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Dynamic fire disaster risk management in the Norwegian Fire Brigades?

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WESTERN NORWAY UNIVERSITY OF APPLIED SCIENCES

Master Thesis in Fire Safety Engineering

Haugesund
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Western Norway University of Applied Sciences

Dynamic fire disaster risk management in the Norwegian Fire Brigades?

Master thesis in Fire Safety Engineering

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This thesis is part of the master's programme in Fire Safety engineering at Western Norway University of Applied Sciences. The author is responsible for the methods used, the results that are presented, the conclusion and the assessments done in the thesis.

Western Norway University of Applied Sciences

Preface

This master thesis was written during the autumn and spring semester of 2021 and 2022 at the department of fire safety at the Western Norway University of Applied Sciences (WNU). The master thesis represents the final year of the master's in Fire Safety with 60 credits, ING5002 Master Thesis. The thesis is written in collaboration with the WNU and is associated with WNU´s NFR-project 298993 "Reducing fire disaster risk through *dynamic risk assessment and management* (DYNAMIC)".

After being in contact with several people regarding the thesis in spring 2021, it was the topic that professor Torgrim Log suggested: how the Norwegian fire brigades work to improve their dynamic risk-based emergency management. This was interesting to me because it is relevant to my background and a very topical issue.

Moreover, it presented the possibility to investigate topics such as dynamic risk-based emergency management, risk reduction measures, risk warning and proactive preparedness, throughout the literature review and interviews with key stakeholders.

Oslo, 1 June 2022

Brit Schei

Western Norway University of Applied Sciences

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Abstract

Extraordinary fires, such as the fires in Lærdal, Flatanger and Frøya January 2014, Sokndal April 2019 and Sotra June 2021, require extraordinary measures. To understand in advance that the fire risk is high may help regarding improved preparedness mentally as well as regarding manning, equipment, and recognizing and sharing need for possible support with neighbor fire brigades. Such improved preparedness will likely lead to reduced losses should an extraordinary fire start developing.

The thesis has inquired existing risk-based approaches in the Norwegian fire brigades and possibilities for improved dynamic risk-based emergency management. The semi-structured interview method was used as an instrument for collecting data. The sample consisted of deliberately selected seven fire brigades in Norway, one interview for each fire brigade. Wildland urban interface (WUI) fire disaster prevention and preparedness, such as risk understanding, were analysed. Together with a review of previous WUI fire incidents, legislation in Norway and theory, including fire dynamics, general fire spread, WUI, dynamic risk-based approach and warning systems, this gives a better understanding of dynamic fire disaster risk management in the Norwegian fire brigades.

There is a strong relationship between fire brigade response time and the outcome of fires [1]. The interviews provided understanding of the fire brigades' risk-based emergency management in relation to dynamic risk development. Also, how they may prepare differently in advance of periods of expected increased risk. The thesis will provide suggestions for the fire brigades' risk manning in the future.

According to Norwegian regulations, each fire brigade in Norway must have a risk and vulnerability analysis and contingency analysis [2] that describes, among other things, risk, dimensioning, and how to set up good emergency preparedness. All the interviewed fire brigades had risk- and vulnerability analyses, as well as a contingency analyses, within their municipalities. To be able to improve dynamic risk-based emergency management in the fire brigades, the fire brigades must describe and reveal the different risk in their analyses. There are large variations in how often these are updated. The understanding of how often different risks must be implemented in the analyses also varies. The results show that the smaller fire brigades do not have the capacity or resources to update the analyses as often as they would wish.

An important result that was pointed out by one of the larger fire brigades was that if they are to implement relevant measures to improve their dynamic risk management, they must think risk-based based on factors such as air temperature and humidity, as this has an enormous effect on the spread potential of a fire. Another important finding was that knowledge sharing between fire brigades are very limited. Typically, in the aftermath of a major fire the municipality supported their fire brigade with better equipment, water access, etc. while neighboring municipalities with similar risks just "sit on the fence".

WUI fires are an increasing risk to society; this is a result of settlement and infrastructure development in the vicinity of abandoned (previously managed) landscapes. Accumulated vegetation biomass in combination with dry and warm climates often results in much accumulated dead biomass with very low fuel moisture content [3]. The high disaster frequency experienced in recent years and the climate changes expected during the next decades represent alarming signals for the future [3]. There is therefore an urgent need for innovative and interdisciplinary research to understand the complexity and to proactively

manage the increasing fire disaster risk. Dynamic risk-based emergency management should therefore not be implemented at the expense of preventive WUI fire efforts, such as landscape management.

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Sammendrag

Ekstraordinære branner, som brannene i Lærdal, Flatanger og Frøya januar 2014, Sokndal april 2019 og Sotra juni 2021, krever ekstraordinære tiltak. Å forstå på forhånd at brannrisikoen er høy kan hjelpe både med hensyn til bedre beredskap mentalt, samt angående bemanning, utstyr og erkjennelse og deling av behov for mulig støtte med nabobrannvesen. En slik forbedret beredskap vil sannsynligvis føre til reduserte tap dersom en ekstraordinær brann begynner å utvikle seg.

Oppgaven har spurt om hvilke risikobaserte tilnærminger norske brannvesen allerede har og muligheter for forbedret dynamisk risikobasert beredskapsledelse. Studien er basert på en kvalitativ metode. Et semi-strukturert intervju er brukt som instrument for innsamling av data. Utvalget besto av målrettet utvalgte brannvesen i Norge. Det ble gjennomført syv intervjuer fordelt på syv ulike brannvesen. Skogbrann hendelser, forebygging og beredskap, samt risikoforståelse, ble analysert. Sammen med en gjennomgang av tidligere skogbrannhendelser, lovgivning i Norge og teori, inkludert branndynamikk, generell brannspredning, brannkatastrofer, dynamisk risikobasert tilnærming og varslingssystemer, gir dette en bedre forståelse av dynamisk risikobasert tilnærming i norske brannvesen.

Det er en sterk sammenheng mellom brannvesenets responstid og utfallet av branner [1]. Intervjuene skal gi en bedre forståelse av hvordan brannvesenet jobber for dynamisk risikobasert tilnærming. Oppgaven vil gi forslag til brannvesenets risikobemanning i fremtiden.

Etter norsk brannforskrift skal hvert brannvesen i Norge ha en risiko- og sårbarhetsanalyse og beredskapsanalyse [2] som beskriver hvordan de er dimensjonert, beskriver risiko, og hvordan man legger opp en god beredskap. Resultatene viser at brannvesenet som ble intervjuet har utarbeidet en risiko- og sårbarhetsanalyse, samt beredskapsanalyse. Det er store variasjoner i hvor ofte disse oppdateres. Samtidig varierer forståelsen av hvor ofte ny risiko må implementeres. Resultatene viser at de mindre brannvesenet ikke har kapasitet eller ressurser til å oppdatere analysene så ofte de ønsker. For å kunne jobbe mer dynamisk risikobasert i brannvesenene må brannvesenet beskrive og avdekke risikoen i sine analyser.

Et viktig resultat som ble påpekt av et av de større brannvesenene var at hvis vi skal forbedre dynamisk risikobasert styring, må vi tenke risikobasert ut fra faktorene lufttemperatur og fuktighet, da dette har enormt mye å si om spredningspotensialet til en brann. Et annet viktig funn var at kunnskapsdeling mellom brannvesenene er svært begrenset. Typisk, i etterkant hvor en kommune har hatt en storbrann, støttet kommunen sitt brannvesen med bedre utstyr, vanntilgang og lignende. Mens nabokommuner med lignende risiko bare «sitter på gjerdet».

Skogbranner er en økende risiko for samfunnet; dette er et resultat av utbygging av nabolag og infrastruktur i nærheten av gjengrodd (tidligere vedlikeholdt) natur. Kombinasjon med tørt og varmt klima som ofte resulterer i mye akkumulert død biomasse med svært lavt drivstoffuktighetsinnhold [3]. Den høye katastrofefrekvensen de siste årene og klimaendringene som forventes i løpet av de neste tiårene representerer alarmerende signaler for fremtiden [3]. Det er derfor et akutt behov for innovativ og tverrfaglig forskning for å forstå kompleksiteten og proaktivt håndtere den økende brannkatastroferisikoen. Dynamisk risikobasert tilnærming bør derfor ikke gjennomføres på bekostning av forebyggende skogbranninnsats, som for eksempel landskapsforvaltning.

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Definitions

FB	Fire Brigades
WNU	Western Norway University of Applied Sciences
WUI	Wildland-urban interface
CFWI	Canadian Fire Weather Index
DSB	Norwegian Directorate for Civil Protection
NSD	Norwegian Centre for Research Data
FWI	Fire Weather Index
BRIS	Fire statistics, service from the Norwegian Directorate for Civil Protection.
PB	Prescribed burning
FMC	Fuel Moisture Content
DYNAMIC	Research project at WNU; Reducing fire disaster risk through *dynamic risk assessment and management*
Calluna	*Calluna Ericaceae*
Risk management	Process of identifying, evaluating, and prioritisation of risks

1. Introduction

Fires represent a threat worldwide [4]. Recent major wildland-urban interface (WUI) fires and large urban fires have resulted in increased attention to large-scale fires. An international effort to identify similarities in fire development and fire spread and suggest a roadmap for future research to mitigate such fire risks has recently been initiated [5,6].

Fire has for millennia been a highly valued tool and an integral part of human societies [7]. Nevertheless, during the last couple of years, fire has been perceived mainly as a threat. Large WUI fires are usually, but not always, associated with warm and dry weather. WUI fires are an increasing risk; this is mainly in the United States, Canada, Australia and the Mediterranean area. This is a result of settlement and infrastructure development in areas with densely accumulated vegetation biomass [3].

In Norway, the building fire frequency is highest during winter (from November to January) [8]. This is partly due to the use of open flames, such as candles during Christmas, advent, and New Year celebrations. Along the west coast, wind from the west brings humid air from the Atlantic Ocean. Wind from the east brings adiabatically heated (often sub-zero) dry air plunging from the central Norwegian mountain plains. Windy weather often follows dry, cold periods. Windy weather dries the wooden buildings, making them increasingly vulnerable to fast fire [3]. This was experienced on 18-19 January 2014, when a fire in Lærdalsøyri destroyed 40 buildings. Ten days later, a fire in Flatanger occurred 100 km south of the Arctic Circle, destroying 61 buildings, demonstrating that large winter fires in Norway are not just events of the past [3]. The fire spread mechanism in these two recent fires was identified as spot ignition [9]. In combination with very strong winds, the severity of these fires may be explained by climatic conditions associated with sub-zero dry air and the drying of indoor wooden materials and outdoor vegetation [9,10]. These fires demonstrate that conflagration risk should not be underestimated by modern society.

There is a strong relationship between fire brigade response time and the outcome of fires [11, 12]. The faster the firefighters get involved in active firefighting, the faster the firefighters will be able to put out a fire and prevent it from spreading. Given a constant response time, a comparably faster fire development will result in a more developed fire when the emergency responders arrive on the scene. The thesis will therefore look more closely at how the fire brigade can work to improve dynamic risk-based emergency management, such as experienced in Lærdal, Flatanger and Frøya in 2014.

Understanding risk is necessary to prevent accidents, establish an appropriate emergency response and reduce uncertainty. Risk implies future uncertainty about deviation from expected benefits or expected outcome. When the risk is known and understood, risk-reducing measures can be identified and prioritised to initiate or control the risk.

The master's thesis aims to analyse the current situation regarding risk-based management that selected fire brigades (FB) already have and possibilities for improved dynamic risk-based emergency management. Thus, the current situation must first be established. Then, the possibilities for future dynamic risk management shall be evaluated, including possible showstoppers.

1.1 Background

The high WUI fire disaster frequency which has been experienced in recent years and the climate changes expected during the next decades represent alarming signals for the future. And there is an urgent need for innovative and interdisciplinary research to:

a) Understand the complexity
b) Proactively manage the increasing fire disaster risk.

This implies increased capacity in dynamic risk-based management.

Halvorsen and Grimsrud [13], looking into fire hazards in Norwegian coastal heaths, describe the following: "Unmanaged and overgrown coastal heathlands pose a great fire hazard. This is due to the combination of old, dead heather and the growth of spruce and juniper, which are highly flammable and burn explosively. Improved management of coastal heathlands reduces this fire hazard and thereby lowers the costs of fires to society, which include the costs of firefighting, loss of property and production value, and loss of biodiversity". The most important findings in that study [13] support that heathland management saves society large sums compared to reactive firefighting.

Further, it is found that weather conditions are the most important driver for fires, where lack of precipitation over a longer period in combination with high temperatures and strong winds has the greatest effect on the probability of fire. In particular, many fires are associated with coastal heathlands, and the number of fire emergencies increases in relation to reduced management and consequent overgrowth. Another important finding in the report, fire danger in Norwegian coastal heaths [13], is that increased management of coastal heathlands significantly reduces the risk of fire, especially during periods of drought, heat and strong winds. This is because well-maintained coastal heathlands have limited combustible (dry) vegetation and are not highly flammable even in periods when the fire hazard is otherwise great.

During 11 days in January 2014, three (Lærdal, Flatanger and Frøya) of the largest fires in Norway in the 21st century occurred. In the summer of 2018, Norway was again extremely vulnerable to WUI fires, when throughout 2018 more than two thousand fires were registered in grass and forests, of which close to a thousand were WUI fires [14]. Climate change and vegetational encroachment and degradation indicate that the risk of large fires is increasing [15].

Figure 1 shows the location of the largest heathland wildfires in Norway since 2014. It also shows that the fires are located near the coast of Norway, where it tends to be very windy throughout the year.

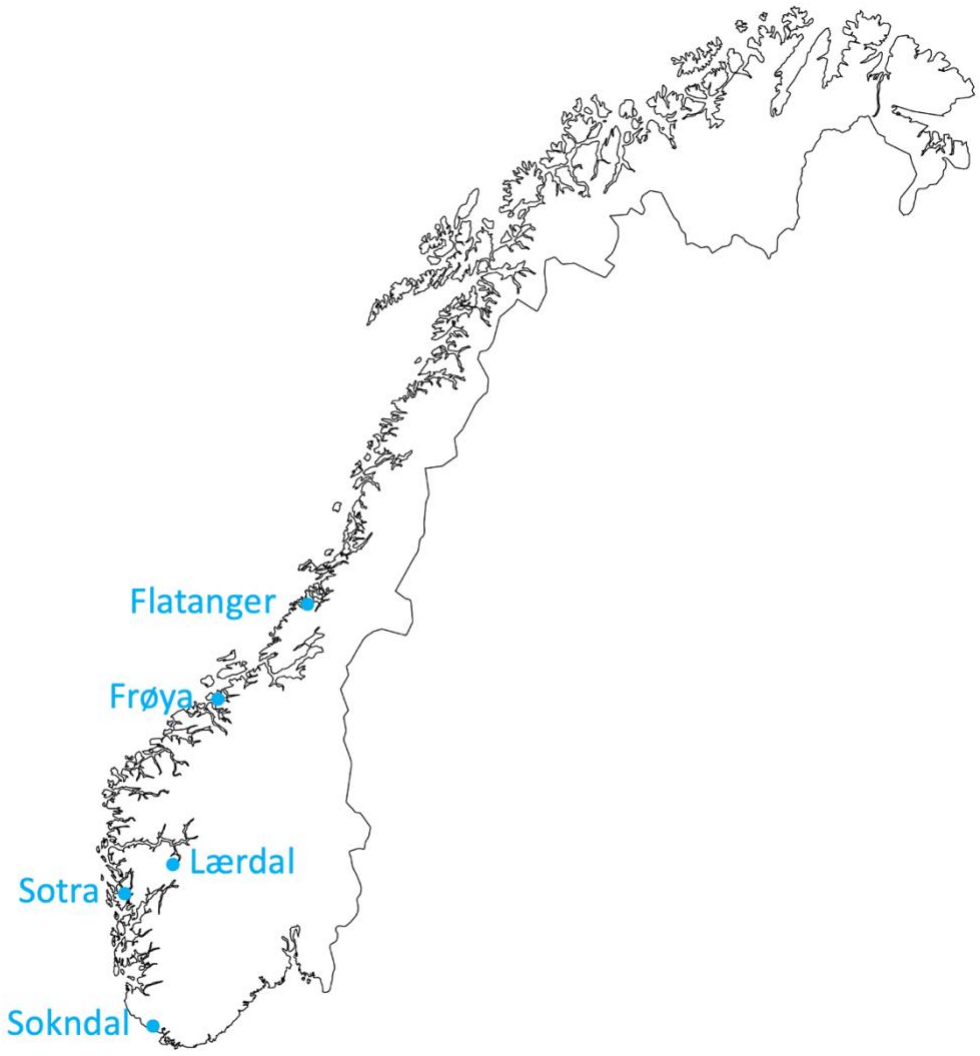

Figure 1: Largest heathland wildfires in Norway since 2014.

Seen in the Norwegian context, what the three fires have in common is that they are described as large. Major incidents such as this will most often trigger a need to use more resources than are available locally [16]. To understand the fire incidents in Norway and the fundament for dynamic risk-based management, the next subchapters will describe the fires and the challenges.

1.1.1 The fire in Lærdal

The fire in Lærdal broke out at Lærdalsøyri on the evening of 18 January 2014. The fire spread quickly in the strong wind. Around 680 people were evacuated from their homes to an evacuation centre. No lives were lost in or as a result of the fire [3]. The fire spread over an area of about 500x200 metres, as well as a small area south of Highway 5, and large parts of the mountainside. These were more buildings than had

been lost in the same fire in Norway since World War II. About 70 people lost their homes and belongings. Four buildings in old Lærdalsøyri were lost [9].

The climate in Lærdal is normally very dry, but in January 2014 it was drier than normal. There was 25.9 per cent of the normal rainfall during the month, which is 25 mm. December and January were also just over four degrees warmer than normal. On the night of 19 January, there was periodically a small easterly storm with a wind speed of 22 m/s in the high mountains. It is a known phenomenon that winds from the east can strike down into the valley, often with undiminished strength, but even more turbulent. Weather and temperature conditions in the weeks before made vegetation and the wood inside the buildings dry and easily ignitable. These factors led to a rapid and unpredictable spread of fire [3].

The wind constantly changed direction and new places were ignited. This led to very demanding firefighting and it was challenging to get an overview of the situation [3].

1.1.2 The fire in Flatanger

The fire in Flatanger in 2014 was a heather fire that broke out on the evening of 27 January and spread very quickly in strong winds. It started burning in the terrain between two holiday homes in the hamlet of Uran. Strong winds resulted in short circuit sparks from suspended electrical power cables igniting dry and snow-free grass and heather [16].

Flatanger was affected by a very dry January in 2014. Precipitation was 6.9 per cent of the monthly norm of 79 mm. The measuring stations located closest to the coast had medium winds up to a strong south-easterly gale with a wind speed of 20 m/s. The strong wind resulted in a fast fire spread, just 210 km south of the Arctic Circle. Fortunately, all inhabitants were evacuated before the fire became life-threatening. The firefighters struggled to control the fire. The terrain was rugged, there was very limited access to the area and the firefighting equipment quickly froze [16].

The fire in Flatanger did not cause physical injury to persons. After burning 15 km^2 [16] of *Calluna* dominated Atlantic heathlands and destroying 63 wooden structures, among these 23 houses and holiday homes, the fire finally burnt itself out at the North Sea. Flatanger is the most extensive fire in Norway, in terms of the number of buildings lost, since 1923 [3].

1.1.3 The fire in Frøya

Just before 11 a.m. on 29 January, the 110-alarm centre in Trondheim was notified of a fire. It had been a particularly dry January in 2014: only 6.2 per cent of the normal precipitation for the month of 87 mm [16]. This period with so little rainfall had made the heather and scrub vegetation dry and easily ignitable. Weather reports in the vicinity during the period of the fire measured a mean south-easterly wind speed of 15 m/s, with gusts up to 23 m/s. The wind caused the fire to spread rapidly in a north-westerly direction, away from the nearby buildings [16].

A few hours after the fire started, the commander-in-chief on Frøya reported that they had no control over the fire and that it appeared to be spreading to buildings. The area where it burned is a vegetational area of about 10 km^2, which consists of grass and heather. No major items of value were lost in the fire, only one cabin was lost. No persons were injured in or because of the incident. Just under 200 people were evacuated [16].

1.1.4 Common for these fires

The main common features of these three fires were dry and windy weather conditions. The weather had for weeks been characterised by strong high pressure from the east. This blocked the usual low-pressure passage from the west. This led to the low pressures remaining roughly across the UK and to easterly to southerly winds over most of Norway. For the first time, Western Norway, Trøndelag, and Northern Norway had the driest January on record [16].

In many places, the dry wind became very strong, with gales and periodical storms in exposed places. This is not unusual on this part of the Norwegian coast, but the strongest wind often comes from the southwest towards the north-western area [4].

Even a modern fire brigade cannot prevent a fire from spreading from house to house with such fires as the ones in Lærdal and Flatanger, which turned out to lead to unfortunate circumstances. The challenges apply not only to old wooden houses that are close together but also to ordinary residential buildings and sparsely populated areas. In recent years, the need for more knowledge about fires of this type has been pointed out. In Norway we should take more knowledge from major fires and forest fires such as California, Australia and Southern Europe [3].

1.1.5 Fires in Sokndal and Sotra

April 2019 was characterised by a long period of drought and increasing forest fire danger in Rogaland. On 23 April, the police were notified that two people were surrounded by flames in a heather area in Sokndal. The fire occurred after a long period of drought and increasing forest danger. Later, the main rescue centre reported that they had been retrieved from the area. On the same day, several fires were reported in Sokndal municipality. The wind was strong from the east and the fire spread to Hauge, the municipal centre of Sokndal. The fire spread quickly and 138 people were evacuated. Fire brigades from five municipalities were involved. Several forest fire helicopters participated [17].

The fire at Sotra in early June 2021 occurred due to a combination of dead grass, old heather, juniper and forest, which is easily ignited and burns rapidly [13]. The fire ravaged several square kilometres in Øygarden municipality. It was so intense that the helicopter pilots were unable to cover the entire area. Two houses burned, one of which was completely burnt out. Many people were forced to evacuate. It was very demanding for the firefighters to get control of the fire, as it was very dry and windy [15].

1.1.6 Final remarks

In the Lærdal, Flatanger, Frøya, Sokndal and Sotra fires, the number of homes at risk in the WUI, the rapid-fire spread, and spot fires made the firefighting challenging. Less severe fire development in previously burned areas made them acknowledge possible prescribed burning; “an army of goats” or “volunteer efforts” for fire fuel removal in the defensible space were also suggested [15]. The thesis will look at parameters that can prevent such incidents from happening in the future. Understanding how the fire brigades can improve their work on dynamic risk-based management is important, but they should also look at and understand other measures that can be preventive.

1.2 Fire legislation in Norway

To understand the Norwegian legal framework for fire protection, the associated rules and regulations were briefly analysed. According to the Norwegian Parliament Report no 35, Norwegian Ministry of Justice and Public Security, 2008-2009 [18], the national goals for fire protection are:

- Fewer fire-related fatalities
- Prevent the loss of irreplaceable cultural-historical values
- Prevent fires that paralyse critical societal functions
- Strengthened preparedness and ability to act
- Reduce material losses due to fires.

How to prevent catastrophic fires, wildland-urban interface and other fires in Norway is regulated by several laws and regulations. These state, among other things, how the fire brigade in Norway will work to prevent fires and the dimensioning of the fire brigade. The most relevant fire legislation is listed in Table 1.

Table 1: Overview Regulations in Norway.

Regulations (Norwegian)	**Source**
Act relating to prevention of fire, explosion and accidents involving hazardous substances and the fire service (*Brann- og eksplosjonsverloven*)	[19]
Regulations on fire prevention (*Forskrift om brannforebygging*)	[20]
Regulations on municipal emergency preparedness (*Forskrift om kommunal beredskapsplikt*)	[21]
Regulations on the organisation and dimensioning of the fire service (*Forskrift om organisering og dimensjonering av brannvesen*)	[22]
Regulations on the organisation, staffing and equipment of the fire and rescue service and the emergency call centres (*Brann- og redningsvesenforskriften*)	[2]
Civil Protection Act (*Lov om kommunal beredskapsplikt, sivile beskyttelsestiltak og Sivilforsvaret*)	[23]

Fire and Explosion Act

The Fire and Explosion Protection Act [19] and associated regulations give municipalities the obligation to handle fires, including WUI fires. The municipality shall carry out a risk and vulnerability analysis so that the fire and rescue service is best adapted to the tasks. The Fire and Explosion Act [19] states that the municipality shall ensure the establishment and operation of a fire brigade that can take care of statutory preventive and emergency preparedness tasks efficiently and safely. Furthermore, it states that the municipality shall assess incidents to ensure continuous learning and improvement of preventive and

emergency preparedness work. Section 9 describes that the municipality shall ensure the establishment and operation of a fire service and section 10 says that the municipality shall document fulfilment of the obligation under section 9.

The municipality shall develop safe and robust local communities and has a general and basic responsibility to safeguard the population's safety and security within its geographical area [24].

Through the Fire and Explosion Protection Act with regulations on fire prevention [20], the municipality is required to identify and keep a list of areas where fire could cause major damage to material or cultural-historical values. For municipalities with dense wooden housing or wildland-urban interfaces worthy of protection, it will be natural for these to be considered.

Regulation on fire prevention

The fire prevention regulation [20] chapter 4, sections 14 to 22, deals with the regulations for the municipality, including developing a risk and vulnerability analysis. The goal is to identify likely fire scenarios and corresponding risk management measures. In municipalities with densely built wooden heritage sites, a conflagration is a likely worst-case scenario. The municipalities, therefore, are obliged to plan and implement preventive measures to mitigate this risk and develop a fire safety plan. Risk-based supervision of identifying special fire objects is mandatory. In the context of this study, typical risk objects can be determined based on cultural-historical value or WUI fires, e.g., densely built wooden heritage sites.

Regulations on the organisation and dimensioning of the fire service

Regulations of 26 June 2002 no. 729 on the organisation and dimensioning of the fire service (the dimensioning regulations) with effect from 1 July 2002 supplement the Fire and Explosion Protection Act of 14 June 2002 [22]. The guide has been prepared by the Directorate for Civil Protection and Emergency Planning (DSB) and is aimed at municipalities and municipal fire protection authorities [22].

The regulations on the organisation and dimensioning of the fire brigades [22] shall ensure that each municipality has a fire brigade that is organised, equipped and manned to satisfactorily handle tasks and incidents as required by relevant laws and regulations. It must be dimensioned based on the existing risk and vulnerability. Cooperation with other municipalities and emergency organisations is required, including the need for reserve forces [22]. The emergency preparedness must be organised based on standard requirements and mapped risk and vulnerability so that it takes into account the interests of new personnel and the safety of the fire service personnel. In addition, the fire service should be cost-effective.

Chapter 5 [22] describes that there shall be a contingency plan for efforts against fire and accidents in every municipality. There are requirements for the minimum task force, management of task forces and location of emergency preparedness. The requirements for the service´s emergency preparedness follow from sections 5-3 to 5-6.

The fire and rescue service´s total emergency response force shall be staffed with at least 16 people, of which at least four shall be qualified as emergency managers. The number of people in the emergency response force can be increased based on the contingency analysis [2]. A fire squad shall consist of at least one emergency manager and three firefighters. The number of squads in relation to the number of residents in the municipality is also described.

Regulations on the organisation, staffing and equipment of the fire and rescue service and the emergency call centres

On 15 September 2021, the DSB laid down regulations on the organisation, staffing and equipment of the fire and rescue service and the emergency call centres (the fire and rescue service regulations) [2]. The regulation entered into force on 1 March2022. This replaces the regulations on the organisation and dimensioning of the fire brigades [22].

The Fire and Rescue Services Regulations largely continue regulations on the organisation and dimensioning of the fire service (the dimensioning regulations). Much of the content of the new regulations is recognisable to the municipalities/fire brigades [2].

The municipality shall organise, staff and equip the fire and rescue service based on a [2]:

a. Risk and vulnerability analysis
b. Preventive analysis
c. Contingency analysis

The fire and rescue service shall ensure that relevant actors are invited to participate in the work of preparing the analysis and ensure the necessary endorsement of the analysis process and results. The analyses shall be updated in the event of changes in risk and vulnerability that may have an impact on the organisation, staffing and equipment of the fire and rescue service. The analysis must be updated at least every four years.

The purpose of the municipal emergency preparedness obligation is for the municipalities to work holistically and systematically on social security and emergency preparedness across the sectors in the municipality. Knowledge of risk and vulnerability is essential to reduce the likelihood of an adverse event occurring and to reduce the consequences if it occurs.

The comprehensive risk and vulnerability analysis shall:

- Provide an overview of undesirable events that the municipality might face
- Raise awareness of risk and vulnerability in the municipality
- Capture risk and vulnerability across sectors
- Provide knowledge about roofs to avoid and reduce risk and vulnerability in the municipality
- Identify measures that are significant for the municipality's ability to handle stress
- Provide a basis for goals, priorities and necessary decisions in the municipality´s work with community safety and emergency preparedness
- Provide input to risk and vulnerability analyses within other municipal areas of responsibility and county risk and vulnerability

Each fire brigade in Norway must have a risk and vulnerability analysis and contingency analysis that describes how they are dimensioned, describes the risk and how to set up good emergency preparedness.

The municipality shall seek cooperation with other municipalities and emergency preparedness organisations so as to make the best use of the resources in the region. Where an inhabited area is common to (shared among) several municipalities, these shall cooperate on the emergency preparedness

in this area. Identifying and managing risk, whether through the pre-planning and management of emergencies, fire safety, crime and disorder initiatives, training or undertaking other day-to-day activities, is part of the integrated risk management planning process.

The contingency plan should be for efforts against fire and accidents in every municipality. There are requirements for the minimum task force, management of task forces and location of emergency preparedness. Emergency preparedness must be organised and dimensioned and possibly located with the mapped risk and vulnerability. In addition, the municipality must organise, dimension and locate the emergency preparedness based on settlement, population and response times [22].

The Fire and Rescue Services Regulations [2] state that the fire brigades shall prepare a contingency analysis based on the risk and vulnerability analysis and the preventive analysis, cf. regulations sections 7 and 8. The contingency analysis shall answer the extent to which the fire brigades address mapped risk and vulnerability, cf. the regulations section 7. Further, it states that the contingency analysis shall identify and assess which resources, such as equipment, personnel and competence, are necessary to be able to handle dimensioning incidents satisfactorily. The assessment of the number of persons in the emergency response force, the emergency response, the number of duty teams, the reserve force and the location of the emergency response force, cf. the regulations sections 13, 15, 16 and 17 [2], shall include:

- The risk in the area of responsibility
- The requirement for emergency response time
- The attendance time for the personnel who attend the first effort and further effort
- Cooperation with other fire brigades

The municipality must plan and implement measures to reduce the mapped risk, through both the Fire and Explosion Protection Act [19] and the Civil Protection Act [23]. If urban conflagration and massive loss of heritage are identified as a risk, plans on how to reduce the risk must be implemented. This can be done by a dedicated fire protection plan for the urban area at risk.

Contingency

Section 16 reserve forces or forest fires and other incidents [25] describes if the fire and rescue service´s own emergency forces do not have sufficient personnel resources to handle emergencies that may occur, such as areas where there is a significant risk of WUI fires. The fire service alone or in collaboration with other fire and rescue services must ensure that they have sufficient reserve forces for WUI fires and other incidents. The need for reserve forces shall be stated in the contingency analysis, cf. section 9 of the regulations.

The fire and rescue service´s contingency analysis will identify which reserve forces are necessary to be able to respond satisfactorily and to be able to handle incidents that appear in the risk and vulnerability analysis and where efforts are expected from the fire and rescue service. The requirement for reserve forces must be seen in connection with the Fire and Explosion Protection Act section 15 [19].

Fighting WUI fires is part of the fire service´s tasks according to section 11 of the Fire and Explosion Protection Act [19] and is handled primarily by the fire and rescue service´s established emergency preparedness. In some cases, forest fires are significantly larger than the general emergency service can

handle. Experiences from previous forest fires have shown the need for full resource allocation at an early stage [25]. Ordinary effort and extinguishing tactics in the event of a fire in a forest are different from other firefighting and require a larger fire reserve force, for example. Therefore, an obligation has been established to organise a special WUI fire reserve force in those municipalities where the risk of forest fires is greatest.

Section 25, exercise requirements for the fire and rescue service [2] describes that they shall prepare an annual plan for exercises based on the risk and vulnerability analysis and the contingency analysis. The exercises shall vary in type and scope so that the incidents that determine the fire and rescue service´s organisation, equipment and manning are practised over time. The exercises shall contribute to personnel becoming familiar with and trained in the emergency preparedness organisation and use of the equipment so that the person has the necessary competence to perform their tasks and functions.

1.3 Scope

The goal of this study is to get more knowledge of what the fire brigades in Norway already have and possibilities for improved dynamic risk-based emergency management. The master thesis aims to analyse the current situation regarding dynamic risk-based management (e.g., dimensioning) in selected fire brigades with emphasis on large fire incidents that may have very severe outcomes for the affected community. Thus, the thesis aims to first understand the current situation. Then, the thesis investigates the possibilities for improved dynamic risk-based emergency management, including possible showstoppers.

Interviews were conducted with selected fire brigades (mostly located by the Atlantic west coast) in Norway. The fire brigades' methods of fire risk-based management and risk understanding of large fires are investigated. Together with a review of previous incidents and the theory of the study, the interviews will provide a better understanding of how the fire brigade works on risk reduction measures, risk warnings and proactive preparedness.

1.3.1 Problem statement

The purpose of this study is to analyse the current situation regarding a dynamic risk-based approach in selected fire brigades with emphasis on infrequent fire incidents that may have very severe outcomes for the affected community. Therefore, the problem statement for this thesis will be that the fire risk is huge. The fire brigades have limited resources, which can lead to handling being limited. In this study, the writer will investigate why and look for possible solutions. If the fire brigade uses dynamic risk-based management, it can lead to the fire brigade arriving earlier at the scene and putting out the fire before it has a chance to become large.

1.3.2 Research question

The thesis problem statement covers a large subject area and it is therefore limited by the purpose of the thesis. For this reason, three research questions have been formulated that will help to answer the problem.

Research question 1: What is dynamic risk-based management according to the fire brigades and the literature?

It is important that the fire brigade and the literature have the same understanding of the dynamic risk-based management, in order to be able to improve the dynamic risk-based management in the fire brigades. It is the emergency preparedness analysis that is to identify and assesses which resources, such as equipment, personnel and competence, are necessary to be able to handle dynamic dimensioning incidents satisfactory.

Research question 2: How can the fire brigades improve their dynamic risk-based approach?

The question is intended to reveal whether the fire brigade works with a dynamic risk-based approach today, as well as possibly the background for why and how they achieve it.

Research question 3: What identified measures may improve dynamic risk-based emergency management in the future?

The thesis will examine how the fire brigades work today and how they can improve for dynamic risk-based emergency management. This means mapping the risk in the municipalities, looking at what understanding and needs the fire brigades have today while looking at what motivates them to work on dynamic risk-based emergency management. In addition, the task will also map incidents and any showstoppers.

1.4 Limitations

The present interviews are done by interviewing seven fire brigades. These fire brigades were selected based on where the largest wildfires and heather fires occurred in Norway. Also, some fire brigades that work closer to houses, such as wooden structures. At the same time, selected fire brigades are based on locations where the danger of heather fire is greatest in terms of weather conditions.

In this master´s thesis, no analysis of the risk and vulnerability analysis for the different fire brigades has been carried out or studied.

2. Theory

In this chapter, general WUI, prescribed burning, fire dynamics and fire spread will be presented to gain an understanding of how the fire brigades should handle large WUI fires. Furthermore, dynamic risk-based management will be described to understand how the fire brigade should improve their dynamic risk-based management. Finally, risk warning will be presented as this is an important factor in being able to improve dynamic risk-based management.

2.1 Wildland-urban interface (WUI)

Wildland fires have a big impact on the environment, human life and property. Also posed a significant economic loss as demonstrated by devasting wildfires that occurred over the last few years [26]. The ignition and corresponding spread of these fires were predominantly influenced by extreme drought and high winds.

The fire risk is now increasing due to a combination of land-use changes, resulting in large areas of early successional vegetation with an accumulation of biomass, and the interactive effects of climatic changes resulting in increased drought risk [3]. WUI fires are an increasing risk; this is a result of accumulated vegetation biomass in combination with dry and warm climates often resulting in much accumulated dead biomass with very low fuel moisture content. Wildland fires are likely to occur more frequently and be more intense because of global warming [26]. Wildland fire can be mitigated through firefighting and prevention.

2.1.1 Climate change

Both climate and weather drive the temporal variation in fire risk, resulting in greater fire risk under future climates. Landscape succession, new home constructions in the WUI zone and more elderly staying at home change on decadal timescales. Vegetation and wooden home fuel moisture content may change within a few days. Wind strength and thin dead biomass fuel moisture content may change within minutes (cured grass) and hours (twigs and thin branches) [3].

Weather conditions are a very important risk factor for grass, wildland-urban and bush fires. Long periods without precipitation in combination with warm weather make dry, dead heather and grass highly combustible. Thunderstorms with lightning or a bonfire that is not extinguished properly can easily ignite the material. If the wind is strong, the flames spread quickly and it can be difficult to control and extinguish the fire [13].

2.1.2 Vegetation

Most of the *Calluna vulgaris* heath has been left unmanaged. In these unmanaged old *Calluna* stands, the biomass accumulates and the lower canopy consists mainly of dead branches which dry very quickly [3]. Compared to young stands, much more intense fires are therefore experienced in the over 50 year-old stands that are currently representative for the coastal areas of Norway south of the Arctic Circle.

Additionally, unmanaged Norwegian heathlands gradually develop a vegetation composition where juniper, pine and spruce, for example, increase in abundance. The highly flammable resinous juniper foliage contributes significantly to the fire prone biomass [3].

Prescribed burning

A prescribed burning (PB) is a planned fire and is used to meet management objectives. A prescription is a set of conditions that considers the safety of the public and fire staff, weather and probability of meeting the burn objectives. Prescribed fire is a form of land management in which fire is intentionally applied to vegetation. Prescribed fires are conducted under desired conditions to meet specific objectives, such as restoring fire regimes in adapted ecosystems or limiting the amount of dry brush in an area prone to wildfires [27]. In Norway, several recent WUI fires have been attributed to climate change and accumulation of elevated live and dead biomass in degenerated *Calluna* stands due to changes and accumulation activities, i.e., abandonment of prescribed burning for sheep grazing [28].

Local communities in Norway are a key to land-use and WUI fire risk management [29]. In the Haugesund area, an innovative initiative from an informal farmer group (Lyngbrennarar on Haugalandet) has reestablished PB for better grazing and reduced WUI fire risk. The group has a qualified approach, maintains a dialogue with the fire brigades when planning PBs and prioritises personal safety. They have also optimised alternative equipment and approaches during PB fire control, for instance leaf blowers and water mist blowers.

Planning for potential severe fires comes into play regarding, e.g., prescribed burning and proactive emergency organising, as well as what people plant in their gardens. This results in better protection as, e.g., WUI fires become easier to control when the firefighters arrive earlier at a fire scene. Information on the predicted fire risk should be communicated to fire brigades, homeowners and the public. Wildfire prevention stakeholders highlight that traditional landscape and resource management, including prescribed burning, prevents severe wildfires [29]. Log et al. [30] claim that re-establishing prescribed burning at regular intervals could mitigate the risk of WUI fires developing into destructive peat fires. In some areas along the Norwegian coast, initiatives for resuming the heathlands have recently been initiated by civic farmer groups [29, 31]. In most areas, the encroachment continues unconstrained. Thus, there is a need to understand and reduce the increasing WUI fire risk [3].

2.2 Fire in general

As a process, fire can take many forms, all of which involve chemical reactions between combustible species and oxygen from the air. Properly harnessed, it provides great benefit as a source of power and heat to meet our industrial and domestic needs but it can cause untold material damage and human suffering [3].

In some ways, fire is simple. It only takes three components: reacting oxygen from the air (oxygen), plenty of burnable fuel (combustible material) and ignition (heat). A fire can be defined as a process in which substances combine chemically with oxygen from the air and typically give out bright light, heat and smoke, or combustion or burning [32].

A fire that is allowed to burn freely in a room will develop through five phases [32]:

1. Ignition
2. Growth
3. Flashover
4. Fully developed fire
5. Decay

How fast a fire develops and what temperatures are achieved will vary from fire to fire. Typical temperature variation with time in an enclosure fire is shown in Figure 2.

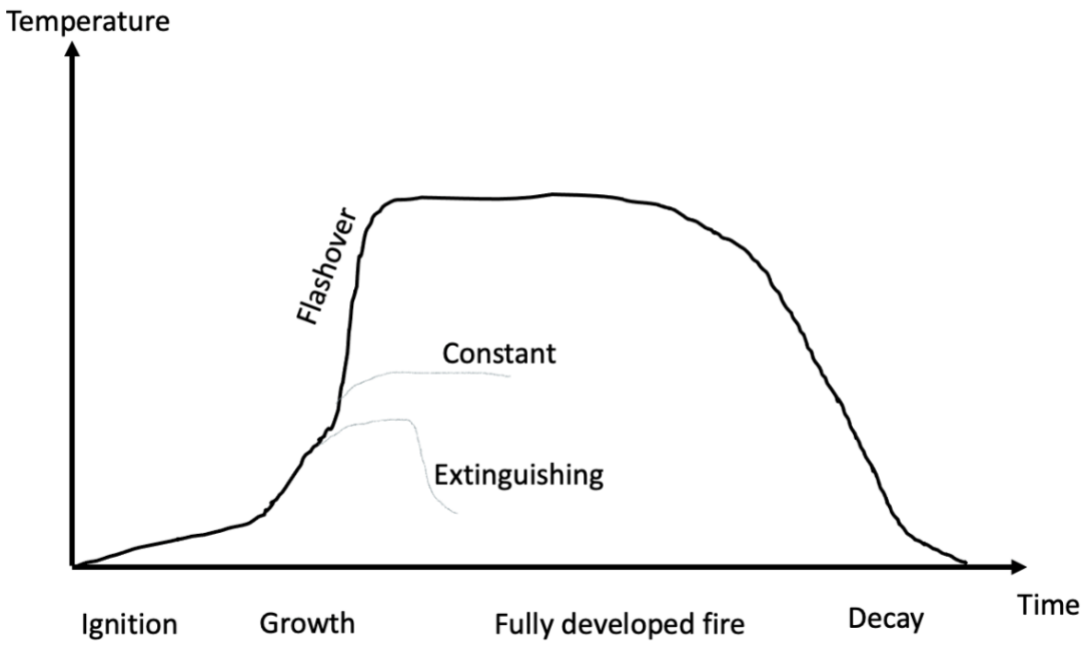

Figure 2: Idealised description of the temperature variation over time in an enclosure fire [32].

A WUI fire will behave differently because of other conditions compared to an enclosure fire.

2.2.1 Fire Dynamics

At the time when *Calluna* dominated the coastal landscapes, the risk of severe wildland fires was close to absent. Gradual build-up of natural biomass has increased the risk of disastrous WUI fires [28].

Because hot air rises, heat transfer through convection tends to move upward. During wildfires, burning materials on the forest floor create convection currents that preheat the leaves and branches of shrubs and trees above the fire. The vertical air currents can also lift burning materials.

Drysdale [33] describes the physical chemistry of combustion in fires and that there are two distinct regimes in which gaseous fuels may burn, namely:

I. In which the fuel is intimately mixed with oxygen (or air) before burning.
II. In which the fuel and oxygen (or air) are initially separate but burn in the region where they mix.

These give rise to premixed and diffusion flames [33].

Except for solid-phase oxidation of charcoal, the combustion takes place in the gas phase (flame) where the products released from the fuel surface react with oxygen entrained in the flame zone.

The most important parameter in fires characterising the fire behaviour is the heat release rate (HRR) [33].

$$\dot{Q}_C = A_f \cdot \dot{m}_f^{''} \cdot \chi \cdot \Delta H_C \ (W) \qquad (1)$$

Where:

A_f: fuel surface area [m^2]

$\dot{m}_f^{''}$: fuel surface mass flux [kg/m^{2}s]

χ: burning efficiency [≤1]

ΔH_C: the heat of combustion for the fuel involved [J/kg]

The incoming heat flux to the surface of the fuel consists of the heat flux from engulfing flames and hot gases, $\dot{Q}_F^{''}$ (W/m^2), and any radiant heat flux from external heat sources, $\dot{Q}_E^{''}$ (W/m^2). The incoming heat flux is balanced by the inwards and outwards surface heat losses, $\dot{Q}_L^{''}$ (W/m^2), and the enthalpy required for pyrolysing the fuel, L_v (J/kg), at the respective fuel surface mass flux, $\dot{m}_f^{''}$ [33]:

$$\dot{Q}_F^{''} + \dot{Q}_E^{''} = \dot{Q}_L^{''} + \dot{m}_f^{''} \cdot L_v \ (\frac{W}{m^2}) \qquad (2)$$

And then solve the equation (1) for the mass flux:

$$\dot{m}_f^{''} = \frac{\dot{Q}_F^{''} + \dot{Q}_E^{''} - \dot{Q}_L^{''}}{L_v} \ (\frac{kg}{m^2}) \qquad (3)$$

Generally, fire spread is caused by direct flame contact (convection), heat radiation and by airborne firebrands and glowing embers. Virgin fuel needs to be heated to temperatures above 100°C to be involved in the combustion. The term L_v includes heating the fuel to 100°C, drying it at about 100°C, heating it to

temperatures typical for the onset of pyrolysis, pyrolysing it, and further heating the pyrolysis products to the ignition temperature [33].

The heat of vaporisation for water is very high ($\Delta H_{vap} = 2.444 \frac{MJ}{kg}$). Higher water content will increase the latent heat of evaporation/pyrolysis considerably and significantly reduce the mass flux of combustibles. This significantly reduces the HRR and the rate of fire spread.

And further, if we look at it the opposite way, the dryer the combustibles, the faster and more intense the combustion and fire development becomes. For dry homes, the fire will develop faster and represent a greater threat to people than a similar start fire when the fuel contains more moisture. The same will apply for dry wildland fuel. Fire behaviour in heathlands is influenced by several factors, such as stand age influencing fuel load, structure and height, the fraction of dead fuel, fuel moisture content and wind speed [34].

Wildfires are also governed by the principal equations (1) and (3). Rather than thermal radiation, it has recently been documented that convective flame heat transfer is the most important near-field fire spread mechanism [26]. The wind is a central factor assisting this heat transfer. As the fire grows, the fire spread may also be assisted and governed by airborne transport of glowing embers and firebrands over very long distances. The drier the wildland fuel, the easier it ignites and the more intensely it burns. When dried beyond a certain level before a fire, the soil may also be involved in the combustion process. Drying of wildland fuel may be quite fast, including in sub-zero temperatures and when dead. The fuel usually dries quickly as no live bark layer limits the drying process [26].

Experience has shown that the topography of the land can have a profound effect on the way in which wildfire will spread, whether as a surface fire (grassland or forest litter) or through scrub or the forest crown. Such fires spread more rapidly if they are travelling uphill than they would on level ground or downhill [33]. When the terrain is complex, wildland fires occasionally propagate without warning at unusual speeds, trapping firefighters and causing multiple fatalities [33].

Wind is one of the factors that is most important in a wildland fire and affects both the combustion and the fire spread rate [9]. Wind affects the development of fire because it:

- Increases the oxygen supply to the fire
- Affects the direction of fire spread
- Dries new fuel, both before and during the fire
- Transports sparks and fly fires further from the main fire
- Leads to preheating of new fuel by pushing heated air further from the fire

Local wind conditions can occur because of local temperature differences and geometry in the terrain [35].

2.2.2 General Fire Spread

A fire can spread between buildings by several mechanisms, which can occur either alone or in combination with each other [35]:

1. Glowing embers
2. Heat radiation
3. Direct flame contact
   a) Flame contact from building in a fire
   b) Flame contact via vegetation

Recent field studies show the tendency of firebrands to ignite many houses during WUI fires, even the ones protected by fuel treatment, and the ability of a burning house to create a large number of firebrands that may propagate a fire in a community, even when the wildland fire no longer impacts it [26].

Glowing embers

Steen-Hansen [35] describe glowing embers as follows ”Hot particles that are transported in the air and fall and ignite combustible materials. Ignition of fire in a place other than the primary fire area, because of a hot enough material with sufficient energy moving from the primary fire”. It has been documented [36] that forest fires can be spread over distances as large as 20 km in glowing embers. This is described after the Black Saturday Kilmore East fire in Victoria, Australia.

A fire in a home will not normally cause a fire to spread through heat radiation over greater distances than 20 m. Ignition of neighbouring buildings in the event of glowing embers can thus occur over significantly greater distances than in the case of heat radiation. It is therefore not sensible to consider distances between buildings as the only method of avoiding the spread of fire via buildings. Rules for choosing materials for exterior cladding and roofs of buildings can reduce the possibilities for such fire spread [35].

Ignition by heat radiation

Ignition by heat radiation can occur at significantly greater distances than the range of flames out of the windows of a building on fire. Estimated heat radiation from a building fire will usually determine the required distance between buildings in densely populated areas. If glowing embers are to be included in the assessment, these distances will be impractically large [35].

Ignition by direct contact with flame

i. Flame contact from building in a fire
   When the temperature of the flue gases in a room where it burns becomes 500-600°C, the heat radiation is so high that the room is a fully developed fire.
ii. Flame contact via vegetation
   Fire in built-up areas can also spread via grass, shrubs and trees between the fire building and the neighbouring building.

The fire spread to buildings via vegetation is also possible in relatively densely populated areas. A fully developed fire in a house can easily spread to the neighbouring house via bushes around the house that is burning, tall grass between the houses and bushes around the neighbouring house.

Spreading via vegetation is particularly relevant in forest and heather fires that threaten buildings. In dense wooden buildings with fire management present, such spread will be easier to prevent. There is a certain risk of rapid-fire spread when it is dry [35].

2.3 Dynamic risk-based emergency management

Dynamic is characterised by constant change, activity or progress. Dynamic risk-based emergency management in this thesis focuses on what risk-based approach the fire brigades already have and possibilities for improved dynamic risk-based emergency management. Increased risk could be when there are periods when it is extremely dry outside and very windy.

Several of the fire brigades are already working in part with dynamic risk-based management, without being aware of the use of the term *dynamic.* An example of this was in 2018 when it was extremely dry and the fire brigade in Oslo (source from private conversation) responded to several rubbish bins and bonfire fires. To avoid this, the fire engine and firefighters drove to parks to inform the population. This is a dynamic approach we want to focus more on. Stationary fire engines that are placed where there are high risk peaks in the municipality are desirable to achieve by means of dynamic risk-based emergency management. Kythira Island in Greece [37], is an example of how this can be achieved.

2.4 Bow tie

Log [3] presents a bow tie for selected parameters influencing fire disaster risk, including examples of risk-mitigating measures focused on in the study. The bow tie diagram in Figure 3 is interesting for presenting factors influencing wooden home fire risk, conflagrations in wooden villages and towns as well as WUI fire risk.

An illustrative bow tie diagram is presented in Figure 3, where the upper half represents fire in a built environment and the lower half represents WUI fires. It also represents a timeline, where the order of magnitude in the time scale is indicated.

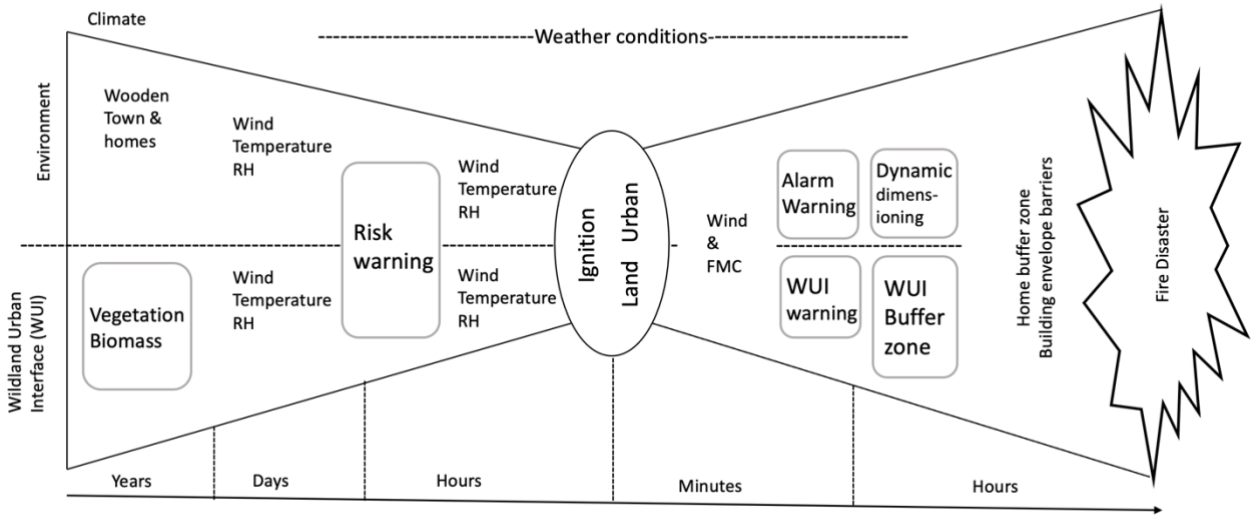

Figure 3: Bow tie diagram for selected parameters influencing fire disaster risk [3].

The likelihood of an ignition source developing sustained burning is highly dependent on the fuel and the fuel moisture content (FMC). The FMC is a function of weather conditions, such as precipitation, temperature, relative humidity (RH) and exposure time. Assuming that an ignition results in sustained burning, subsequent fire development is much faster when dry fuel is involved and the fire spread rate is very dependent on the wind conditions [3].

There may be decades of densification of built environments or succession of heathlands, to the time scale of days and hours for drying of wooden structures and dead wildland fuel, but also biomass. Based on these models, risk maps and alarm warnings for quickly changing temporal risk can likely be developed. Also, education and training in fire disaster risk concepts would be necessary, i.e., education in prescribed burning and dynamic dimensioning of the fire brigades.

2.5 Risk Warning

With the help of funding from the Directorate for Civil Protection and Emergency Planning (DSB), the Norwegian Meteorological Institute has created a new forest fire hazard index for Norway. This method of alert system for forest fire was first used on 29 June 2021 [38]. This index indicates where there may be conditions that allow a forest fire to start and how fast it can spread. The starting point has been the Canadian Fire Weather Index (FWI), which is one of the most widely used internationally. This method is also used in Sweden [39].

The new model considers temperature, humidity, precipitation, wind and snow. When there is no rain, the risk of wildfires increases. If there is wind, the danger increases even more. The wind is also used to

indicate the risk of spreading. There can therefore be large variations in the forest fire danger index from day to day if a windy day replaces a day with little wind [38].

The period where the risk of forest fires has traditionally been greatest is in the spring and the summer. But with snow-free winters, we can have as great a risk of grass and heather fires in winter as in spring. Autumn is usually a wet period, but should there be a prolonged drought, there may be a risk of forest fires at this time of year as well. Just a few days of dry weather after melting snow is sufficient for a great danger of grass and heather fires. We have the same conditions if the winter is snow-free, which in many places will become more and more common in the future [38].

Except for the fire hazard index described above, there is no model for assessing the changes in fire susceptibility of inhabited wooden building settlements through the year. There is an application in progress, this is a predictive fire risk indication model using cloud-based weather data services [40].

A study presented by Stokkenes [40] is to contribute toward reduced conflagration fire risk through dynamic risk assessment and an early warning system. A main contribution of the present paper is to report on the implementation, validation, and further development of the model of Log [3]. The basic idea of the model is to estimate the indoor climate using measured and forecast outdoor climate for computing indoor wooden fuel moisture content and an estimated time to flashover as an indication of fire risk.

Available wildfire danger models are not sufficiently fundamental to handle *Calluna* heath fire risk and no current models predict high-risk conditions in sub-zero temperatures [3]. New, holistic models should be developed for dry fuel contribution to wooden homes fire risk, conflagration risk and degenerated heathland WUI fire risk, including landscape scenarios, under different weather conditions and changing climate. Based on the developed theory, weather recordings and weather forecast, methods for predicting the fuel moisture content in relevant fuel can be developed, for both wooden homes and *Calluna* dominated heathland under different land-use regimes.

3. Methods

3.1 Introduction

The main issue described in this paper is to study measures in place for the Fire and rescue service to prevent WUI fire disasters and how they can improve their dynamic risk-based emergency management. The fire personnel´s own experience is investigated through qualitative interviews.

3.2 Research method

A research method can be described as: "*Procedures and techniques for answering scientific questions and issues*" [41]. According to Lund and Haugen [42], qualitative research provides an opportunity to gain a deeper insight and understanding of the phenomenon.

Figure 4 provides a representation of how the qualitative research process can be visualised [43]. Nevertheless, the qualitative research process is entangled and complex. Therefore, the outlined steps may be altered continually throughout the research period.

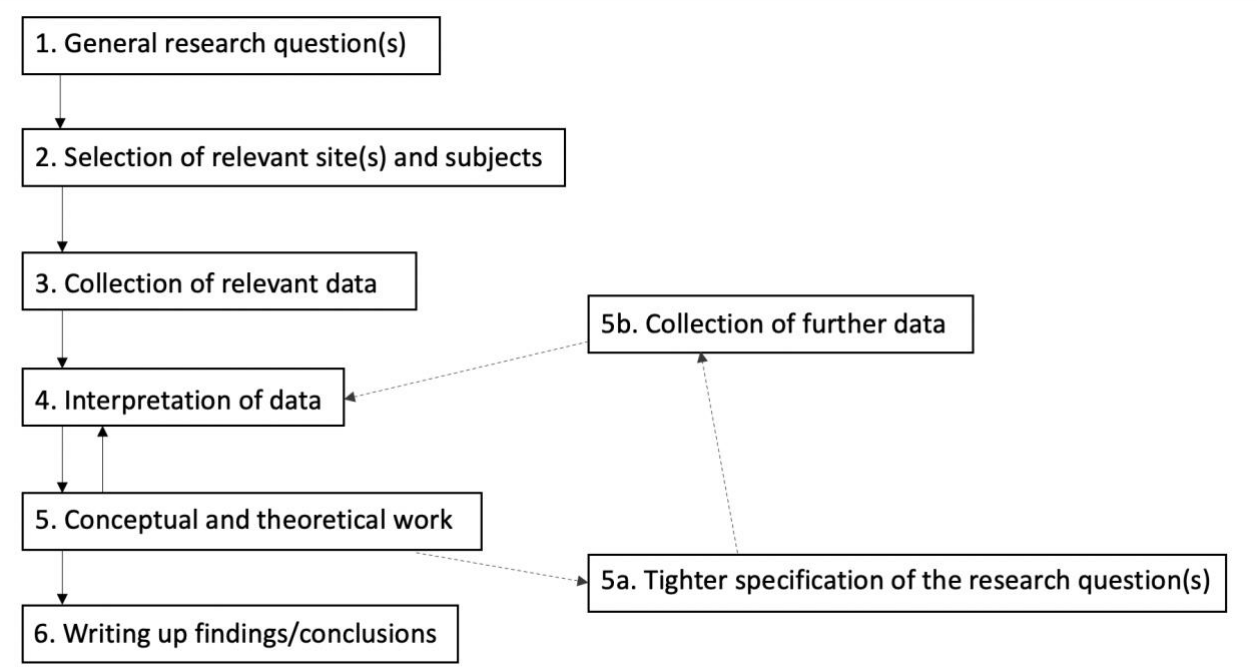

Figure 4: An outline of the main steps of qualitative research [43].

In qualitative methods, we are less concerned with causation and more concerned with understanding or describing how we humans perceive the world and which relationships mean something to us. The methods provide a different insight into life than researchers can gain from large, quantitative studies. We use qualitative methods to express ourselves specifically about social patterns within a limited area. Therefore, researchers conduct interviews or just observe people in everyday life [44].

Qualitative interviews are the most used way to collect your data. It is a flexible method that can be used almost anywhere and makes it possible to get comprehensive and detailed descriptions of what we study. Most informants will probably feel comfortable in an interview, provided the topic is not sensitive [44].

3.3 Case Study (the research method)

In this thesis, a qualitative method will be used to investigate how the fire brigades work risk-based and how they are organised under dynamic risk-based emergency management. The reason for this is that the thesis seeks in-depth knowledge of a topic, as well as information that is not possible to quantify, in the form of attitudes, thoughts and measures within the fire brigades in Norway.

The author of the thesis has a background in the fire brigade. Experience of 4 years in the preventive department as a fire engineer in Norway´s largest fire brigade, Oslo Fire- and rescue service. With the same background as those interviewed, there is a greater probability of the same understanding and that the informants find credibility in answering questions.

3.4 Interview

The interview is probably the most widely employed method in qualitative research. The flexibility, in terms of the time and resources, of the interview is what makes it so attractive [43].

The interview structure is linked to the division of roles between the participants. The interviewer asks questions and follows up on answers from the informant. The purpose is often to understand or describe something. Interviews are often more of a dialogue than pure questions and answers. Registrations of respondents´ informants constitute data or empirical data. As a rule, interviews are recorded on audiotape, digital Dictaphone, mobile or via Teams and then printed. In addition, the interviewer often takes notes during the interviews [44].

There are several types of interviews associated with qualitative research. The interview in this study is based on a prepared semi-structured interview guide, attached as appendix II. Kvale [45] points out seven stages of an interview. Kvale further points out that by building up the interviews in this way, the researcher will have a more structured and systematic research process. The seven points show the interview process from the idea stage to the finished report/paper. These are the seven points my interviews are built on. The writer have chosen to use Kvale´s method because of its systematics and it is a well-known and recognised method. Kvale describes them as follows:

i. Thematisation.

Before starting the interview, it is important to have a clear idea of the purpose of the interview. Then, to find out how the researcher perceives the topic. This can be done by using various what and how questions. Once you have found out how you perceive the topic, you can choose one or more methods.

For my thesis, the purpose appears in the problem: "How can the fire brigades improve their dynamic risk-based emergency management?". As mentioned earlier, the method in this thesis is qualitative. The choice was a qualitative method because it was best suited to get an answer to the problem statement. A qualitative method focuses on ongoing in-depth.

ii. Planning.

Kvale [45] points out that the planning part is important for one to have the opportunity to gather relevant and important knowledge about the problem. In this way, one avoids asking the informants questions that have no significance for the survey. One can therefore keep the focus on the subject in a better way. In the planning stage, one can also look at the moral aspects of the study and evaluate them.

Concerning my study, in the planning phase, the writer spent time finding relevant literature, laws and regulations for the fire brigades and picking out what I wanted to include. After I had decided which theories I would use, they were written down in a separate theory chapter. Based on this theoretical part, an interview guide (Appendix II) was developed. This was made with a background in the theory part and the questions were developed to be in line with the theme of my problem statement.

iii. Interview.

Kvale [45] emphasises that it is important to think about the knowledge one seeks with the interpersonal relationships that arise when conducting an interview. The interviews were conducted with the interview guide as a template. The interviews of the fire brigades were conducted in December 2021 and January 2022.

Before a survey can be conducted, the informants must have consent to participate. This was done by an information letter being approved by the Norwegian Centre for Research Data (NSD), see Appendix I. The informants then received information about the master and had the opportunity to agree or not. The various informants were recruited in the period between December 2021 and January 2022. The seven interviews varied in length. Since the same basic interview guide was used in connection with all interviews, the variation in length can be explained by different experiences in the fire service, the use of examples along the way and any digressions during the conversation.

Before the interviews began, all the informants were asked for permission to make an audio recording of the interview. The recordings were made on Teams and stored locally and transcribed. The reason for using audio recordings was to ensure the best possible basis for analysis in the interpretation of the data material.

iv. Transcription.

In this phase, the researcher prepares the material that was obtained, through an interview, for further analysis. Transcription is usually when you turn oral speech into written text. For example, it is common to record the interviews on tape so as to have the opportunity to return to listening to the interview again. It is difficult to remember everything that is said.

The interviews were transcribed shortly after they were conducted. In this way, they were still fresh in memory. In addition, I could better be able to put the interview behind me and give full focus on the next interview.

v. Analysis.

In this phase, the focus is on analysing the empirical findings. Before the analysis itself, one must find out which analysis method one will use. This is determined based on the study´s purpose, subject area and interview material.

In my thesis, the empirical findings will be discussed regarding the problem and theory that have been presented in the theory part.

vi. Verification.

The main focus of this section is the empirical findings and we then look at generalisability, reliability and validity.

The case study can identify conditions that may be common to other fire and rescue services that are organised in the same way as in Norway. During the discussion chapter, it will be discussed in more detail whether the finding can be generalised. When it comes to reliability and validity, the focus here is on how credible the study is, in addition to looking at whether the issue is highlighted in the study. The reliability and validity of this study will be discussed in section 3.10.

vii. Reporting.

Kvale [45] points out that the findings and the use of methods are disseminated through the reporting. Furthermore, he emphasises that the reporting must be disseminated in a form that complies with scientific criteria. In addition, the findings must be presented in a readable product. It is also important that one thinks about and takes into account the ethical aspects of the study.

For this task, ethics have been considered by signing the NSD consent form (Appendix III). The purpose of the study is presented. The informants have also been informed that they can withdraw at any time along the way, without justification, if they no longer wish to be part of this study. All data collected is also anonymised.

By using Kvale´s seven points, we get a better look at the whole interview process and it will also give us a neat and structured overview of the entire process. Kvale [45] also points out that these seven points must not only be seen separately but also entirely. There is an important interplay between all these seven phases.

3.5 Sampling

Thagaard [46] defines a sample as the groups the researcher uses to obtain information in their research. Furthermore, Thagaard points out that the sample in qualitative interviews should be relatively small. In other words, the number of informants should not be more than permits in-depth analyses of the data that is collected. One of the main goals of a qualitative method is to go in depth but if using an oversized sample this can be challenging.

Furthermore, the sample in a qualitative study describe strategically. That is, the informants are selected based on characteristics or qualifications that prove to be appropriate to the problem [46].

In this thesis, seven informants from different fire brigades (Appendix IV) were selected. According to the subject in the thesis, all fire brigades are selected based on size and location. This is strategically about obtaining the most relevant answers in the thesis. In this way, both large and small fire brigades and their experience are represented in the sample.

3.6 The Semi-structured interview guide

A semi-structured interview is where the researcher has a list of questions or specific topics to be covered, often referred to as an interview guide, but the interviewee has a great deal of leeway in how to reply. Questions may not be asked exactly in the way outlined on the schedule. Questions that are not included in the guide may be asked as the interviewer picks up on interviewees´ replies. But, by and large, all the questions will be asked, and a similar wording will be used from interviewee to interviewee [43].

It was chosen to use a semi-structured interview guide (Appendix II). In this way, relevant questions about the problem can be asked. In addition, the writer has little experience of interviews and the help of this interview guide supported the writer throughout the interview.

3.7 Data collection

Before starting the data collection, identify the research questions reasonably clearly. Develop your data-collection instruments with these research questions at the forefront of your thinking. If this is not done, there is a risk that the results will not be allowed to illuminate the research questions. Thinking about access and sampling issues must also be done if the research gains access to or the cooperation of one or more closed settings such as an organisation. A confirmation needs to be approved at the earliest opportunity of the necessary permission to conduct the work. There is also a need to consider how to gain access to people. These issues lead to sampling considerations, such as the following [43].

- Why does the writer need to study to investigate the research questions?
- How easily can the writer gain access to a sampling frame?
- What kind of sampling strategy will the writer employ (for example, probability sampling, quota sampling, theoretical sampling, convenience sampling)?
- Can the writer justify the choice of sampling method?

While preparing for the data collection, the writer should consider whether there are any ethical problems associated with the research methods or the approach to contacting people [43].

The approach of contacting people in this research is done first by a phone call. Then the writer had a chance to talk to them and hopefully the person will easily say yes to an interview. Further, the writer sent each person an e-mail after the phone call, so they had a chance to read about the master thesis and learn what they are saying yes to.

Initially in the interviews, several of the informants were asked to tell their professional background and what position they have today. Before the interviews, they were sent the questions so that they could be a little prepared.

3.8 Data processing

Kvale [45] points out that in qualitative studies it is common to use a recorder when conducting interviews; in this way one can focus on the topic and the dynamics of the interview. Furthermore, it is emphasised that it is important to keep in mind that the data you transcribe is not tangible but the artificial construction of oral speech into written text. This means that the interview may contain important information that does not come down on paper. Such as body language and what is said "between the lines". It is important that a researcher is aware of this and has it in mind during this process. Written text is nevertheless better suited for analysis.

When a researcher interprets and analyses the data material that is a product of interviews, a researcher must be aware that the informant's and the interviewer's attitudes, values and understanding will influence the result. The informant will answer the various questions he or she receives based on his or her attitudes and values. In addition, the researcher will interpret and analyse the answers based on their attitudes and values. It is important that the researcher is aware of this and thinks about it when interpretation and analysis work begins. As a researcher, one must also consider that the informant answers what he or she thinks the interviewer wants to hear. In this way, the informant may not respond based on their attitudes and values.

3.9 Ethical assessments

Thagaard [46] emphasises the importance of a researcher having to think about the ethical aspects when researching. The Personal Data Act was introduced in 2001. Since then, all projects that contain sensitive information that is processed with electronic aids must report. This notification obligation is made to the Norwegian Centre for Research Data (NSD). In addition, there are three main ethical points to keep in mind when researching.

“Informed consent, confidentiality and consequences of participating in the research project”.

NSD is a national centre and archive for research data. It facilitates the sharing and reuse of data on people and society. It provides advice on handling data and privacy in research and archives data in line with international standards. In this master thesis, the data collection is done by interviewing people in fire brigades through Teams.

Informed consent

Thagaard [46] points out that each research project must start with the participant´s informed consent. Research projects that depend on people participating actively should only start if the researcher has the participant´s informed and free consent. When applying via the Norwegian Centre for Research Data, participants have the right to withdraw if and whenever they want to. These ethical guidelines have been drawn up with a view to individuals’ right to control their own lives. They must have control over the information they share about themselves, which in turn is shared with others. In addition, the people who

participate in a research project have the right to know the purpose of the project and the main features of the project.

In this study, the informants were first contacted by telephone and asked if they could participate in an interview. An e-mail was then sent to the person in question. An inquiry was attached to this request, which contained a description of the project´s purpose. In addition, a letter of informed consent was attached. Before the actual interview was started, the informants were reminded of consent and a statement of consent was confirmed during each recording (see Appendix III). Before the interview was started, the informants were reminded of what was in the information letter and that they could withdraw from the project if they wanted.

Confidentiality

According to NSD, confidentiality means that the people who participate in a research project have a right to the information they contribute being treated confidentially. The researcher must be responsible for the information that emerges. The information should not harm the people who contribute to the research project. In other words, the researcher is responsible for ensuring that the informant´s identity is kept secret [43].

Confidentiality also means that the information coming from the informant must not be publicly available. This means that other people will not have access to the collected material [43].

Regarding this thesis, the interview guide did not ask questions that required the informants to provide personal information. The material developed based on the interviews was treated confidentially. It was my supervisor and me, as well as two researchers in the DYNAMIC project, who had access to the material. At the end of the project, all recordings were deleted. In addition, the informants were anonymised in the report, so that any readers could not recognise people. The informants were informed of this.

Consequence of participation

A distinction that has attracted interest in recent years is between deontological and consequentialist ethics. Deontological ethics consider certain acts as wrong (or good) in and of themselves. Consequentialist ethics looks at the consequence of an act for guidance as to whether it is right or wrong [43].

Thagaard [46], highlights the consequences of participating in research projects when it comes to the researcher's ethical responsibility. This means that those who participate in the research project should not be exposed to an increased risk of physical or mental injury or strain as a consequence of participation. The researcher must act based on fundamental respect for human dignity. In addition, the researcher must think about any consequences the study may have for the informants who participate in the study. The researcher is also responsible for ensuring that the integrity of the informants is protected, in addition to the research not having negative consequences.

Bryman [43] explains that a researcher is better able to make constructive and reflective decisions both at the planning stage and along the way if they are aware of and consciously think about the ethical

challenges. In addition, it is important to focus on ethics throughout the seven points of the interview, as mentioned in subchapter 3.4 Interview.

Both Bryman [43] and Thagaard [46] point out how important it is to focus on ethics throughout the research process. It is not only in special situations that one must focus on ethics. If a researcher knows of this, there is a greater chance that ethical principles are followed throughout the research process. A researcher needs to know ethical principles.

3.10 Reliability, replication and validity

Bryman [43] noted that reliability and validity are important criteria in establishing and assessing the quality of quantitative research. However, there has been some discussion among qualitative researchers concerning the relevance of these criteria for qualitative research. Moreover, even writers who do take the view that the criteria are relevant have considered the possibility that the meanings of the terms need to be altered.

Reliability

Reliability is concerned with the question of whether the results of a study are repeatable. The term is commonly used to the question of whether the measures that are devised for concepts in the social sciences (such as poverty, racial prejudice, relationship quality, religious orthodoxy) are consistent [43].

A weakness about the reliability might be that several of the interviews were conducted and the material analysed only by the writer. Reliability may have been strengthened if we were two researchers during the interview. Due to time constraints and the scope of the assignment, it was difficult to get two researchers for each interview.

Replication

The idea of reliability is very close to another criterion of research: replication and more especially replicability. Sometimes researchers choose to replicate the findings of others. There are various reasons for doing so, such as a feeling that the original results do not match other existing evidence. For replication to take place, a study must be capable of replication - it must be *replicable.* This is an obvious point: if researchers do not spell out their procedures, replication is impossible [43].

Validity

A further and in many ways the most important quality criterion is validity. Validity is concerned with the integrity of the conclusions that are generated from a piece of research. It is important to be aware of the main facets of validity that are typically distinguished [43]:

- Measurement validity: relates primarily to quantitative research and the search for measurements of social science concepts. It is to do with the question of whether a measurement that is devised for a concept does reflect the concept that it is supposed to be denoting.
- Internal validity: relates mainly to the issue of causality. Internal validity is concerned with the question of whether a conclusion that incorporates a causal relationship between two or more variables holds water.

- External validity: is concerned with the question of whether the results of a study can be generalised beyond the specific research context.
- Ecological validity: is concerned with the question of whether social scientific findings apply to people´s everyday, natural social settings.
- Inferential validity: An issue that is sometimes neglected is whether the authors of a report of research produce inferences and draw conclusions that are warranted by their research and the findings generated from it. This consideration is often bound up with the question of the connection between the research design used and the interpretation of the findings generated from it.

Concerning my study, the interviews were conducted systematically. In advance, the writer have created a relatively structured interview guide, where the concepts are taken from renowned theorists. All the interviews have been conducted with the same framework. The study has a reasonably large scope. The transcribed interviews make up 43 pages of material. This material is based on seven interviews, in which everyone represents their fire brigade (Appendix IV) in different parts of Norway.

Internal validity is based on the degree to which one can draw causal conclusions in the study. To ensure internal validity within qualitative research, the informants can be asked questions about causation. In my study, I have not asked questions about causation, so I cannot explain the internal validity. External validity is based on the extent to which one can generalise the findings. Within qualitative research, one is not so concerned with finding generally valid rules, but with finding which areas one can benefit from the knowledge. The focus is on the fact that each situation and phenomenon has its structure and inner logic.

Concerning this study, the results cannot be generalised. Nevertheless, the results and knowledge that emerge from this study will be useful for other fire brigades that come across similar incidents. The thesis aims to analyse the current situation regarding dynamic risk-based emergency management and dimensioning in selected fire brigades, with emphasis on infrequent fire incidents that may have very severe outcomes for the affected community. Based on the research method it will only give an insight into how exactly these fire brigades think and handle the incidents they have had in their municipalities. This will tend to weaken the study's reliability. On the other hand, this method will be an important tool for handling the problem, which I think will strengthen the validity of the thesis.

4. Results and analysis

Dynamic risk-based emergency management is important for the fire brigade to be able to handle an incident as early as possible and be prepared if a major incident might occur. Dynamic emergency management may be adopted in relation to notified dangers, i.e., warning systems and experience of catastrophic events. The faster the firefighters get involved in active firefighting, the better the outcome of their efforts will be. In this chapter, the results from the data collection will be presented. Each subchapter will begin with a presentation of the significance of the research question, before continuing with the results of the interviews.

4.1 Risk-based dimensioning

During the interviews, it was observed that several had different understandings of the questions that were asked from the interview guide. Especially on one question: How is risk-based management perceived in the fire and rescue service?

One informant answered: "*Those who work full time and emergency personnel take it for granted that they are risk-based and that they are linked to risk-based dimensioning*".

Another informant answered: "*A little difficult. Dimensioning of the fire brigades is based on municipal finances. The willingness to put in a little extra based on when there is a higher risk in the municipality is not as high everywhere*".

The answers to the question are different and the understanding of the concept of risk-based dimensioning is different. The reason for this may be that the definitions are unclear, at the same time the concept of risk-based dimensioning is described in the legislation. As well as how the fire brigades should be dimensioned. At the same time, it is seen that the understanding of an expanded emergency preparedness is present, but that the economy in the municipality makes it difficult. The understanding of the dimensioning of the fire brigades is part of the dynamic risk-based emergency management.

To improve dynamic risk-based emergency management it is important that the fire brigades understand the risk of better handling of situations that may arise. During the fires in Lærdal, Flatanger and Frøya, the task force was taken care of by both the fire brigade and the police. According to DSB´s [16] evaluation report, there were several examples of being unclear who led the effort. This is unfortunate and can lead to misunderstandings and delays during action. As mentioned before, the relationship between fire brigade response time and the outcome of fires is important. It is therefore important to understand how the fire brigades prepare risk-based emergency management, and how to improve this.

One fire brigade describes the following: "*Establishes risk-based emergency management from risk and vulnerability analyses. To ensure good enough preparedness for the challenges the fire brigade has. Contingency analyses come as a natural part of this job. Collaborates with another municipality. The fire chief is responsible for the municipalities in their fire brigade. They work to obtain analyses that cover these municipalities*".

Then, another fire brigade describes emergency management as follows; "*The emergency management is based on numerous factors. A contingency analysis that describes the contingency we have and want, including the laws and regulations (revised every fourth year). Changes should be made to better handle*

major incidents, as well as avoid these. But also changes and understanding in advance of renewed risk. What happens daily and factors or incidents that lead to strengthening preparedness beyond basic preparedness, the fire brigade changes the dimensioning, i.e., wildfire index, increased risk of wildfires, extreme weather. Risk-based emergency management is based on two things, one is a system for the long-term and the second is more acute".

There are several understandings of this, and another fire brigade says, "*The basis for how they organise and prioritise measures in emergency preparedness is risk and vulnerability analysis, preventive analysis and contingency management analyses. Contingency analysis is the main analysis that gives a better understanding of how they should work. The risk and vulnerability analysis will reveal the challenges they face in their district. The district consists of several municipalities and covers a large area.*

The risk and vulnerability analysis identifies a lot of measures, risks and prevention of major incidents. Based on the dimensioning regulations and the normative requirements, the municipality should be aware of the vulnerabilities the municipality is facing. The risk and vulnerability talk about vegetation/heather fires and dry wooden structures. The preventive department has the most important measures to prevent incidents.

Evaluations of accidents and fire investigations after major incidents are being executed. Statistics and research are also essential to understanding risk-based preparedness. All the analysis forms the basis for a plan in the municipality. The planning goes more in detail on how to handle and prevent incidents".

Every fire brigade from the interview described that it has a risk and vulnerability analysis and contingency analysis. There was great variation in how often the risk and vulnerability analysis and contingency analyses were updated, but also how often the fire brigades used it daily. But there is a big difference in how often they revise or upgrade it. The smaller fire brigades do not upgrade it as often as the bigger fire brigades. This is mainly because small fire brigades often have a fire chief who does most of the tasks. It is expected that the analyses will be updated, but it will be difficult for the small fire brigades to update the analyses because of the staff is smaller.

This is a challenge for the smaller municipalities and their fire brigade, because they cannot evaluate incidents to the same extent as the larger ones. This is probably mainly because they do not have a large enough staff, or one person has too much responsibility.

An important point mentioned by a small fire brigade during the interview is that you must focus on the risk using the available resources and prioritise correctly.

In the guide to regulations on organisation, staffing and equipment of fire and rescue services and the emergency call centres [25], it is described that DSB experienced great variation in the quality of the risk and vulnerability analysis, and it was difficult to see the connection between risk, vulnerability and chosen dimensioning.

The guide to a comprehensive risk and vulnerability assessment in the municipality [24] states that it may be relevant to limit the number of unwanted incidents that are included in the risk and vulnerability analysis. There are several challenges here. In the interviews, it emerges that the risk and vulnerability

analysis has been made for both the contingency department and the fire prevention department. Both departments have different needs. The contingency department is interested in how the emergency resources are dimensioned and what challenges the firefighting entails so that one is well prepared to handle a fire once it has occurred, while the fire prevention department is interested in uncovering where the risk of fire is greatest.

Pedersen and Roaldsø [47] describe that if both departments are to be able to benefit from the risk and vulnerability analysis, a compromise must be reached in the content of the analysis, which weakens the use value for both departments. The contingency department´s need for dimensioning and preparation in relation to accidents and major fires must be described in a good enough way for the fire brigade to be able to improve their dynamic risk-based emergency management.

4.2 Risk understanding

The interview from the fire brigades shows that reducing the biomass in unmanaged heathlands, especially in the WUI zone but also close to buildings near the woods, is something we should focus on to control the risk.

During the interviews, two fire brigades pointed out that a resource that emergency services want to make more use of is preventive personnel and the sweeper. These can help distribute food and drink to personnel in action during a forest fire. The sweeper often visits people and talks a lot with the population; one measure the sweeper could assist with then is informing and checking biomass around homes.

One of the questions the informants were asked was: "*What understanding of risk peaks do you have in general*?". The questions ask both about disaster fires in nature and wooden structure towns.

One of the informants clarifies that risk understanding is based on three factors:

1. Drought in the soil
2. Forest and topography
3. Wind, humidity and air temperature.

The fire brigades have become better at assessing potential much earlier than before. The informant also describes the importance of understanding the potential for a large fire. The importance of understanding the difference between a fire uphill and downhill in a forest helps to determine how fast the fire spreads and behaves in the terrain. And at least most of the time the buildings and forests ignite easily when there is warmer air.

New, holistic models should be developed for dry fuel contribution to wooden homes fire risk, conflagration risk and degenerated heathland WUI fire risk. This should also include landscape scenarios, under different weather conditions and changing climate.

Another informant says: "*The understanding is there, but more challenges with the opportunities to do what they want. Economy and access to resources. Fully aware of the risk and what needs to be done to reduce it. Create an action space to create opportunities within the framework they have. It does not help to have a sense of risk if you do not have the opportunity to do something about it. Work on this as of*

today. For smaller fire brigades, it is difficult to get what they want because the municipalities may not understand the need, but this means that the fire brigade do not get to achieve all the tasks they want".

There is a difference in the understanding of different fire brigades in Norway and the personnel can see a difference between large and small municipalities. But also, if they have experienced a big WUI fire or fire in wooden structures.

One of the larger fire brigades describes the risk of understanding "*Temperature, wind. The first measures they take when there is increased wind and gather two stations at once. How fast the fire escalates depends on the wind. But then comes temperature and drought. If you put all these three factors together, there will be even more measures. What he sometimes misses is the opportunity to deploy more people. Maybe a couple of days a year where the risk hangs over us. And be out early. The state takes several measures to help the fire brigade, fire helicopters are made available. Very good. The threshold is low to call them out. Some measures are being taken. Slightly different on dense wooden houses and heather, but they both must react quickly. You need a little different equipment. Access to water, crews and miscellaneous. Out in the terrain, you must work more tactically. Wind, water and topography.*

Some differences here, considering the risk you have. But also looking at what kind of biomass which are present".

Many of the fire brigades use the risk assessments and one of the informants describes: "*The fire brigades take continuous risk assessments where the danger is greatest. Feel that they have a good understanding of risk in advance. As well as this with the season and weather situation. Ongoing risk assessment. Background adjustment with this weather, wind.*

The same goes for ice and ice protection, preventing drowning. Mapping everything of risk is the same type of understanding and mapping of this. The fire service is called out for all types of incidents, should know a lot about fire preventing, WUI fire, understanding risk, health assignments and much more".

Several of the fire brigades describe that they understand risk, but what does not appear is how they adjust their preparedness according to the risk they have mapped. The importance of understanding the risk must be seen in the context of how the fire brigade can improve dynamic risk-based emergency management.

When the risk is known and understood, risk-reducing measures can be identified and prioritised to initiate or control the risk. The interviews from the fire brigades show that reducing the biomass in unmanaged heathlands, especially in the WUI zone but also close to buildings near the woods, is something we should focus on to control the risk. Prescribed burning is something a few municipalities or fire brigades have focused on, but several fire brigades do not focus on this nowadays. Several fire brigades are positive on controlled prescribed burning, but they need education and training.

4.3 Fires in Lærdal, Flatanger and Frøya

Based on the laws, the writer understands that the fire brigades will evaluate fires for the purpose of learning and improving the preventive work. Have the fire brigades interviewed in this thesis improved

the preventive work after the fires in Lærdal, Flatanger, Frøya, and Sokndal? What have the fire brigades done after incidents to improve preventive work and emergency preparedness?

When asked if there have been improvements after the fires in Lærdal, Flatanger, and Frøya, the various fire brigades say:

"*The organisation must be in place, it is a success factor that they take with them further and especially in exercises. It involves organisation from the emergency manager to the crew and the task leader. We work in a different way. The more events, the more experience they get. Experience makes you better and you become better at handling new incidents*".

"*Yes, there have been improvements. This applies, among other things, to previous helicopter support and much more aware of this with temperature and drought regardless of the season. The Lærdal fire was a surprise. You gradually see with information and awareness-raising, the level of knowledge has become much better. The experiences from these fires have made the fire brigades more aware*".

A fire service also describes that it is much easier to get a helicopter on standby. This is also described in [14]. The informant also points out the importance of knowing about the consequences, so the fire brigade knows how to prevent a fire from getting bigger.

Raising awareness about the fires in Lærdal, Frøya, and Flatanger has led to an improved level of knowledge. Increased focus on courses and competence has also been highlighted as learning. It becomes more important to have the flexibility for increased preparedness in the fire brigades because the risk varies greatly. The fires in Lærdal, Flatanger, Sotra, and Frøya show that major WUI fires and grass and heather fires occur in Norway. It is therefore important to understand the parameters that cause these to occur, to start an effort early. WUI fires are demanding and take a long time to put out, it is important to dispose the firefighters in the best way. The fact that the fire brigade understands and begins to work with dynamic risk-based emergency management can lead to a more effective way of both preventing and avoiding major incidents if an incident occurs. Together with other methods to prevent, such as heather burning, as well as looking to the future and current challenges, this can lead to other ways to work to avoid disaster fires.

An informant says that in general, everyone should be better at learning from incidents. Extensive work is done to evaluate and investigate incidents, but the results are not used well enough to adjust the fire brigade as one might wish. It is known that when it is dry and windy, you must prevent the incidents from becoming large. You do not have a budget to have everything available, but a balancing act for how each fire service should be able to handle incidents in the best possible way. In both prevention and dimensioning of preparedness, one must be aware of the conditions that affect the risk. The fire brigades must have an overview of the risk in their areas, but there are differences between the municipalities and various factors that influence them.

It emerges in the interviews that there have been great lessons learned after the events in Lærdal, Flatanger, and Frøya. A good organisation and management is a success factor. The incidents have also taught the fire brigades the importance of good leadership and that you get the opportunity to practise

incidents. The more events, the more experience they get. Experience makes you better and you can handle the events in a better way.

4.4 Dynamic risk-based emergency management

For the fire brigade to work in a dynamic risk-based emergency management, it is important that the fire brigade understands the term and how to accomplish a dynamic risk-based approach. At the same time, this must be described in their analysis, as the dimensioning is based on risk and vulnerability analysis, but also the contingency analysis.

Two of the fire brigades describe, among other things: "*The basis for how they organise and prioritise measures in emergency preparedness is risk and vulnerability analyses, preventive analysis and contingency analysis. These are the main analyses that will provide a better understanding of how to work. The risk and vulnerability analysis will identify the challenges they face in their district, as well as identify a good number of measures and risks..*"

Further, another fire brigade describes: "*Basing the emergency preparedness on several things, but mainly a contingency analysis that describes the emergency preparedness the fire brigade should have and the risk they have, as well as what is based on law and regulations. Shall change the emergency preparedness if new risks arise*".

Section 9, Contingency analysis [2] describes that the emergency preparedness analysis shall identify and assess which resources, such as equipment, personnel and competence, are necessary to handle dimensioning events. This is the only part of risk-based dimensioning of the fire brigade mentioned in the regulation. It is quite broadly described and it places the responsibility on each fire brigade because it must be included in the contingency analysis. The results from the interview show that the fire brigade has an understanding of how a contingency analysis and risk and vulnerability analysis should be described and used, but on an overall level. The understanding of dynamic risk-based emergency management is understood by the Norwegian fire brigade, but the legislation and municipalities make it hard to accomplish risk-based emergency management.

From the interviews, this subject of dynamic risk-based emergency management is very wide and the understanding is different and sometimes missing. It is also hard to get common knowledge to do anything about it, but the most difficult issue is the municipal finances.

One of the fire brigades points out the parallel from the incidents in Lærdal, Flatanger and Frøya with the Froland fire when it comes to changes after incidents; *"The fire in Froland (the largest forest fire in Norway since World War II) back in 2008, changed a lot in Norway. Everyone knew about the risk, everyone knew that the fire would occur. It had to happen before you could start and strengthen the municipalities with extra funding and forest fire equipment before they started to strengthen the civil defence. Also before our directorate started to establish national leadership support schemes, helicopter support scheme, everything this based on the fire in Froland in 2008.*

Gjerdrum is also an example of this describing risk in the analysis and USAR (urban search and rescue). Those who manage the economy in the municipality set the framework based on the economy and the analysis is not entirely correct. And leads to becoming difficult to work according to the risk described in

contingency analysis, when you do not have the opportunity to possibly deploy more people because the municipality says there is no finance for it. Then it becomes difficult for the fire brigade to work risk-based".

The fire brigades already capture data and information to support the core functions of their organisations, such as operations, fire safety, emergency planning, fire investigations, health and safety, incident debriefs and reports etc. Fire brigades vary in the extent of the data collected and held and the policies and processes related to the use, storage and dissemination of this data and information. However, data and information may be stored in isolation and the consequent data integration issues may affect efficient operational pre-planning and incident management.

From the interview, it seems that updating the legislation is different in relation to how the fire brigade has the opportunity to update their analyses, including both risk and vulnerability analysis and contingency analysis. This often makes it difficult for the fire brigade to update the analyses with today´s risk.

"*Has a risk-based dimensioning. Own risk assessments and fire regulations, which describe the dimensioning and organisation come from 1997, which is 25 years ago. So, it's starting to get a little out of date. Still work risk-based the way they work, as well as the management documents/regulations/legislation the fire brigades have to deal with. Bring to the administration the importance of the funds they want to get through. Risk planning and various small municipalities stop it by finances. Our fire department delivers a proposal to the municipal council to show the resources (equipment and crew) they need; it is not certain that the administration/municipality understands the need. So, it is a great challenge to live up to the wishes based on the framework they receive".*

Another fire brigade with quite high staffing describes: "*Has a fire system, which is the same all year round. No tops or bottoms. The minimum staffing is quite high. Could of course imagine more the times there are risk peaks. Greatest risk about weather and wind. Maybe had more people out early and observed, like with the old forest fire tower at night*".

From the interviews, the fire brigades in Norway are a bit sceptical about how to improve dynamic risk-based emergency management, because of the "money bag" in the municipality. Another informant describes it as follows: "*Given periods when it is very dry, he could have imagined having more crews on duty than today. But sceptical of an opening for it. The crews probably see the value of this, but those with the "money bag" are probably more sceptical. Do not see the same as the fire department and has other priorities. Of course, one could have imagined having larger staffing in certain periods. Can refer to the Lærdal fire when you have had extreme events. Refer to experiences. Develop collaboration agreements, so that you can quickly gather crews. Dialogue with the population.*

Unfortunately, the fire brigades in Norway are very event-driven.

Must be good at showing the need in analyses and plans. How vulnerable we are, and when it should be taken up in the municipal council. View the consequences and events. Refer to previous events and refer to things that are happening".

There is a difference between small and big fire brigades; "*A little more demanding for those who are not full-time firefighters. Because when the fire chief puts someone on guard, it is the minimum. They also have*

other stations. If it gets big, it requires so much. One is completely dependent on assistance from other stations. Puts many on duty to get started with the first effort".

Comparing to a larger fire brigade, which described; *"In periods of increased risk, there is a staffing of security forces. Heavy rainfall or extreme drought. Proximity to resources here. Although it is not necessary to staff, they inform employees that they should be available if something is to happen in a short time. Happens via SMS notification from the 110-alarm centre".*

A challenge for risk management in the Norwegian municipalities is that they are not adjusted to highly dynamic variation in the risk picture along with temporal (weather) and spatial (WUI) dimensions. Firefighters generally do not consider dynamic risk variations during their training or within their daily work routines. This depends on the size of the fire brigade and what types of risks there are in their municipality. The importance of information flow in the transfer of experience must not be underestimated. Information between the fire brigades does not guarantee learning, but it increases the potential and must be highlighted as a clear prerequisite. The information should be filtered: valuable information for some may be perceived as unnecessary for others.

From the interviews it emerged that there is not good enough cooperation between the fire brigades, there is a lack of training and exchange of experience. This is something that needs to be improved to improve the dynamic risk-based emergency management. An important point mentioned by one of the larger fire brigades was that if we are to start thinking new, we must think risk-based on the basis of the factors air temperature and humidity, as this has a great significance for the spread potential of a fire.

The regulations [2] state that changes in risk must be described but there is no arrangement to do this in the smaller fire brigades. An important parameter is that the smaller fire brigades are aware of the risk they have, but they cannot clarify this in their analyses because they do not have the capacity.

A measure that can be implemented in the fire brigade to improve dynamic risk-based emergency management is the mapping of existing heather areas. This will be most relevant for the fire brigades that have heather, but the same mapping may be executed for forests and land. The municipalities and the fire service must cooperate and pass on knowledge to those who have the same problems. It is important that the fire brigades learn from each other and share the knowledge across the organisations.

An important parameter is to inform residents. As vegetation is constantly increasing, climate change and the risk of forest fires are increasing, it is important to inform about what measures everyone can take. Information and taking precautions were important principles, along with fire brigades, to avoid disaster fires.

To be able to improve dynamic risk-based emergency management in the fire brigades, the fire brigades must describe and reveal a risk in their analyses. At the same time, the municipalities must enter into agreements for cooperation. This is also described in the Fire and Rescue Services Regulation [2] section 5. It is also important that the municipalities are aware of the risks the neighbouring municipalities have, so the cooperation works well. The exchange of experience and information flow between the municipalities and the fire brigades is an important parameter.

4.5 Economy barriers and showstoppers

To improve dynamic risk-based emergency management of the fire brigades it is important to identify any showstoppers, then look at the possibilities, also look at the background for why and how they achieve it or not.

An answer from one of the larger fire brigades when asked the question of how risk-based management of the fire brigades is perceived: "*Dimensioning of the fire brigades is based on municipal finances. The willingness to put in a little extra based on when there is a higher risk and the municipality is not as high everywhere."* Furthermore, one of the part-time fire brigades describes that "*the biggest limitation in emergency preparedness is the economy. They must create an action plan that describes costs, as well as job resources, skills and equipment. This must be submitted to the municipality and possibly adopted, this means that the finances are limited for emergency preparedness*".

Based on the results in this study, the larger fire brigades in Norway have the resources and economy to determine the organisation. The part-time fire brigades in Norway do not have the resources necessary to follow up on the regulations. The biggest limitation that the fire brigade points out is money. In the municipalities, there is competition for the "moneybag". It is important to be creative within the framework each fire brigade is given or has access to. The fire brigade must create an action plan that describes its costs. This also involves job resources, competence and equipment. Most people know that you need good equipment to be able to do a good job and everyone has their challenges. You have to fight a little for what you might want and the focus must be right.

Section 26, Evaluation and learning after events [2] describes that the fire and rescue service shall have a system for evaluating incidents and for sharing and receiving evaluations from others, so as to identify relevant learning points. The fire and rescue service shall document how learning points are implemented to ensure that learning takes place in the organisation.

The interviews show that there is no system for evaluating incidents in a good way for sharing experience with one another. The biggest fire brigades do evaluate incidents but do not share experiences in a system for exchange of experience with other fire brigades.

The Fire and Rescue Service Regulation [2], allows for more risk-based emergency management, but it is uncertain whether it will be well received by the employees. The municipal councils will have an opportunity to organise lower staffing and operating expenses. It seems like increasing staffing over a period when it is dry outside is well received by the employees.

It seems like the municipality and the fire brigades do not have the same understanding even when the regulations says: "The regulations shall ensure that every municipality has a fire service that is organised, equipped and staffed, so that what is imposed by law and regulations is performed satisfactorily. Furthermore, the regulations shall ensure that the fire service is organised and dimensioned based on the risk and vulnerability that exists".

The Fire and Rescue Service regulation [2] is very clear that the fire brigades shall work on risk-based emergency management. But it seems that the municipality does not give the fire brigade the economy to continue with it. It is therefore important to be creative within the framework given or there is access to.

There is also a difference in the size and location of the fire brigade. The smaller fire brigade gets less equipment and resources. There are large differences between the fire brigades that experienced incidents, e.g. Lærdal, Flatanger, Frøya, and the fire brigades with no such experience. If a fire brigade experienced a catastrophic fire or incident, it is much easier to refer to the incident to gain more access to equipment and resources.

In the interviews, it emerges, especially from the smaller fire brigades, that you must work for a good trust, both administrative and political, in the municipality. This means that the fire brigades get impact in what they want or should ask for. Also, be aware of what they are asking for, when they are asking for it and why they are asking for it. Even if this is done, there are still major shortcomings in the fire brigade, such as obtaining course funds and gaining sufficient competence.

Often, risk assessments are based on earlier incidents, i.e., research or experience, and an event or accident must occur before we learn from it. This probably also coordinates for the municipalities, because you see that the fire service that experienced large fires often gets extra equipment and crew. If the municipalities do not understand dynamic risk-based emergency management, it will be difficult to provide money to complete it. Even though it is stated in-laws and regulations, it must be clear that it must also be executable.

As the Regulation [2] suggests, there is a lot of planning, documentation and analyses to be carried out. Therefore, it becomes more important for the fire brigades to describe the risk, resources, equipment and similar, so that any deficiencies are presented in their analyses.

Unfortunately, the fire brigades in Norway are very incident-driven. What is meant by this is that we do not “understand” the seriousness of the events until they have happened. This makes us run after and extinguish. This is something that needs to be changed and more emphasis put on prevention, as well as risk understanding.

The preparatory work states, among other things, that [2]: “Operational environments such as the fire and rescue service, the police and the health service largely develop their ability to handle by learning from real incidents or exercises. If similar incidents are to be avoided in the future and an improvement of the business is achieved, a qualified evaluation of incidents must be carried out with a learning view. Learning is about becoming aware of the need to change routines or understand why something works better. It is not enough to map the incident or to determine the cause of the fire.

The Ministry points out that this requirement has been further actualised after the major fires in Lærdal, Frøya, and Flatanger in January and February 2014. The purpose of the evaluations is primarily to create a culture in the Norwegian fire and rescue service to work systematically on learning from incidents. The Ministry agrees with the consultative bodies that point out that there is a need to elaborate on the requirement for evaluation in regulations and guidance. Clarifications that are absolute requirements for the evaluation work must be included in regulations*”.*

Based on the fire brigades interviewed in the thesis, it appears that the learning exchange is appalling. Several fire brigades point out that it is an important aspect to learn from each other, but they do not have an implemented procedure for this.

To increase the chances of a functioning system that can take care of the transfer of experience and raise awareness of the topic, a need for a change in culture and attitude is important. What the management pays attention to, measures and controls help to influence the culture in the fire brigade. Without a formal system of experience transfer, it becomes randomly based on each leader and their practise. From the interview it emerges that today´s challenges are the organisational culture and that the fire brigades do not look at the challenges and the transfer of experience in their entirety. This makes it difficult to shed light on the challenges in the municipalities as a whole and difficult for the municipalities to see the current problems. According to the new Fire and Rescue Regulations [2], it will be easier to make the municipalities more aware via analysis, but this presupposes that the fire brigade has good procedures for and awareness of dynamic risk-based emergency management and shedding light on any challenges they have.

4.6 Fire legislation

The Fire and Rescue Service regulation [2] entails a modernisation and simplification of the repealed dimensioning regulations [22], but some major measures are also being taken to contribute to the further development of the fire and rescue service. It is described that the regulations are adapted to greater fire cooperation in line to develop even better fire and rescue services than today. The guidance [25] states that the purpose of the guidance is to facilitate an equal understanding and practise of the regulations across municipal boundaries.

DSB has focused on continuing what is good and that has worked in the dimensioning regulations, in line with input from the fire and rescue services and other consultation efforts. In addition, the new fire and rescue services regulations include clarifications of the repealed dimensioning regulations and current practise. The most important changes are:

- The analysis requirements (sections 6-9)
- A clarification of the fire chief's responsibilities and tasks (section 11)
- Alarm of the nearest resource (section 24)
- Detailed duties of the emergency call centre (sections 28-33)

In addition, clarifications of the previous dimensioning regulations and current practise have been included in the new fire and rescue services regulations. There are also several detailed requirements for planning, exercises, evaluations and critical communication network. What is interesting about this is whether there will be more focus on dynamic risk-based emergency management and whether the changes will lead to improvements.

The determination in the regulations [2] section 26 is new. This determination sets requirements for documentation of learning points *after incidents*, where previously there were requirements for documentation *after exercises*. In the event of amendments to the Fire and Explosion Protection Act no. 36 of 29 May 2015 [19], a requirement was added: The municipality shall evaluate incidents to ensure continuous learning and improvement of the preventive and emergency preparedness work.

The guide [25] section 26 states that the fire and rescue service shall have a system for assessing incidents and sharing and receiving evaluations from others, so as to identify relevant points. When appropriate,

the fire and rescue service and the emergency call centre shall cooperate, as well as cooperate on evaluation and learning after incidents.

The way the current Norwegian performance-based fire safety regulations are interpreted may also be addressed to make the stakeholders realise that the suggested approach complies well with the requirements [3].

Change in regulations, fire prevention

On 1 January 2016, the regulations on fire prevention entered into force and replaced the regulations on fire prevention measures and supervision of 2002 [20]. The purpose of this thematic guide is to provide the fire and rescue service with a tool to be able to carry out systematic risk-based preventive work. By systematic risk-based preventive work, it is meant that a risk mapping shall form the basis for which measures are to be implemented and that the work shall be part of a system. The system shall consist of goals, plans, measures and procedures [48].

The increased freedom for the municipalities is also balanced by an expectation that they establish and document a satisfactory system for assessing and managing the real risk in the municipality [48]. There is also a difference not only between small and large fire brigades, but also where in the country they are located. According to this thesis, it is known that the danger of heather fires does not exist throughout Norway, but experiences and events show that these are often located by the coast of Norway. It is important to ensure that all fire brigades have a system that relays the evaluation of major incidents. The incidents must be exchanged between fire brigades that could have the same incidents in their municipality.

Section 19 of the Regulations on fire prevention [20] states that the fire and rescue service must obtain knowledge about:

i. How fires start and spread
ii. Characteristics of people who die or are injured in fires
iii. Characteristics of buildings and built environments that become involved in fires
iv. Which preventive and contingency measures affect the course and outcome of fires

This means that the municipalities must make sure to follow up where major incidents occurred. The advantage of new regulations is in addressing the danger of heather fires, on the basis that the municipalities are obliged to disseminate knowledge about how fires start and develop. The regulations are not significant on how the fire brigades work or exchange experience of these types of incidents.

A requirement under section 15 of the regulations on fire prevention [20] is to reduce the mapped risk effectively.

It appears from the emergency management from the Western Norway University of Applied Sciences [25]:

"A challenge with a risk and vulnerability analysis, it is not very suitable for providing answers on how we should handle the risk. What is good preventive work and what resources are needed for this (i.e., how should we proceed to prevent something from going wrong) is as challenging as determining what is good handling of unwanted incidents and how the emergency preparedness should be dimensioned to make this happen" [25].

An analytical approach to how to handle the mapped risk (described throughout the risk picture), the risk and vulnerability analysis can be followed up by two more or less independent analyses: a preventive analysis and a contingency analysis. It is appropriate to divide this into two analyses as there are two different risk-reducing areas. The preventive analysis shall contribute to reducing the risk with the help of various preventive measures. These can be among other things sprinkler systems in special areas and buildings. Preventive measures can thus be implemented to reduce the risk and not least that a contingency can be established to handle the residual risk.

Most operational risks are foreseeable, however the risks posed by events such as adverse weather conditions or civil contingencies are not easily quantifiable. A combination of operational risk information and available generic risk assessments, local knowledge, and professional judgment will help ensure that an appropriate risk management process can be put in place. An operational risk information management system should:

- Bring together the outputs from existing and establishing systems
- Develop and support a common approach to the strategic and dynamic analysis of risk
- Determine the appropriate application of resources and processes to address those risks which impact the firefighter, other emergency responders, members of the public, the environment etc.

The fire brigades point out good organisation and cooperation between the fire service and their actors, as well as exercises coordinated with others. The new regulations [2] stipulate those improvements must be possible, as pointed out in the interviews.

Risk-based emergency response

Log and Metallinou [3] describe that risk awareness is a key to human responsiveness and safety. Even though risk-based management has been required for over 20 years, it has not been practised. Dry wood fire risk is easier to comprehend and may represent a proper case for introducing risk-based emergency management.

Suggestions for increasing risk understanding regarding dry homes fires, i.e., to understand when fires develop fast and firefighter turnout and driving time consumes more than the available time for controlling the fire, are outlined by Metallinou and Log [4]. The firefighter´s preparedness may be increased by innovative practical training or low-cost simulations and serious games.

Contingency

The regulations on the organisation and dimensioning of the fire brigade, which came into force in 1995, were largely based on the fire and smoke diving. With more and more rescue missions, it is time to look at alternatives to improve dynamic risk-based emergency management.

The literature, based on laws and regulations, is very clear that the fire brigades must work in a risk-based dimension. It does not emerge enough in a dynamic risk-based emergency management. The understanding of the term dynamic must probably be clarified in most fire brigades. It is also clear that those who decide and lay down the regulations do not have all the knowledge that makes it fully possible to implement this.

Lack of knowledge means that there are large differences between the small and large fire brigades in Norway. In the interviews, this became clear and it will be difficult for the small municipalities to maintain a risk-based dimensioned preparedness. Because in the small municipalities, the fire chief often has too many tasks and responsibilities following the job description. It is also clear in the regulations [2] how much is to be described, risk assessed and possibly changed after incidents.

4.7 Warning systems

In order to improve dynamic risk-based emergency management in the fire brigades, a good warning system can be an important tool. This will help the fire brigade to collect important data so they can be prepared in the best way and prevent bigger incidents. A good warning system will also tell if a fire brigade needs more resources than usual.

As mentioned earlier, there aren´t many warning systems used by the fire brigades. This is also a question asked during the interviews. The fire brigades mostly use the forest fire index which is on yr.no. Some of the fire brigades also have warnings by messages through phones to residents.

During the interviews, several fire brigades mentioned that the existing warning system is not 100% reliable. The new warning system by DSB, the forest fire danger index, does not have all the criteria to understand the upcoming weather, because the index is quite rough.

An important parameter for a good warning system, where one fire brigade had a very interesting answer while talking about heather or WUI fires: "The fire brigade *believes that the points mentioned below contribute to increasing the potential for a large fire:*

- *One is the forest fire index from MET, which maps for them and focuses on drought in the soil. How dry the soil is affects the fire risk. A factor that comes into play.*
- *The second is the type of forest and topography, this also comes into play. Some forests burn faster than others. Then there is the uphill and downhill aspect, which is in a way pure fire physics.*
- *The third factor is wind and air temperature because we see when it is 30-35 degrees Celsius on a really hot summer day, fires occur much more easily. Buildings ignite more easily and everything ignites more easily when there is warmer air.*

This must be put together yourself to capture this, so having an alert system that sets up these three factors would have provided better alert quality".

Another good example of why the WUI fire index does not fully work is: "*The warning systems that they have are what everyone has access to, such as yr and the forest fire warning of DSB (forest fire danger index). It is not entirely suitable for the areas with islands. Towards the sea, it dries much faster than further inland. Misses more alert to cover the islands. It should have been clearer how complex it is. Read it*

carefully, as it is a bit rough. The Forest fire hazard index is not good enough to capture all information on the islands off the mainland.

One of the reasons why the fire brigades did not understand the seriousness of the biggest WUI fire was that the warnings did not show that it was as dry as it was. There can be big differences between places that are near each other, because of terrain and nature; the difference can be huge. Topography can be completely different, even at short distances. It is about knowing the areas and about reading maps. The index is quite rough".

Some of the fire brigades do not use any warning system. The interviews gave some idea on what the warning system should have a focus on and what important parameters should be implemented in the warning system. During the interview, several fire brigades mentioned that existing warning systems did not have the correct parameters. There were also several uncertainties. It was pointed out that there was no common teaching on how to use or read the index correctly, which can lead to incorrect decisions.

From the interview from a study by Log and Gjedrem [15], it was confirmed that warnings better aligned with the real fire danger would have triggered alertness and increased emergency manning. The interviewee stated that such a fire warning could provide an incentive for helicopters to be stationed closer in high-risk periods. It is unclear why the Canadian Fire Weather Index (CFWI) based fire warnings only indicated yellow warnings, i.e., why they underpredicted the fire danger. This model is, however, developed for boreal forests while juniper and Sitka spruce on thin soil layers may require an adapted model. It could also be that models based on first principles, e.g., water vapour pressure deficit (VPD), could be appropriate.

5. Discussion

In this chapter, the writer will discuss the procedure, results and method. Also, the number of fire brigades and the background for choosing them will be discussed. Finally, a discussion of the findings, the quality of the findings and a look at how this corresponds with other articles and literature will be presented.

5.1 Approach

The data collection for the thesis was done using a qualitative method. Seven interviews with different fire brigades in Norway were conducted. The interviews were individual interviews, except for one where there were two informants. The interviews were recorded as audio recordings via Teams and later transcribed.

The method was a simplification of Bryman [43], where Bryman believes the data should first be coded and then categorised and analysed. This was considered to take a lot of time and, due to the scope of the interviews, it was decided that the interviews should be recorded and transcribed right after the interviews, while they were still fresh in my mind, and I could focus on the next interview.

5.2 Method

One thing that could have been done differently in the interviews is to perhaps start by initially asking the informants to present their understanding of dynamic risk-based emergency management. And thus, explained what is meant by it in this exercise. Then, I think that I would have secured the informants´ understanding of the concept, unaffected by the definition of the thesis and that we had gained a common understanding throughout the rest of the interview. It became a bit confusing with the interview guide, as I sometimes presented what I meant by the term and asked directly. Some of the fire brigades probably did not have the same perception of dynamic risk-based emergency management. The focus then was mostly on risk-based dimensioning.

If I had changed the procedure a little, I would have ensured that the informants answered the questions with the same theoretical basis on which the questions were prepared. Unfortunately, I was not consistent enough initially in the interviews to ask the informants about their professional background and what kind of work tasks they perform today. Before the interviews, I was aware of their position and, based on my experience in the fire brigade, I thought I knew what the position contained. But this varies between large and small fire brigades.

In my study, I have used a qualitative interview as a tool. It will therefore be difficult to ensure that the study has high reliability. Ensuring a high level of reliability would have been easier if I had used a quantitative method. As mentioned earlier in the thesis, both the interviewer and the informant will always influence the interview. If another person had used the same interview guide as is used in this assignment, there is no guarantee that it would have given the same result. What I have done to try to increase the study's credibility is that I have planned the questions in the interview guide carefully, to avoid asking leading questions. During the interviews, I also tried to create an open and trusting situation so that the informants hopefully felt that they could answer as honestly as possible. This is to prevent them from answering what they think I might want to hear. If I have asked follow-up questions, I have also used open, and not leading questions.

The interviewer should have been more consistent in getting the fire brigades to tell about their professional background and what work tasks they carry out today. At the same time, initially in the interview guide there should have been a question about how they interpret dynamic risk-based emergency management. Could it be that the procedure ensured that the informants were not influenced until they had presented their definition, and that we had a mutual understanding of what was meant by dynamic risk-based emergency management as a concept?

The interview guide was changed a bit after the first two interviews. This was based on the fact that some of the questions were a bit general, which meant that it became difficult for the informants to understand what I was asking about. Some of the questions were thus changed, to get a more concrete discussion and better answers to what I should answer in my problem statement.

But overall, the method used in this thesis gave good results. Several of the interviews also led to discussions on the topics, which led to the results being reinforced regarding finances. It was not a direct question in the interview guide but appeared in most interviews.

5.3 Fire brigades

Early in the semester, it was decided that approximately eleven different fire brigades would be interviewed. Furthermore, the choice of the various fire department was based on where in the country they are located and where the biggest incidents in Norway have been regarded as heather fires and wooden structures fires. It was also based on the location of heather and wildland in Norway where it is often dry and windy. Both large and small fire departments were included in the interviews. This was based on getting different experiences and whether you can learn from each other.

During the interview process, a total of seven fire brigades were interviewed. The rest were not included when we decided to process the data and start working on the result that had already been obtained. If more fire brigades were interviewed, the results could turn out different. Then, more interviews would have been obtained, more locations of the fire brigades, experience and knowledge of more fire brigades would have been collected. It would probably have been interesting to interview more fire brigades, to collect different results and a bigger selection to compare with. The results would probably also have been strengthened with even more views and experiences.

Based on the interviews, all the fire brigades had prepared a risk analysis and contingency analysis. Several of the fire brigades informed that the risk and analyses of incidents had been described and uncovered, but the challenges of being able to practise it and carry out what is described can be challenging. The smaller fire brigades say that their contingency analysis has identified and assessed what resources are needed to be able to handle dimensioning incidents satisfactorily. The challenges are that the fire brigades express that they need more people to carry out all the tasks they are required to do, but that the municipalities are not willing to give these finances. The economy is a limitation on emergency preparedness.

The risk and vulnerability analysis in the fire service is used by both the contingency department and the prevention department. The two departments have different purposes and the analysis is therefore used for emergency preparedness, dimensioning and prevention. This compromises and reduces the

applicability of the analysis to the various purposes. In the Fire and Rescue Services Regulations [2], there are clear requirements for analyses, but how the fire services are to use the risk and vulnerability analysis and the contingency analysis must be specified.

The fire brigades submit a proposal to the municipal council to show the resources (equipment and crew) they need, but it is not certain that the municipality understands the need. This can lead to not getting the resources they need. An important parameter that may need to be changed is that the fire brigades clarify what is needed by the regulations. At the same time refer to incidents and describe the risks in their contingency analysis. This assumes that the contingency analysis is well described and updated to the current situation. The risk and vulnerability analysis provides answers to what can go wrong and where it can go wrong. How the mapped risk is to be handled is followed up through a preventive analysis and a contingency analysis.

The need for reserve forces varies by the size of the fire brigade and where they are located in Norway. From the interviews, most of the fire brigades had no collaboration with other actors or other fire brigades. They had some actors, e.g., farmers, who could take part in extreme cases, but nothing that was documented. One fire brigade had several collaborations with different actors. This was, cooperation with hiking associations, to facilitate more campfire sites in the field. They also took the initiative to cooperate in the region, to communicate even better. Information to residents is an important part of preventive work. After the fires in Lærdal, Frøya, and Flatanger, getting a good start with the extinguishing work as early as possible, to avoid major incidents, is important. The state resources have become more available after such incidents and the helicopter is available early.

Exchange of experience

The interviews show that the fire brigades are not good at learning through experience sharing. It is desirable that everyone shares their own and learns from experiences after efforts. It must be emphasised that experiences after incidents are particularly interesting because the incidents the crews must deal with are real (as opposed to experiences made during exercises). It emerges from the interviews that a system can safeguard learning through the exchange of experience. There might not be a clear distinction between information and experience transfer in the fire brigade. Information seems to be both a corresponding transfer of experience, without necessarily involving learning, and a prerequisite for the transfer of experience. If there is no information flow, there will be no transfer of experience.

A report from DSB [49] on experiential learning among the Norwegian fire brigades pointed out that the agencies' organisational culture and structure are diverse, which means that various measures are required to create effective experience sharing. The different measures are adapted to each agency. A simple municipal fire brigade with 2-3 full-time positions has completely different prerequisites and challenges from agencies that are owned by several municipalities and have over 300 employees. When the structure of the organisation is similar, for example in the number of sections in the emergency department, different agencies may face some of the same challenges. Culture and attitudes in the fire brigade can be different, especially the local culture which depends on the history and practise of each agency.

The new fire and rescue regulations [2] have made some changes to the dimensioning regulations, where the most important changes are the analysis requirements and a clarification of the fire chief´s responsibilities and tasks. There are thus higher requirements for the analysis and this also means evaluation after incidents. This should help to make the fire brigade even better at exchanging experiences, the challenges are probably that a system has not been created that makes it work optimally yet.

A possible system requires time and human resources, to ensure quality and continuity, including in the work of collecting, storing, and distributing information and experiences. Better computer skills and use of Teams (or similar) can contribute to better and easier exchange of experience.

5.4 Findings

The fire and rescue service is a traditional and conservative industry. The findings and the challenges of implementing any changes can therefore be thought to be similar for many Norwegian fire brigades. The findings show that the fire brigades have potential for improvements when it comes to improving their dynamic risk-based emergency management. It is also clear that the exchange of experience must be developed and used, as well as information about incidents that may occur in other municipalities being communicated and focused on the areas, by means of exercises, for example. One of the main findings is that the legislation does not work in practise. This was before the new fire and rescue regulation [2] was being used, so there may be some changes. The writer sees that the legislation makes too many demands and has too little dynamic directed at the fire brigades: it is difficult to implement what they want. Although the legislation says it should be a specific way, several fire brigades have experienced that it does not work as they do not have the resources or capacity to carry it out. It will then be interesting to see if the fire brigade harmonises and operates in line with the fire and rescue regulations [2].

Reports [37, 50] claim that learning from real-life incidents is usually more valuable than from exercises and that it is, therefore, necessary for the fire brigades to transfer experiences from operations to several fire brigades. The findings in this study support [37, 50] their findings.

The best way to prevent fire is to prevent ignition. As mentioned earlier, it is generally known that dry wood burns better than more humid wood. The Norwegian fire brigade understands that dry wood burns better than humid wood, but the understanding of implementing this in a dynamic risk-based emergency management is not entirely in place. The fire brigades which experienced WUI fires have a different understanding from the ones that have not experienced this. The fire brigades located in the western part of Norway have grass and heather. The fire brigade fears more grass fires after the incidents in previous years, e.g., Sotra and Flatanger. Grass and heather fires are a problem as there is more and more vegetation and fewer goats and sheep are grazing, in addition to not moving the grass as much as before. The west coast dries up quickly due to accumulation of biomass and *Calluna Vulgaris*-dominated heathlands; therefore the fire brigades located there should be extra aware.

Another finding that emerges in the interviews is that several fire brigades use prescribed burning. There may also be several fire departments besides those interviewed that carry this out. During the interviews, it also emerged from the fire brigades that there is a lack of competence within the subject area.

Metallinou [29] represents learning process in a civic group resuming prescribed burning in Norway. A survey of fire brigades that have heather in their municipality should be carried out to know which fire brigades need education and training to carry out safe and secure prescribed burning.

Log and Gjedrem [15] describe that developing fire protection plans for wooden heritage buildings has been shown to give positive effects on fire safety. Just developing municipal plans for heathland management gave reduced firefighting costs. Managing areas of valuable *Calluna* heathland is already supported. With much higher fire danger in neglected heathlands, funding heathland restraint would be even more beneficial cost-wise.

The results from [40] show that it is feasible to use a combination of measurement data and forecast data for computing a viable fire risk indication. The results demonstrate that the best option is to combine the two using measurement data to properly adapt the model relative to days of previous weather. Furthermore, it does not accumulate large amounts of weather data. Regarding the run-time efficiency, most of the time is spent fetching data from the external services. It further described that further work may include continuous experimental evaluation through whole years. Wind speed, wind direction and building density could also be included for site-specific fire and conflagration risk warnings.

This shows that the Predictive Fire Risk Indication Model using Cloud-based Weather Data Services focuses on wooden homes in Norway. It is also at an early stage, so several factors are not included. But this application is a good risk warning for wooden homes.

The scope in this thesis had to be limited based on time, but it would be interesting to compare several different fire brigades to draw parallels between the prerequisites and challenges of the fire brigades. Having more organisations also increases the possibility of generalising the findings. Some of the findings in this study are nevertheless general enough that other fire brigades can benefit from them in their work to improve dynamic risk-based emergency management. If one or several fire brigades have implemented a dynamic risk-based emergency management, it would be interesting after a period of time to measure its effect.

5.5 Quality of the findings

Prescribed burning should be used more and seems to be comparable with a study [60] where they present prescribed fire treatments and allowing fires to burn under moderate weather conditions as managers to decrease the severity of subsequent fires.

The interviews with the fire brigades show that the use of warning systems is not much used. This varies with the different fire brigades, as well as their location and size. The risk warning systems used today are yr and DSB´s forest fire hazard index. During the interviews, it emerged that several of the fire brigades pointed out that existing warning systems are not one hundred per cent reliable. This was also shown during the fire in Sotra [15], where CFWI-based fire warnings only indicated yellow warnings when the fire danger was high. One of the fire brigades points out important factors that must at least be present for a good warning system about the challenges mentioned in the thesis. These results about other findings show that some of the fire brigades understand the missing parameters to get a good warning system. A

study [58] describes a Canadian Fire Weather Index System´s Drought Code, which can also be used by the Norwegian Fire Brigades.

A report [51] says that fire regimes are determined by climate, vegetation and topography and are strongly influenced by the presence of humans. This indicates that my result from several fire brigades understands the context of climate, vegetation and topography must be implemented for a good warning system for the heathland WUI fires.

Inspections, supervision and surveys are accomplished in the fire brigades today, but this is most often for special fire objects. An important factor that might be considered is inspections of buildings or houses near forests and outlying areas. This can be accomplished by chimney sweeps when they are visiting private households. Information about drought, wind, biomass etc. must also be given to residents.

We know that the forests are becoming overgrown by trees, grass and heather. The reports [16, 5] describe methods for preventing forest fires and climate change. The forest fires in the USA, Canada, and Australia are examples of how large the WUI fires can be. But also, in recent years in Portugal and Greece we learned at great cost that wildfire risk is an ever present and increasing threat in Europe. The fires are extraordinary in their size, intensity and severity. “Megafires” are challenging the capacities of national wildfire protection programmes and represent a major concern for the Union [52]. Therefore, it is important to prevent based on learning, information, experiences and the knowledge we have today. This also applies to a large extent to the fire brigades for them to improve dynamic risk-based emergency management. A preventive measure for preventing WUI fires is removing biomass around the homes described in this thesis. A study that substantiates this is [53] where houses directly adjacent to fire in continuously forested fuels have higher exposure compared to homes separated by a large distance from fuels. Meaning that removing biomass from the homes prevents faster spreading to the houses.

WUI fires are an increasing risk. The high disaster frequency experienced in recent years and the climate changes expected during the next decades represent alarming signals for the future. There is therefore an urgent need for innovative and interdisciplinary research to understand the complexity and to proactively manage the increasing fire disaster risk. A report [54] describes the importance of vegetation modification in California. Therefore, it may be safe to assume that results in this thesis are broadly representative.

The new fire and rescue regulation [2] has not been practised long enough to comment on whether it works for the fire brigade and the improvements in the fire and rescue regulation.

The present study shows from the result from the interviews that there is a lot of good risk understanding, but there are improvements to be made in a way of working for dynamic risk-based emergency management.

6. Conclusion

The present study has inquired what risk-based approach the fire brigades already have and possibilities for improved dynamic risk-based emergency management in the Norwegian fire brigades. Document studies have shown that there is legislation that describes the minimum dimensioning of the fire brigades but it does not focus much on dynamic risk-based emergency management. The fire brigades have presented most of the empirical work with their knowledge, thoughts and opinions on the topic. This in summary has laid the foundation for answering the question of how the fire brigades should improve their dynamic risk-based emergency management.

One of the main findings of the thesis is that the legislation does not work in practise. This is before the new fire and rescue regulation [2] has been used, so there may be some changes. The legislation has many requirements for the fire brigades that they do not have the opportunity to fulfil and it is difficult to get what they want to be implemented. Although the legislation says there should be a specific way, several fire brigades have experienced that it does not work as they do not have the resources or capacity to carry it out. It will then be interesting to see if there will be improvements in the Norwegian fire brigades after using the new fire and rescue regulations [2].

A challenge for risk-based management in the Norwegian municipalities is that they are not adjusted to highly dynamic variation in the risk picture along with temporal (weather) and spatial (WUI) dimensions. Firefighters generally do not consider dynamic risk variations during their training or within their daily work routines. This depends on the size of the fire brigade and what types of risks there are in their municipality.

From the interviews it emerged that there is not good enough cooperation between the fire brigades, there is a lack of training and exchange of experience. This is something that needs to be improved to improve the dynamic risk-based emergency management. An important point mentioned by one of the larger fire brigades was that if we are to start thinking new, we must think risk-based on the basis of the factors air temperature and humidity, as this has a great significance for the spread potential of a fire.

7. Further work

Looking at dynamic fire disaster risk management in the Norwegian fire brigades has been an interesting topic to work on and there is a need for further research. It is a very relevant topic in Norway and worldwide; the wildfires are also more and more relevant. As mentioned earlier, this is a study based on a qualitative research method with a small sample of fire brigades. It could therefore be interesting to do even more research on the other fire brigades as well, to gather even more data and compare.

Evaluating incidents, which applies to both exercises and incidents that the fire brigades have participated in, is a very important finding. There must be a description of what went wrong, improvements, learning from each other and similar. This will hopefully be taken care of by the new fire and rescue regulations [50]. Suggestions for further work are to investigate how various fire brigades evaluate incidents in practise and whether it works or not.

There must also be awareness-raising in the municipalities about what is needed for dynamic risk-based preparedness. This will vary with the location, size and experience of the different fire brigades. It emerged in the interviews that not everyone had an equal understanding of the concept of dynamic risk-based emergency management. This must be informed in a good way for each fire brigade.

From Stokkenes' paper [40], further work may also include continuous experimental evaluation through whole years. Wind speed, wind direction and building density could also be included for site-specific fire and conflagration risk warnings. This would be very valuable for densely built wooden town areas also outside Norway.

It could be interesting to compare closely the Norwegian model (fire index from DSB) with the Canadian Fire Weather Index. This can draw similarities, but also what is missing. An important parameter is the different locations and different hazards in Norway and Canada.

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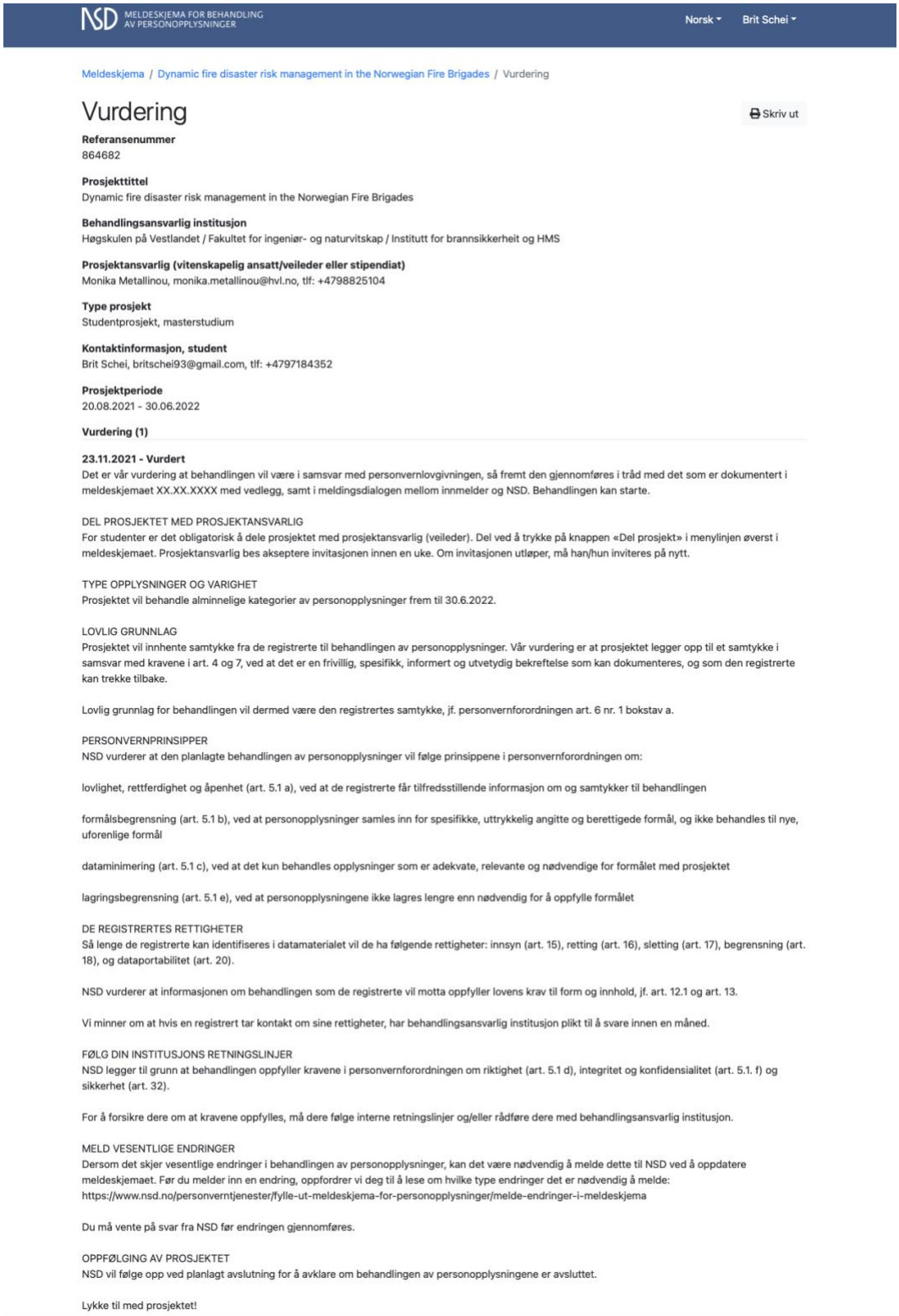
9. Appendix

Appendix I



NSD MELDESKJEMA FOR BEHANDLING AV PERSONOPPLYSNINGER

Norsk ▾ Brit Schei ▾

Meldeskjema / Dynamic fire disaster risk management in the Norwegian Fire Brigades / Vurdering

Vurdering

Skriv ut

Referansenummer
864682

Prosjekttittel
Dynamic fire disaster risk management in the Norwegian Fire Brigades

Behandlingsansvarlig institusjon
Høgskulen på Vestlandet / Fakultet for ingeniør- og naturvitskap / Institutt for brannsikkerheit og HMS

Prosjektansvarlig (vitenskapelig ansatt/veileder eller stipendiat)
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Type prosjekt
Studentprosjekt, masterstudium

Kontaktinformasjon, student
Brit Schei, britschei93@gmail.com, tlf: +4797184352

Prosjektperiode
20.08.2021 - 30.06.2022

Vurdering (1)

23.11.2021 - Vurdert
Det er vår vurdering at behandlingen vil være i samsvar med personvernlovgivningen, så fremt den gjennomføres i tråd med det som er dokumentert i meldeskjemaet XX.XX.XXXX med vedlegg, samt i meldingsdialogen mellom innmelder og NSD. Behandlingen kan starte.

DEL PROSJEKTET MED PROSJEKTANSVARLIG
For studenter er det obligatorisk å dele prosjektet med prosjektansvarlig (veileder). Del ved å trykke på knappen «Del prosjekt» i menylinjen øverst i meldeskjemaet. Prosjektansvarlig bes akseptere invitasjonen innen en uke. Om invitasjonen utløper, må han/hun inviteres på nytt.

TYPE OPPLYSNINGER OG VARIGHET
Prosjektet vil behandle alminnelige kategorier av personopplysninger frem til 30.6.2022.

LOVLIG GRUNNLAG
Prosjektet vil innhente samtykke fra de registrerte til behandlingen av personopplysninger. Vår vurdering er at prosjektet legger opp til et samtykke i samsvar med kravene i art. 4 og 7, ved at det er en frivillig, spesifikk, informert og utvetydig bekreftelse som kan dokumenteres, og som den registrerte kan trekke tilbake.

Lovlig grunnlag for behandlingen vil dermed være den registrertes samtykke, jf. personvernforordningen art. 6 nr. 1 bokstav a.

PERSONVERNPRINSIPPER
NSD vurderer at den planlagte behandlingen av personopplysninger vil følge prinsippene i personvernforordningen om:

lovlighet, rettferdighet og åpenhet (art. 5.1 a), ved at de registrerte får tilfredsstillende informasjon om og samtykker til behandlingen

formålsbegrensning (art. 5.1 b), ved at personopplysninger samles inn for spesifikke, uttrykkelig angitte og berettigede formål, og ikke behandles til nye, uforenlige formål

dataminimering (art. 5.1 c), ved at det kun behandles opplysninger som er adekvate, relevante og nødvendige for formålet med prosjektet

lagringsbegrensning (art. 5.1 e), ved at personopplysningene ikke lagres lengre enn nødvendig for å oppfylle formålet

DE REGISTRERTES RETTIGHETER
Så lenge de registrerte kan identifiseres i datamaterialet vil de ha følgende rettigheter: innsyn (art. 15), retting (art. 16), sletting (art. 17), begrensning (art. 18), og dataportabilitet (art. 20).

NSD vurderer at informasjonen om behandlingen som de registrerte vil motta oppfyller lovens krav til form og innhold, jf. art. 12.1 og art. 13.

Vi minner om at hvis en registrert tar kontakt om sine rettigheter, har behandlingsansvarlig institusjon plikt til å svare innen en måned.

FØLG DIN INSTITUSJONS RETNINGSLINJER
NSD legger til grunn at behandlingen oppfyller kravene i personvernforordningen om riktighet (art. 5.1 d), integritet og konfidensialitet (art. 5.1. f) og sikkerhet (art. 32).

For å forsikre dere om at kravene oppfylles, må dere følge interne retningslinjer og/eller rådføre dere med behandlingsansvarlig institusjon.

MELD VESENTLIGE ENDRINGER
Dersom det skjer vesentlige endringer i behandlingen av personopplysninger, kan det være nødvendig å melde dette til NSD ved å oppdatere meldeskjemaet. Før du melder inn en endring, oppfordrer vi deg til å lese om hvilke type endringer det er nødvendig å melde: https://www.nsd.no/personverntjenester/fylle-ut-meldeskjema-for-personopplysninger/melde-endringer-i-meldeskjema

Du må vente på svar fra NSD før endringen gjennomføres.

OPPFØLGING AV PROSJEKTET
NSD vil følge opp ved planlagt avslutning for å avklare om behandlingen av personopplysningene er avsluttet.

Lykke til med prosjektet!

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Appendix II

Interview guide.

Questions:

- How is your risk-based readiness today?
- Do you have a dense wooden house environment?
- In that case, when are they most at risk?
- What do you do to reduce the risk? (Both heather fires and fires in dense wooden houses. Also both emergency preparedness and preventive)
- What experience do you have with heather fires/wildland fires/wooden structures?
- What are you doing today to prevent heather fires/forest fires?
- Do you have any warning systems that let you know when it´s dry outside? Or the greater danger of fire?
- How can alert systems increase risk awareness before the incident?
- What risk-reducing measures for a dense wooden structural environment have you implemented in your routines?
- What risk-reducing measures for heather fire/forest fires in the border zone have you implemented in your routines?
- What risk understanding do you have in advance of risk peaks for large fires in the marginal zone between nature and buildings? Which is typical of their fire department.
- What risk understanding do you have in advance of risk peaks for dense wooden house environments? Which is typical of their fire department.
- Has the type of inspections been carried out? By checking the terrain, or close to buildings. (Biomass around the houses)
- What resources do you use in forest/heather fires today? What equipment do you not have today that you may need in the future?
- What do you think about the number of crew on duty when it is extremely dry out in the field/forest? Focusing on possible dynamic risk-based emergency management.
- What can the fire brigade do?
- What experiences do you have that you would like to be involved in the new routines?
- Have there been improvements or other methods to work on after the incidents/ fires in Lærdal, Flatanger, and Frøya?
- How do you think any risk-based emergency management is received by the employees? For example, with dynamic dimensioning, more people are on duty when there are risk peaks.
- Possibly showstoppers? Financing?

- Is there anything you want to add?

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Appendix III

Samtykkeerklæring

Jeg har mottatt og forstått informasjon om prosjektet DYNAMIC, og har fått anledning til å stille spørsmål. Jeg samtykker til:

- ☐ å delta i intervju
- ☐ Opptak av intervju
- ☐ at publisering av opplysninger om din rolle og/eller geografisk spesifikasjon (som vil kunne være personidentifiserende)

Jeg samtykker til at mine opplysninger behandles frem til prosjektet er avsluttet

---

(Signert av prosjektdeltaker, dato)

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Appendix IV

The following fire brigades have been interviewed:

Fire brigade	Employees (approximately)	Part-time	Municipality
Oslo Fire and Rescue Service	530		Oslo
Frøya Fire department	34	X	Frøya
Lofoten Fire and Rescue Service	55	X	Vestvågøy, Flakstad and Moskenes
Bergen fire department	250		Bergen
Lærdal fire department	18	X	Lærdal and Årdal
Flatanger fire department	95	X	Flatanger and Namsos
Rogaland Fire and Rescue IKS	430		Gjesdal, Klepp, Kvitsøy, Randaberg, Sandnes, Sola, Stavanger, Strand and Time.