a critical role in the fire department's technological capacity. Smaller municipalities face greater challenges due to limited financial resources. This difference echoes the findings of Bodin and Nohrstedt (2016), who emphasized the importance of regional cooperation and resource sharing in effective fire management. The issue is not only about having financial resources but also about the prioritization of expenditures within municipalities.

The empirical findings show that municipalities need to prioritize the implementation of new technology. In addition, there is a discrepancy between the fire services who see the need for new technology and decision-makers who control the budget and may not prioritize these expenses. This perspective aligns with the conclusions of Steelman and Nowell (2019), who emphasized that acceptance by leadership and decision-making are crucial for adapting fire management strategies to new technology. Furthermore, the findings of this study highlight a gap between available technology and its practical implementation due to budget constraints, resonating with the findings of Log and Gjedrem (2022), who discuss the challenges of implementing new tools and frameworks for fire disaster prevention, emphasizing that budget constraints often hinder the adoption and integration of advanced technologies within the fire services.

Another important economic challenge identified in this study is the costs associated with training and maintaining skills in using new technology. When this is deprioritized due to cost issues, it has consequences for knowledge and competence which also are highlighted as significant obstacles for the implementation of new technology. These findings reinforce the need for prioritized funding for continuous training and skill development, as emphasized by Fernandez-Anez et al. (2021), who highlighted the need for better training and education to adapt to changing fire management strategies.

The need for dedicated leadership to drive technological advancement is also pointed out in the findings of this study. Effective leadership is crucial for prioritizing funding for integration of new technology into fire management strategies. Gjedrem and Metallinou (2023) emphasize the importance of having dedicated experts driving innovative practices in

fire management. Another point made in the findings of this study is the problem of poor financial priorities concerning wildfire preparedness. The costs of a major wildfire are often higher than the cost spent on equipment to extinguish the fire early. This reflects a broader concern in the literature that prevention and early intervention are often more cost-effective than response and recovery (Moritz, 2014). The tendency to underfund preparedness measures, despite their potential to reduce larger expenses later, is a common problem in emergency management (Waugh, 2015).

In summary, the empirical findings indicate that financial constraints are a significant barrier to the successful implementation of new technology in wildfire management. This barrier affects not only the acquisition of equipment but also the training and maintenance required for effective use. To overcome these challenges, there is a need for increased funding and better prioritization of expenditures within municipalities. Regional cooperation and resource sharing, as highlighted by Bodin and Nohrstedt (2016), can help alleviate some of these financial challenges.

6.3.2 Technological Integration: The Importance of Training and Building Expertise

The empirical findings indicate that integrating new technology with existing systems and ensuring user-friendliness are crucial. However, technologies must be compatible with current practices and intuitive enough for responders to use effectively under pressure. This concern is reflected by Pine (2017), who emphasizes that technology must be accessible and user-friendly to handle the inherent uncertainties in emergency situations. Discrepancies among different information systems are also highlighted by Essen et al. (2023), which aligns with the fire services' challenges posed by outdated and non-interoperable tools in wildfire response.

My data shows that the Norwegian fire service has insufficient knowledge to fully utilize new and emergent technology. The findings raise a number of important concerns about facing a fire, making wrong decisions, and potentially endangering personnel or the public due to a lack of understanding of the situation. This mirrors the findings of Log and Gjedrem (2022), who highlighted the need for adaptive strategies and the importance of training in managing wildfire incidents. Sørensen et al. (2020) found that collaborative exercises enhanced learning but did not fully translate into practical utility, underscoring the need for more effective training.

Furthermore, leadership training is lacking in Norway, and technical skills are often prioritized over leadership skills. Effective leadership is necessary to guide and support the implementation of new technology. This aligns with Steelman and Nowell (2019), who emphasize the importance of co-management and leadership to improve coordination and communication in wildfire response. The findings' suggestion of a specific sector leader course aligns with the need for specialized training to handle the complexities of wildfire response effectively.

Despite access to new technology, there is a tendency to revert to traditional methods like using pen and paper. This indicates a lack of comfort and proficiency with new tools, a barrier also noted by Brændeland and Refsdal (2013) in their discussion on the importance of risk assessment and early decision-making. The Unified Command System (ELS) in Norway aims to optimize response by establishing a clear organizational structure, but the findings suggest that communication systems need to be more effectively integrated and utilized. This aligns with the study by Oh and Lee (2020), which emphasizes that effective communication is crucial in disseminating accurate and timely information, thereby reducing confusion, and preventing panic during emergencies.

6.3.3 Organizational Aspects: The Importance of Cooperation and Standardization

The differences in Norway's emergency services complicates the adoption of standardized technologies and procedures. This fragmentation is evident in the disparities in funding, resources, and priorities among municipalities, aligning with the theoretical perspectives of Bodin and Nohrstedt (2016) who highlight the importance of inter-agency cooperation and assistance, and social inter-agency networks in effective emergency management. The fact that the fire service in Norway is organized into various departments across the different municipalities is identified as a major hindrance to inter-organizational cooperation, supported by informants who point out the exclusion of fire and rescue services from certain platforms due to their municipal status.

Previous research by Sørensen et al. (2020) discuss the challenges of achieving effective collaboration during emergency response exercises in Norway, noting that differences in organizational structures and lack of unified platforms can limit the perceived benefit of such exercises in real-life scenarios. The empirical findings resonate with Sørensen

et al., demonstrating that differences in municipalities leads to inconsistencies in response capabilities and hinders the adoption of comprehensive technology solutions.

Disparities in resources among municipalities further complicate the implementation of new technologies. Informants noted that smaller municipalities have fewer resources compared to larger ones, impacting their ability to adopt and utilize new technologies effectively. This aligns with observations by Log and Gjedrem (2022) in their study on the Sotra fire, highlighting the varying levels of preparedness and resource availability in different regions. The findings suggest that these disparities contribute to a lack of uniformity in wildfire management capabilities across Norway.

Several informants suggested that the fire service should be state-run to achieve a more unified approach, akin to the police and ambulance services. This suggestion reflects views from previous research advocating for more centralized and standardized approaches to improve coordination and response efficiency (Storesund et al., 2018). The empirical findings indicate that a centralized approach could potentially mitigate the challenges posed by the current fragmented and municipal-based system.

The need for professional, national wildfire teams is highlighted as a solution to address the limitations of the current municipal organization. Pyne (1982) in his historical overview of wildfire management in the United States underscores the importance of centralized, professional organizations such as the United States Forest Service in developing and implementing effective wildfire management strategies. The establishment of such organizations was crucial in standardizing procedures, enhancing resource allocation, and ensuring coordinated responses across different regions. This aligns with Gjedrem and Metallinou's (2023) focus on the importance of risk reduction and fire mitigation strategies. Additionally, McLennan et al., (2005) also support the establishment of national wildfire teams. They highlight the advantages of having dedicated, professional teams that can provide consistent training, advanced equipment, and standardized procedures across different regions. The findings suggest that national teams could provide specialized expertise and resources, ensuring a more effective and unified response to wildfires.

6.3.4 Summary

Research Question 3 explores the primary barriers to the successful implementation and adoption of new technology in wildfire management. One major challenge is economic constraints. Financial limitations significantly hinder the acquisition and use of advanced

technologies. Informants highlight that budget priorities within municipalities greatly affect technological adoption, with smaller municipalities facing more significant challenges due to limited financial resources. This financial disparity is also evident in regional cooperation and resource-sharing issues. Additionally, financial constraints extend beyond equipment costs to include the expenses related to training and maintaining skills necessary for using new technology effectively. Dedicated leadership is crucial for driving technological advancement, yet poor financial priorities and underfunding of preparedness measures continue to be significant obstacles.

Technological integration is another challenge, where ensuring compatibility with existing systems and user-friendliness is essential. Current knowledge within the fire service is often insufficient to fully utilize available technology, potentially leading to unnecessary risks during wildfire incidents. Training and leadership development are critical, yet often lacking, which further complicates the effective adoption of new technology. There is a tendency to revert to traditional methods due to discomfort with new tools, emphasizing the need for continuous practice and training to maintain proficiency. The importance of effective communication systems and inter-agency cooperation is highlighted, as the current fragmented nature of the emergency services hinders standardized technology adoption.

Organizational structure poses additional challenges, with the fragmented nature of Norway's emergency services complicating the adoption of standardized technologies and procedures. Disparities in funding and resources among municipalities lead to inconsistent response capabilities. Some informants suggest that a state-run fire service could achieve a more unified approach, similar to the police and ambulance services, which would mitigate the challenges of the current municipal-based system. The establishment of national wildfire teams is proposed as a solution to address the limitations of the current organization, providing specialized expertise and resources for a more effective and unified wildfire response.

In summary, financial constraints, technological integration issues, and organizational structure complexities are significant barriers to the successful implementation and adoption of new technology in wildfire management. Addressing these challenges requires increased funding, better prioritization of expenditures, enhanced training programs, leadership development, improved technology integration, and a more unified organizational approach.These findings indicate the need for an integrated approach to the implementation of

new technology in wildfire management, where financial support, technological integration, continuous training, and a unified organizational structure are critical factors for improving response. This is in line with previous research that highlights the importance of communication, collaboration, and technological innovation in effective emergency management.

7 Conclusion

In this study, I have examined the current methods, improvement potential, and barriers in the context of communication and technology utilization during wildfire emergency response in Norway. To address the problem statement, I return to the three foundational research questions upon which this study is built.

I first asked which communication methods that are used by the Norwegian fire service during wildfire response operations, and how these facilitate information sharing. The study reveals that a combination of physical communication, radio communication, digital tools, and traditional methods are employed in wildfire response. Physical communication, involving face-to-face interaction, is crucial for clarity and immediacy in decision-making, especially in the initial stages of response. It fosters trust and coordination among emergency responders, despite facing logistical challenges in large-scale incidents. Radio communication, particularly through the TETRA system, facilitates real-time information sharing and resource allocation, though its effectiveness is contingent on user training and familiarity. However, TETRA's limitation in sharing visual information is a significant drawback. Digital tools like CIM, RAYVN, and LOKUS enhance information logging, planning, and real-time visual sharing via drones, improving situational awareness but also posing risks of resource misallocation and over-reliance on technology. Traditional methods, such as paper maps and written logs, remain essential backups, ensuring continuous documentation and operation when digital tools fail. However, traditional methods can take longer, resulting in inefficient use of time in a time-sensitive situation.

The second research question addressed improvement potentials in communication processes during wildfire response in Norway, and which strategies or technological tools that could be employed for communication enhancement. Improvement of communication in wildfire management can be achieved through several key strategies. Comprehensive training on communication systems and protocols is essential to reduce misunderstandings and improve efficiency. Standardizing equipment and procedures across fire services and agencies

can streamline operations, reduce delays, and ensure that all responders comprehend shared information. Expanding the use of digital tools, such as GPS tracking and real-time data sharing, can enable precise and timely decisions, although careful implementation is needed to avoid information overload. Improved collaboration through joint exercises, regional partnerships, and shared protocols between fire departments and external organizations can lead to more cohesive and effective responses. Strong leadership is crucial for fostering trust and understanding among different agencies, facilitating effective communication and problem-solving.

Finally, I asked the question of which key barriers prevent successful implementation and adoption of new technology in Norwegian wildfire response. The primary challenges to implementing new technology in wildfire management are economic constraints, technological integration issues, and organizational complexities. Financial limitations hinder the acquisition and use of advanced technologies, with smaller municipalities facing greater challenges due to limited resources. The prioritization of expenditures within municipalities and the need for increased funding are critical factors. Technological integration must ensure compatibility with existing systems and user-friendliness, requiring continuous training and leadership development. The tendency to revert to traditional methods indicates discomfort with new tools, emphasizing the need for regular practice and training. Organizational fragmentation complicates the adoption of standardized technologies and procedures, with disparities in funding and resources leading to inconsistent response capabilities. A more unified approach, potentially through an establishment of national wildfire teams, could address these challenges by providing specialized expertise and resources. Addressing these barriers requires a comprehensive strategy that includes financial support, technological integration, continuous training, and organizational restructuring.

As a final remark, enhancing communication and adopting new technological advancements in wildfire management in Norway involves addressing key areas such as comprehensive training, standardization of equipment and procedures and improved inter-agency collaboration. Financial constraints, technological integration issues and organizational fragmentation must be overcome through increased funding, better prioritization of expenditures, and a more centralized and standardized approach to emergency services. By integrating these elements, Norway can significantly improve its wildfire response capabilities, leading to more efficient and effective management of wildfires and better protection of communities and natural resources. This integrated approach aligns

with previous research that emphasizes the importance of communication, collaboration, and technological innovation in emergency management, providing a robust framework for future improvements in wildfire response operations.

Main conclusions are summarized visually, as illustrated in Table 9.

Table 9: Main Conclusions, illustrated by the author.

Current Methods			
Physical Communication	**Radio Systems (TETRA)**	**Digital & Technical Tools (RAYVN, LOKUS, CIM, Drones)**	**Traditional Methods (Sketching, Pen and Paper)**
Key Areas for Enhancement			
Enhanced Training and Familiarity	**Standardization of Equipment and Procedures**	**Expansion of Digital & Technical Tools (GPS-tracking, Real-time Data Sharing)**	**Improved Collaboration (Joint Exercises, Regional Partnership)**
Barriers			
Economic Constraints (Financial Limitations)	**Technological Integration Issues (Compatibility, Ease of use)**	**Organizational Structure Complexities (Fragmentation, disparities)**	
Integrated Approach for Improvement			
Comprehensive Training	**Standardization of Equipment and Procedures**	**Improved Inter-agency Collaboration**	**Address Financial Constraints**	**Address Technological Integration Issues**	**Address Organizational Fragmentation**

7.1 Contributions of the Study and Future Research

The study demonstrates the importance of communication and technological integration in wildfire management. It synthesizes existing research on the effectiveness of training, leadership, and inter-agency collaboration, highlighting the importance of these elements in emergency response. The study also fills gaps in current knowledge and identifies gaps in practices, providing a basis for future research on optimizing communication systems and technological tools in emergency management.

In terms of practice, the study offers recommendations for the Norwegian fire service on how to enhance wildfire response operations in Norway. It largely supports the findings of previous research regarding the need for comprehensive training programs, standardized equipment and procedures, and enhanced inter-agency collaboration. The findings suggest the adoption of advanced digital tools, such as GPS tracking and real-time data sharing platforms,

but also addresses potential challenges like financial constraints and technological integration issues. By implementing the recommendations of this study, fire services can enhance their efficiency and effectiveness in managing wildfires, ultimately leading to better protection of communities and natural resources.

This study highlights gaps in our knowledge on optimization of training programs, standardization of equipment and procedures, and enhancement of inter-agency collaboration in wildfire management. My study reveals the need for an in-depth investigation of the integration and impact of advanced digital tools, challenges like financial constraints and technological compatibility.

Disclaimer

In this work, I have used Generative AI tools to revise wording throughout the production of the text. ChatUiT, during several time periods, was used, using the underlying GPT-4 Large Language Model. I reviewed, edited, and take responsibility for all outputs of the tools used in this work.

8 References

Adams, R., Singh, A. (2018). *Analytical models for communication links in emergency management simulation.* https://doi.org/10.1002/dac.3500

Agar, J. (2020). *What is Technology?* Annals of Science, 77:3, 377-382, https://doi.org/10.1080/00033790.2019.1672788

Agee, J. K. (1993). *Fire Ecology of Pacific Northwest Forests*. Island Press.

Alexandrov, A V. (2004). *How to Write a Research Paper*. https://doi.org/10.1159/000079266

Arrow, K. J. (1979). *The economics of information*. In M. L. Dertouzos, & J. Moses (Eds.), The computer age: a twenty year view (pp. 306–317). Cambridge: MA MIT Press.

Asbury, J. (1995, November 1). *Overview of Focus Group Research*. https://journals.sagepub.com/doi/10.1177/104973239500500402

Atwood, R., & Dervin, B. (1982). *Challenges to sociocultural predictors of information seeking: a test of race vs. situation movement state.* In M. Burgoon (Ed.), Communication Yearbook 5 (pp. 549–570). New Brunswick, NJ: Transaction

Bates, B. J. (1988). *Information as an economic good: sources of individual and social value*. In V. Mosco, & J. Wasco (Eds.), The political economy of information (pp. 76–94). Madison, WI: University of Wisconsin Press.

Bertrand, J T., Brown, J E., & Ward, V M. (2023). *Techniques for Analyzing Focus Group Data.* https://journals.sagepub.com/doi/10.1177/0193841X9201600206

Bharosa, N. and M. Janssen (2010). *Extracting principles for information management adaptability during crisis response: A dynamic capability view.* In: Proceedings of the 43rd Hawaii International Conference on System Sciences (HICSS), 1–10.

Bharosa, N., Lee, J. and M. Janssen (2009). *Challenges and obstacles in sharing and coordinating information during multi-agency disaster response: Propositions from field exercises.* Information Systems Frontiers 12 (1), 49–65.

Blaikie, N. and Priest, J. (2019) *Designing Social Research.* (3rd edition). Polity.

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

Boin, A., Kuipers, S., Overdijk, W. (2013). *Leadership in Times of Crisis: A Framework for Assessment.* https://doi.org/10.1080/12294659.2013.10805241

Brann- og eksplosjonsvernloven. (2002). *Lov om vern mot brann, eksplosjon og ulykker med farlig stoff og om brannvesenets redningsoppgaver*. (LOV-2002-06-14-20). Lovdata. https://lovdata.no/dokument/NL/lov/2002-06-14-20?q=brann

Brann- og redningsvesenforskriften. (2022). *Forskrift om organisering, bemanning og utrustning av brann- og redningsvesen og nødmeldesentralene*. (FOR-2021-09-15-2755). Lovdata. https://lovdata.no/dokument/LTI/forskrift/2021-09-15-2755

Brannstatistikk. (u.å). Retrieved March 2024 from: https://www.brannstatistikk.no/brus-ui/search

Brinkmann, S., Tanggaard, L. (2012) *Kvalitative metoder – Empiri og teoriutvikling*. (1. utgave). Gyldendal norsk forlag.

Brændeland, G., Refsdal, A. (2013). *Risk Factors in Emergency Response: a Review of Investigations of Emergency Response in Norway.* SINTEF Digital / Sustainable Communication Technologies. SINTEF.

Bui, T., Cho, S., Sankaran, S. and M. Sovereign (2000). *A framework for designing a global information network for multinational humanitarian assistance/disaster relief.* Information Systems Frontiers 1 (4), 427–442.

Bui, T. X. and R. Subba (2009). *A tale of two disasters: Assessing crisis management readiness.* Proceedings of the 42nd Hawaii International Conference on System Sciences (HICSS), 1–10.

Bumgarner, J. (2008) *Emergency Management*. (1st edition). ABC-CLIO.

Buckland, M. K. (1991). *Information as thing*. Journal of the American Society for Information Science. https://doi.org/10.1002/(SICI)1097-4571(199106)42:5<351::AID-ASI5>3.0.CO;2-3

Canton, L. (2019) *Emergency Management.* (2nd edition). Wiley.

Carreras-Coch, A., Navarro, J., Sans, C., Zaballos, A. (2022). *Communication Technologies in Emergency Situations.* DOI:10.3390/electronics11071155

Chang, R. S.-J., & Rice, R. E. (1993). *Browsing: a multidimensional framework*. https://api.semanticscholar.org/CorpusID:128513448

Cheng, J., Wang, C., Meng, M.Q-H. (2019). Robust Visual Localization in Dynamic Environments Based on Sparse Motion Removal. DOI:10.1109/TASE.2019.2940543

Coleman, A. (2020) *Crisis Communication Strategies.* (1st edition). Kogan Page.

Creswell, J. W., & Miller, D. L. (2000). *Determining Validity in Qualitative Inquiry. Theory Into Practice*, 39(3), 124-130. https://doi.org/10.1207/s15430421tip3903_2

Damaševičius, R., Bacanin, N., Misra, S. (2023) *From Sensors to Safety: Internet of Emergency Services (IoES) for Emergency Response and Disaster Management.* DOI:10.3390/jsan12030041

Danbold, F., & Bendersky, C. (2019). *Balancing Professional Prototypes Increases the Valuation of Women in Male-Dominated Professions*. Organization Science 31(1):119-140. https://doi.org/10.1287/orsc.2019.1288

Direktoratet for samfunnssikkerhet og beredskap (DSB). (2011). *Veileder om enhetlig ledelsessystem (ELS) – Ved håndtering av hendelser innen brann, redning og akutt foruresning.* Acquired from: https://www.dsb.no/veiledere-handboker-og-informasjonsmateriell/veileder-om-enhetlig-ledelsessystem-els/

Donovan, G. H., & Brown, T. C. (2007). *Be careful what you wish for: The legacy of Smokey Bear*. Frontiers in Ecology and the Environment, 5(2), 73-79.

Duane, A., Piqué, M., Castellnou, M., & Brotons, L. (2015). *Predictive modelling of fire occurrences from different fire spread patterns in Mediterranean landscapes*. International Journal of Wildland Fire, 24(3). https://doi.org/10.1071/WF14040

Dunn, J.C., Lewandowsky, S., Kirsner, K. (2002). *Dynamics of communication in emergency management*. https://doi.org/10.1002/acp.846

Eide, A.W., Haugstveit, I.M., Halvorsrud, R., Borén, M. (2013). *Inter-organizational Collaboration Structures during Emergency Response: A Case Study.* https://api.semanticscholar.org/CorpusID:16028292

Engen, O. A. H., Pettersen Gould, K. A., Kruke, B. I., Lindøe, P. H., Olsen, K. H., & Olsen, O. E. (2021). *Perspektiver på Samfunnssikkerhet* (2nd ed.). Cappelen Damm.

Essen, M., McCaffrey, S., Abrams, J., Paveglio, T. (2022). *Improving wildfire management outcomes: shifting the paradigm of wildfire from simple to complex risk*. https://doi.org/10.1080/09640568.2021.2007861

Fernandez-Anez, N. (2021). *Current Wildland Fire Patterns and Challenges in Europe: A Synthesis of National Perspectives.* https://doi.org/10.1177/11786221211028185

Fischer, D.P., Posegga, O., FischBach, K. (2016). *Communication Barriers in Crisis Management: A Literature Review.* Twenty-Fourth European Conference on Information Systems (ECIS). İstanbul, Turkey

Fusch, P., Fusch, G. E. & Ness, L. R. (2018). *Denzin's Paradigm Shift: Revisiting Triangulation in Qualitative Research.* Journal of social *change, 10* (1). 10.5590/JOSC.2018.10.1.02

Gerring, J. (2016) *Case Study Research.* (2nd edition). Cambridge University Press.

Gjedrem, A M., Metallinou, M M. (2023). *Wildland-urban interface fires in Norwegian coastal heathlands – Identifying risk reducing measures.* https://doi.org/10.1016/j.ssci.2022.106032

Haddow, G.D., Haddow, K.S. (2008) *Disaster Communications in a Changing Media World*. (1st. edition). Elsevier Inc.

Harrald, J. R. (2006). *Agility and discipline: Critical success factors for disaster response.* The Annals of the American Academy of Political and Social Science.

Heide, M., & Simonsson, C. (2019). *Internal Crisis Communication*. (1st edition). Routledge.

Hennink, M., Hutter, I., Bailey, A. (2020). *Qualitative Research Methods*. (2nd edition). London: Sage Publications.

Hirschleifer, J., & Riley, J. (1992). *The analytics of uncertainty and information* (esp. Chap. 5: Information and informational decisions). Cambridge, UK: Cambridge University Press.

https://www.dsb.no/nyhetsarkiv/2022/europeisk-samarbeid-gir-bedre-beredskap/ Hentet: 12.12.2022

https://www.cnbc.com/2022/07/20/europe-heat-wave-photos-london-fire-departmentbusiest-day-since-wwii.html Hentet: 13.12.2022

Jacobsen, D. I. (2005). *Hvordan gjennomføre undersøkelser? Innføring i samfunnsvitenskapelig metode* (2nd. edition). Kristiansand: Høyskoleforlaget.

Jimenez, Y., Morreale, P. (2015). *Social Media Use and Impact on Interpersonal Communication.* In: Stephanidis, C. (eds) HCI International 2015 - Posters' Extended Abstracts. HCI 2015. Communications in Computer and Information Science, vol 529. Springer, Cham. https://doi.org/10.1007/978-3-319-21383-5_15

Johannessen, A., Christoffersen, L. & Tufte, P. A. (2016). *Introduksjon til samfunnsvitenskapelig metode* (5th edition). Oslo: Abstrakt.

Kapucu, N. (2006a). *Interorganizational Coordination in Dynamic Context: Networks in Emergency Response Management*. Connections.

Kapucu, N. (2006b). *Interagency Communication Networks During Emergencies: Boundary Spanners in Multiagency Coordination.* The American Review of Public Administration.

Kedia, T., Ratcliff, R., O'Connor, M., Oluic, S., Rose, M., Freeman, J., Rainwater-Lovett, K. (2020). *Technologies Enabling Situational Awareness During Disaster Response: A Systematic Review.* DOI: 10.1017/dmp.2020.196

Kemal, S.A., Mikalsen, R.F., Fjærestad, J.S., Ulvang, A-I., Li, T., Pantelis, V., Margariti, K., Soltatos, J. (2023). *The Roan Norwegian winter wildfire case study (TREEADS).* DOI: 10.13140/RG.2.2.22738.94407

Kendell, A. et al. (2023) *The Path of Flames.* (1st edition). CRC Press.

Kamberelis, G., Dimitriadis, G. (2013). *Focus Groups: From Structured Interviews to Collective Conversations.* (1st edition). London: Routledge.

Kraut, R., et al. (1990). *Informal Communication in Organizations: Form, Function, and Technology*. Human-Computer Interaction.

Krueger, R. A., & Casey, M. A. (2015). *Focus Groups: A Practical Guide for Applied Research*. SAGE Publications.

Lievrouw, L. A. (1998). *New Media and the `Pluralization of Life-Worlds': A Role for Information in Social Differentiation*. Volume 3, Issue 1. https://doi.org/10.1177/1461444801003001002

Log, T., Gjedrem, A M. (2022). *A Fire Revealing Coastal Norway's Wildland–Urban Interface Challenges and Possible Low-Cost Sustainable Solutions*. DOI: 10.3390/ijerph19053038

Log, T., Vandvik, V., Velle, L G., Metallinou, M M. (2020). *Reducing Wooden Structure and Wildland-Urban Interface Fire Disaster Risk through Dynamic Risk Assessment and Management.* DOI:10.3390/asi3010016

Lunde, I.K. (2019). *Praktisk krise- og beredskapsledelse.* (2nd edition). Oslo: Universitetsforlaget.

Lune, H., Berg, B. (2012). Qualitative Research Methods for the Social Sciences, Global Edition. (8th edition). Pearson Education Limited.

Luokkala, P., Nikander, J., Korpi., Virrantaus, K., Torkki, P. (2017). *Developing a concept of a context-aware common operational picture.* https://doi.org/10.1016/j.ssci.2016.11.005

Lynggaard, K. (2012). Dokumentanalyse. I S. Brinkmann, L. Tanggaard (Red.), *Kvalitative metoder. Empiri og teoriutvikling.* Oslo: Gyldendal Akademisk.

Madigan, M. (2017). *First Responders Handbook*. (1st edition). CRC Press.

Marcot, B. (2020). *The Science and Management of Uncertainty*. (1st edition). CRC Press.

Mayring, P. (2021). *Qualitative Content Analysis.* 1st (edition). SAGE Publications Ltd.

McComb, S., Kennedy, D. (2020). *Team Communication in Theory and Practice*. In: Computational Methods to Examine Team Communication. Computational Social Sciences. Springer, Cham. https://doi.org/10.1007/978-3-030-36159-4_1

McCreadie, M., & Rice, R. E. (1999). *Trends in analyzing access to information. Part II. Unique and integrating conceptualizations*. https://doi.org/10.1016/S0306-4573(98)00038-7

McLennan, J., Birch, A., Cowlishaw, S., Hayes, P.A.J. (2009) *Maintaining volunteer firefighter numbers: Adding value to the retention coin.* Australian Journal of Emergency Management 24(2):40-47

Merriam, S. B., & Tisdell, E. J. (2016). *Qualitative Research: A Guide to Design and Implementation* (4th ed.). San Francisco, CA: Jossey-Bass. 346 pp.

Merriam, S. et al. (2019). *Qualitative Research in Practice.* (2nd edition). Jossey-Bass.

Metallinou, M M. (2020). *Emergence of and Learning Processes in a Civic Group Resuming Prescribed Burning in Norway.* DOI:10.3390/su12145668

Moritz, M. A., et al. (2014). *Learning to coexist with wildfire*. DOI:10.1038/nature13946

Nasjonal Veileder for Planverk og Samvirke i Redningstjenesten (2018). (1st. edition). Hovedregningssentralen.

Neuman, W. L. (2011). *Social research methods: qualitative and quantitative approaches* (7. ed., internat. ed.). Boston, Mass.: Pearson.

Norsk brannvernforening. (2021). *Enhetlig Ledelsessystem*. (1st edition). Oslo: Rolf Ottesen AS.

Nowell, B., Steelman, T. (2015). *Communication under Fire: The Role of Embeddedness in the Emergence and Efficacy of Disaster Response Communication Networks.* Journal of Public Administration Research and Theory 25 (3): 929-952. doi:10.1093/jopart/muu021

Oh, N., Lee, J. (2020). *Changing landscape of emergency management research: A systematic review with bibliometric analysis.* https://doi.org/10.1016/j.ijdrr.2020.101658

Parker, A., & Tritter, J. (2007). *Focus Group Method and Methodology: Current Practice and Recent Debate*. https://doi.org/10.1080/01406720500537304

Patton, M. Q. (2015). *Qualitative Research & Evaluation Methods*. SAGE Publications.

Perry-Parrish, C., & Dodge, R. (2010*). Research and Statistics: Validity Hierarchy for Study Design and Study Type.* https://doi.org/10.1542/pir.31-1-27

Pine, J. (2017). *Technology and Emergency Management.* (2nd edition). Wiley.

Puchta, C., & Potter, J. (2011). *Focus Group Practice*. https://methods.sagepub.com/book/focus-group-practice

Pursiainen, C. (2018). *The Crisis Management Cycle*. UK: Routledge.

Pyne, S J. (1982). *Fire in America: A Cultural History of Wildland and Rural Fire*. University of Washington Press.

Quarantelli, E. L. (1988). *Disaster Crisis Management: A Summary of Research Findings.* Journal of Management.

Ramsay, J. et al. (2020) *Theoretical Foundations of Homeland Security.* (1st edition). Routledge.

Rebmann, T., Carrico, R.M., English, J.F. (2008) *Lessons Public Health Professionals Learned from Past Disasters.* Public Health Nursing 25(4):344-52 DOI:10.1111/j.1525-1446.2008.00715.

Reddy, M.C., Paul, S.A., Abrahama, J., McNeese, M., DeFlitch, C., Yen, J. (2008). *Challenges to effective crisis management: Using information and communication technologies to coordinate emergency medical services and emergency department teams*. Elsevier Ireland Ltd

Saban I.L. (2014). *Disaster emergency management: the emergence of professional help services for victims of natural disasters*. State University of New York Press, Albany.

Salles, M. (2015). *Information as Recorded Knowledge.* Societal Epistemology Review and Reply Collective. Vol. 4, No. 9, 13-39. http://wp.me/p1Bfg0-2hz

San-Miguel-Ayanz, J., Artes, T. 1, Oom, D., Pfeiffer, H., Branco, A., Liberta, G., De Rigo, D., Grecchi, R., Maianti, P., Boca, R., Durrant, T., Ferrari, D. (2021). *Weekly & monthly analysis of wildfires in the Amazon region and South America*. November 29 – December 05, 2021, European Commission, Ispra, JRC127796

Schreier, M. (2012). *Qualitative Content Analysis in Practice*. (1st edition). SAGE Publications Ltd.

Seeger, M. and Sellnow, T. (2019) *Communication in Times of Trouble*. (1st edition). Wiley-Blackwell.

Sedgwick, P., & Greenwood, N. (2015). *Understanding the Hawthorne Effect.* DOI:10.1136/bmj.h4672

Shan-Ju L. Chang, R., & Rice, R. E. (1993). *Browsing: a multidimensional framework*. https://api.semanticscholar.org/CorpusID:128513448

Silverman, D. (2005). *Doing qualitative research: a practical handbook.* (2nd ed.). London: Sage Publications Ltd.

Silverman, D. (2013). *Doing Qualitative Research*. (4th edition). London: Sage Publications Ltd.

Silverman, D. (2020). *Qualitative Research*. (5th edition). London: Sage Publications Ltd.

Steelman, T., Nowell, B. (2019). *Evidence of effectiveness in the Cohesive Strategy: measuring and improving wildfire response.* International Journal of Wildland Fire. https://doi.org/10.1071/WF18136

Storesund, K., Steen-Hansen, A., Sesseng, C. (2018). *Assessment of the Response Time of Norwegian Fire and Rescue Service.* Conference: Nordic Fire & Safety Days At: Trondheim, Norway

Stortingsmelding 16 (2023-2024). *Fire and Rescue Services, Proximity, Local Knowledge and Rapid Response Nationwide.* Ministry of Justice & Public Security.

Sugden, N. A., & Moulson, M. C. (2015). *Recruitment strategies should not be randomly selected: empirically improving recruitment success and diversity in developmental psychology research*. https://doi.org/10.3389/fpsyg.2015.00523

Sørensen, J L., Halvorsen, C., Aas, J P W., Carlström, E. (2020). *"Share Your Tools"—A Utility Study of a Norwegian Wildland-Fire Collaboration Exercise.*

Thagaard, T. (2013). *Systematikk og innlevelse: en innføring i kvalitativ metode.* Bergen: Fagbokforlaget.

Thagaard, T. (2018). *Systematikk og innlevelse: en innføring i kvalitativ metode.* (5th edition). Bergen: Fagbokforlaget.

Thompson, M.P., Wei, Y., Calkin, D.E., O'Connor, C.D., Dunn, C.J., 4 Anderson, N.M., Hogland, J.S. (2019) *Risk Management and Analytics in Wildfire Response.* https://doi.org/10.1007/s40725-019-00101-7

Tjora, A. (2021). *Kvalitative forskningsmetoder i praksis* (4. utg.). Gyldendal

Wankhade, P., & Patnaik, S. (2019*). Collaboration and Governance in the Emergency Services.* [edition unavailable]. Palgrave Pivot.

Warrick, D.D. (2023). *Revisiting Resistance to Change and How to Manage it: What Has Been Learned and What Organizations Need to Do*. Graduate School of Business, University of Colorado, Colorado Springs, USA.

Waugh, W. (2015) *Living with Hazards, Dealing with Disasters: An Introduction to Emergency Management.* (1st edition). Routledge.

Weick, K. E. (1993). *The collapse of sensemaking in organizations: The Mann Gulch disaster.* Administrative Science Quarterly, 38(4), 628–652. https://doi.org/10.2307/2393339

Xia, W., Becerra-Fernandez, I., Rocha, J., Gudi, A. (2012). *Task Uncertainty and Emergency Management Task Performance: The Mediating and Moderating Roles of Knowledge Sharing.* AIS Electronic Library.

Yin, R. K. (1994). *Case Study Research: Design and Methods* (2. utg.). Sage Publications.

Yin, R. K. (2018). *Case study research and applications: design and methods* (6 utg.). Los Angeles: Sage Publications.

Marcot, E., Miqueles, L. (2024). *Digital twins in safety analysis, risk assessment and emergency management.* https://doi.org/10.1016/j.ress.2024.110040

Attachments

Attachment 1:

Coding Frame - Communication and Technology for Wildfire Emergency Response in Norway: Current Methods, Improvement Potential, and Barriers.

Theme	Subcategories	Description	Quotes from text
Communication Methods	Direct Communication	Face-to-face interactions for immediate coordination and decision-making.	"We involve the leadership of the police and preferably health services, so we constantly have contact between the leaders at the incident site." … "The last time we had an incident here, both the police and civil defense were present locally in separate rooms, allowing us to walk and talk together."
	Radio Communication	Use of radio systems like TETRA for coordinating efforts and real-time information sharing.	"The most important thing is probably the radio communication so that we can give notice if dangerous situations arise." … "A major limitation with the digital emergency network today is that we do not have the ability to share images or

			data through the network.”
	Digital and Technical Tools	Use of technical and digital tools like drones and mapping systems like LOKUS to enhance real-time information sharing.	“The drone technology that has come now is very good. The drones available today have thermal cameras, and a fire may look like it is extinguished when it is not.” … “The system is called LOKUS, and it is essentially a mapping system where you can create action plans. You can add water lines, fire hydrants... Only your imagination limits it.”
	Traditional Methods	Continued use of paper maps and written logs, especially in areas where digital tools are unavailable.	“We very often go back to pencil and paper. Having something you can draw on is great, but I do see that a paper map that gets folded a lot deteriorates over time.”
Improvement Potentials	Training and Familiarity	Enhancing training on communication tools and protocols.	“If everyone has undergone basic training and knows

			the technical language, it becomes much easier.” … “The greatest potential for improvement is mostly at the leadership level.”
	Standardization	Standardizing equipment and procedures to reduce miscommunications.	“There is currently no standard terminology that unifies the fire service and fire helicopters.” … “Perhaps we should have a standardized grid for a wildfire in Norway?”
	Integration of Technology	Expanding the use of digital tools to improve coordination and response times.	“Each fire service had marked their hose equipment with QR codes.” … “GPS tracking where we could see where we have personnel in the field.”
	Collaboration with Other Agencies	Improving cooperation and shared protocols with other emergency services.	“It has been unsatisfactory because large incidents have not been planned together.” … “Personal chemistry

			will always be crucial, especially at the leadership level."
Identified Barriers	Financial Constraints	Budget limitations affecting the acquisition and implementation of new technologies.	"The biggest obstacles are, of course, financial." … "It's not just about money for equipment, but also about freeing up people to become proficient in what needs to be done during an operation."
	Technological Integration	Challenges in integrating new technologies with existing systems.	"I have a concern that we might suddenly face a fire and make the wrong decisions." … "As of today, there are numerous different information tools for crisis management."
	Training and Expertise	Importance of adequate training and ongoing practice with new technologies.	"The biggest obstacle to improving the equipment and technology used is perhaps knowledge?" … "Leadership training in Norway is

			unfortunately not very widespread.”
	Organizational Aspects	The fragmented nature of emergency services complicates the adoption of standardized technologies.	“The way we are organized makes us a bit vulnerable.” … “If each person didn't stick to their own turf with their own resources, collaboration could be improved.”

Attachment 2:

Preparing Questionnaire for Semi-structed Interviews.

TREEADS

A Holistic Fire Management Ecosystem for Prevention, Detection and Restoration of Environmental Disasters

Spørreundersøkelse

Du mottar dette spørreskjemaet for at du skal ha mulighet til å forberede deg til samtalen/intervjuet vi har avtalt. Du er valgt ut basert på din rolle under øvelsen i [redacted] mai 2023, men vi ber om at du svarer på generelt grunnlag basert på hele din erfaring på temaet.

Begrepsforklaringer:
Begrepet *skogbrann* omfatter her alle typer naturbranner, også gress- og lyngbranner.
Begrepet *logistikk* omfatter her tilgjengelig utstyr, teknologi, personell og andre ressurser, tilgang til og lagring av data om funksjonen og status på utstyr, kommunikasjonsmidler og former, utstyrsmanualer og servicestatus, sjekklister og samarbeidsmåter, fasiliteter for bespisning, toalett med mer.
Begrepet *utstyr og teknologi* omfatter teknisk utstyr som brukes ved innsats, datasystemer, kommunikasjonsmidler med mer.

Spørsmål:

1. Hvor fornøyd eller misfornøyd er du med logistikken under skogbranner? (1 = Svært misfornøyd, 2 = Litt misfornøyd, 3 = Verken fornøyd eller misfornøyd, 4 = Litt fornøyd, 5 = Svært fornøyd, 6 = Vet ikke)

   a. Hvilke aspekter er du fornøyd/misfornøyd med?

2. Hvordan oppfatter du samarbeidet mellom brannstasjonene, der samarbeid er påkrevd under skogbranner? (1 = Ikke tilfredsstillende, 2 = Lite tilfredsstillende, 3 = Noe tilfredsstillende, 4 = Stort sett tilfredsstillende, 5 = Optimalt, 6 = Vet ikke)

   a. Hva avgjør om samarbeidet blir godt/dårlig?

3. Hvis du legger til grunn de siste fem årene, hvor stor betydning har logistikkdelen å si for samarbeidet mellom brannstasjonene? (1 = Har ikke betydning, 2 = Lite betydning, 3 = Noe betydning, 4 = Stor betydning, 5 = Avgjørende betydning, 6 = Vet ikke)

   a. Hvilke logistikk-aspekter tenker du er viktig for godt samarbeid?

4. Hvordan opplever du kommunikasjonen mellom brannvesenet og andre nødetater under skogbranner? (1 = Svært dårlig, 2 = Dårlig, 3 = Verken god eller dårlig, 4 = God 5 = Svært god, 6 = Vet ikke)

   a. Hvilke kommunikasjonskanaler- og metoder blir brukt?

5. Hvor fornøyd er du med opplæring og vedlikeholdstrening på innsatspersonell ved skogbranner? (1 = Svært misfornøyd, 2 = Litt misfornøyd, 3 = Verken fornøyd eller misfornøyd, 4 = Litt fornøyd, 5 = Svært fornøyd, 6 = Vet ikke)

   a. Hvordan er opplæring og vedlikeholdstrening på innsatspersonell ved skogbrannbekjempelse lagt opp?

6. Hvordan oppleves koordinering og planlegging av innsatsen i den tidlige fasen? (1 = Ikke tilfredsstillende, 2 = Lite tilfredsstillende, 3 = Noe tilfredsstillende, 4 = Stort sett tilfredsstillende, 5 = Optimal, 6 = Vet ikke)

a. Hvilke aspekter ved koordinering og planlegging fungerer godt/dårlig?

7. Hvor raskt blir det gjort en risikovurdering og iverksatt tiltak under en skogbrann? (1 = 0-15 minutter, 2 = 15-30 minutter, 3 = 30-60 minutter, 4 = 1-2 timer, 5 = Over 2 timer)

a. Hvilke faktorer avgjør tidspunktet for når en risikovurdering med påfølgende tiltak iverksettes?

8. Hvordan oppleves tilgjengelighet til vann og vannkapasitet under skogbranner? (1 = Svært dårlig, 2 = Noe dårlig, 3 = Verken dårlig eller god, 4 = Noe god, 5 = Svært god, 6 = Vet ikke)

a. Hvilke hjelpemidler finnes i en tidlig fase for å kartlegge tilgjengelighet til vann og vannkapasitet?

9. Hvor godt fungerer utstyr og teknologi som anses som mest kritisk i forbindelse med innsats/beredskap under skogbrann i dag? (1 = Ikke tilfredsstillende, 2 = Lite tilfredsstillende, 3 = Noe tilfredsstillende, 4 = Stort sett tilfredsstillende, 5 = Optimalt, 6 = Vet ikke)

a. Hvilket utstyr og teknologi anser du for å være mest kritisk i forbindelse med innsats/beredskap under skogbrann?

10. Tilstand på utstyr:

a. Hvilken kjennskap har du til den tekniske tilstanden og den operative evnen til utstyret som brukes ved innsats under skogbrann?
b. Hvordan blir tilstanden til utstyret sporet/loggført?

11. Forbedring og hindringer:

a. Hvordan mener du utstyret og teknologien som brukes i forbindelse med innsats under skogbrann kan forbedres, for eksempel med hensyn på bedre og mer effektivt utstyr eller nye teknologiske løsninger?
b. Hva mener du er de største hindringene for å forbedre utstyret og teknologien som brukes ved innsats under skogbrann?

12. Er det noen spesielle områder der du ser rom for at teknologi kan bedre effektiviteten ved innsats under skogbrann?

Attachment 3:

Focus Group Interview Guide.

Guide fokusgruppe Skogbrann

Formål: Hensikten med fokusgruppen er å kartlegge hvilke aspekter av logistikken i krisesituasjoner som fungerer bra, og hvilke som har utfordringer. Derfor er det viktig å samle informasjon om tilgjengelige ressurser i dag og de ressursene som vil være nødvendige fremover.

Deltakere: Målgruppen for undersøkelsen består av førstelinjepersonell i brann- og redningsorganisasjoner, inkludert innsatsledere og innsatspersonell som jobber direkte i feltet under redningsoperasjoner og bruker tilgjengelige ressurser aktivt.

Moderator: Anette Mauno Torbjørnsdatter er moderator, leder diskusjonen, og sørger for at alle deltakerne får muligheten til å uttrykke sine meninger.

Gjennomføring: Fokusgruppen vil bli gjennomført via Teams den 12.12.23 klokken 09.00. Tre deltakere fra ulike brannstasjoner, alle med erfaring i lederroller i håndtering av lyng- og skogbrann, er invitert. Før fokusgruppen vil deltakerne motta et forberedelsesnotat som gir dem mulighet til å reflektere over de temaene som vil bli diskutert.

Overordnet tema: Logistikk i håndtering av lyng- og skogbrann

Vi ønsker å se på hvordan kommunikasjon påvirker Common Operational Picture (COP) og hvordan det bidrar til felles situasjonsforståelse.

Det settes av cirka 20 minutter til å diskutere hvert undertema.

Snakkepunkter:

1. Funksjon og effektivitet i forbindelse med kommunikasjonsmidler- og verktøy under håndtering: verbal kommunikasjon, visuell kommunikasjon
2. Beskriv prosessen rundt informasjonsdeling under en hendelse
3. Hva er nøkkelpunkter en innsatsleder trenger informasjon om under en hendelse?
4. Beskriv prosessen rundt beslutningstaking under en hendelse