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Author: Marija Stevkovska Pedersen Sarah Bethune Askey	
Supervisor at UiS: Roger Flage Co-supervisor: External supervisor(s):	
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“Balance is not something you find,
it’s something you create.”

Jana Kingsford

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Summary

On New Year's Day 2020, Stavanger Municipality incorporated Finnøy and Rennesøy municipalities. With this merger came additional challenges for the risk management of the municipality. A comprehensive risk and vulnerability assessment (CRVA) was conducted to obtain a more accurate risk picture for the newly merged municipality. This assessment is used as a data source for investigating the main topic of this thesis: "Addressing the balance between preventive and consequences-reducing measures regarding avoiding drifting into failure while increasing resilience in municipalities."

In addition to the Stavanger CRVA (2019b), supporting theories and concepts on risk governance, risk management, barrier management strategies, barrier balance, systems thinking, and drifting into failure are described to assist in investigating the main topic. A qualitative research study consisting of two parts is conducted. The first area of interest is the new measures proposed in the Stavanger CRVA (2019b), resulting from their gap analysis, as access to all existing measures is unavailable. The authors have classified these measures for their preventive and consequence-reducing qualities. In addition, the measures have been classified by barrier element type; organizational, operational, technical, and citizen action. These classification results represent the municipality's distribution of measures, departmental accountability, and critical societal functions. The second area is a document search to support this research, including Norwegian laws and regulations, national publications, Stavanger municipality meeting minutes, and budget reports relevant to the Stavanger CRVA (2019b).

Results from the data and document search, combined with the theory and concepts, are used to investigate the main topic, and answer the four research questions posed in this thesis: 1. What is the current distribution between the proposed preventive and consequence-reducing measures in Stavanger Municipality? 2. Should the measures balance be different from today, and if so, why? 3. How can the measures balance be adjusted to provide a better fit for Stavanger Municipality? and 4. Is a holistic approach useful for adjusting the balance in complex organizations?

It was identified that most of the proposed measures in the Stavanger CRVA (2019b) were preventive. These measures do not represent the overall distribution of measures in Stavanger municipality since an overview of existing measures was unavailable. There is also uncertainty surrounding the implementation of the proposed measures. Most of these measures are identified as organizational using the Barrier Memorandum by the Petroleum Safety Authority of Norway as a guide.

While it is challenging to address barrier balance in Stavanger Municipality, for many reasons described in this thesis, relevant observations have been made on the relations between balance, barriers, resilience, systems thinking and drifting into failure. A key finding is that barrier management used in a municipal setting can increase focus on barrier element types, their interactions, and viewing the system holistically. Another key finding is that focusing on the emerging properties of barrier interaction can lead to drifting into failure, but this can be avoided through increased focus on developing resilience in the system.

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Acronyms

CRVA - Comprehensive risk and vulnerability assessment
NDCP – Norwegian Department of Civil Protection
PSAN – Petroleum Safety Agency of Norway
PSP – Public Safety and Preparedness
PBA – Plan and Building Act
MDSPS – Municipal Department of Public Safety and Preparedness

1. Introduction

1.1. Background

Stavanger Municipality's (2019b) comprehensive risk and vulnerability analysis (CRVA) states that the electricity supply and electronic communications (e-com) are probably the most critical infrastructures. They address this by proposing a measure to increase preparedness in the case of a long-term power outage, where the citizens should be able to be self-sufficient for 72 hours in preparation for the scenarios described below.

Harsh weather has caused a major defect in one of the main lines leading to a power outage for a significant portion of the Stavanger region. A snowstorm rages outside, winds reach up to 30 m/s, and temperatures drop below zero on a Monday morning. Staying warm is crucial in such harsh weather conditions. However, with the power outage, prepared individuals, organizations, schools, and hospitals can resort to alternative heating methods, while unprepared people face far greater consequences than cold and darkness. The subzero temperatures and the absence of heating options can cause pipes to burst, leading to further damage. The scenario presented here by the authors exemplifies societal consequences and interdependencies from (unintentional) events that arise from natural hazards and the importance of preparedness.

Furthermore, municipalities must also focus on security issues, explicitly protecting society's basic needs and vulnerabilities. Take, for example, the scenario described above with the addition of the intentional malicious action of a highly intelligent and adaptable perpetrator driven by predefined political motives – a threat. If such an actor, be it an individual, group, organization, or state, were to target and disrupt the power supply in the Stavanger region, it will cause various consequences for the society, but not significantly different than those posed by the unintentional event mentioned above. Regardless of the power outage's root cause and whether this cause is unintentional or intentional, such an event's consequences heavily affect society.

Electronic communication (e-com) failure is possible in a long-term power outage. In that case, valuable information for mitigating the problem cannot be shared easily with crisis management. The citizens will be unable to communicate with the authorities, each other, and the emergency services in case of need. These are just a few examples of a long list of interdependencies between the electricity supply, e-com, and other vital services society needs for normal functioning. Such scenarios highlight infrastructural interdependencies.

Hazard and threat-induced accidents, crises, and disasters are serious issues that societies face and try to mitigate or avoid. Managing risk in the public interest is done through policy, legislation, regulations, and laws. The Norwegian Civil Protection Act (2010) demands that life, health, the environment, material assets, and critical infrastructure and functions are protected through the use of non-military force in times of war, or when war threatens, when the kingdom's independence or security is in danger, and in the case of unwanted incidents occurring in peacetime. Thus, this law puts the responsibility for public protection and preparedness primarily with the Norwegian municipalities through a risk-based approach,

systematically identifying and archiving adverse events on their territory, assessing their likelihood and the consequences these can bring. This information must be assessed and compiled in a comprehensive risk and vulnerability analysis (CRVA) which must be regularly revised and updated in accordance with the Planning and Building Act (PBA) revisions and changes in the municipal risk picture (Civil Protection Act, 2010).

The municipality's preparedness plan for meeting these adverse events and their consequences is based on their CRVA results and must have an overview of their risk mitigation measures. As the Regulation on Municipal Preparedness Duty (2011) states, this plan must be revised at least once a year. Therefore, the local government plays a crucial role in identifying vulnerabilities, developing response plans, and implementing measures to protect necessary infrastructure and functions within their jurisdictions. The Norwegian Directorate for Civil Protection (NDCP) collaborates closely with municipalities, providing guidance and support in strengthening their preparedness capabilities (Engen et al., 2016; Fimreite et al., 2014). Municipalities serve as the frontline defenders against potential hazards and threats. Their active engagement in risk assessment, contingency planning, and coordination with relevant stakeholders is essential to ensure an effective response and swift recovery in the face of disruptions to vital aspects of society important for normal functioning (Engen et al., 2016; Fimreite et al., 2014). However, risk management does not happen in a vacuum, and the social, cultural, and political context in which a specific hazard or threat is mitigated must be considered (Aven & Thekdi, 2022; Engen et al., 2016; Fimreite et al., 2014; Renn, 2008). Decisions about risk are influenced by politics, ideology, and ethics, with the societal and administrative structure potentially being a significant risk management issue (Aven & Thekdi, 2022; Engen et al., 2016; Fimreite et al., 2014; Renn, 2008).

Balancing prevention and consequence reduction is essential to municipalities. This is why good risk management is required, where all the measures and activities are carried out so that opportunities, value creation, and development are honored, while on the other hand, losses, accidents, and catastrophes are avoided - In other words, the main risk management task is balancing value creation and protection (Aven, 2015, p. 4; Aven & Vinnem, 2007). Safety and security measures are implemented so that the likelihood and the consequences of a hazard or a threat are removed, decreased, modified, transferred, or kept to a reasonable level without impairing societal development and value creation. These measures are risk management (reducing) tools. Two fundamental strategies are commonly used for mitigating risk: the risk-informed strategy based on risk assessment and the strategy based on the cautionary/precautionary principles that use robust and resilient arrangements and measures (Aven & Kristensen, 2019). In Norway, The Civil Protection Act (2010) and The Security Act (2019) require risk management in public safety and preparedness based on a risk-informed strategy.

There is not much research published on balance between municipal preventive and consequence-reducing measures in the Norwegian context per se. The balance between protection and resilience has been discussed in part previously by researchers such as Baskerville et al. (2014), Bristow & Hay (2014), and Haimes et al. (2008). On the other hand,

the petroleum industry has worked on barrier management for many years and has several publications that build on each other, resulting in the latest Barrier Memorandum (2017). However, even this publication warns that organizational and operational barriers are not considered as much as they should (PSAN, 2017).

Stavanger municipality represents a complex, tightly coupled system of systems, both internally and externally, with many interdependencies between the services they provide, the services they need, critical national infrastructure, and functions necessary for everyday operations. The assets and vulnerabilities in this system are of all categories (technical, operational, organizational, and human), which means that implementing adequate measures in Stavanger municipality requires considering interdependencies and the potential for these measures to introduce new risks, vulnerabilities, and even more interdependencies, all while facilitating societal development. The distribution of preventive and consequence-reducing measures is investigated by looking into the proposed measures from Stavanger municipality's CRVA (2019b) to see how the political context influences the measures and how the balance could be necessary for increasing resilience while avoiding drifting into failure. The reliable operation of infrastructure is vital for public safety, economic stability, and society's overall well-being (O'Rourke, 2007).

In this thesis, municipalities are defined as dynamic-adaptive, complex, tightly coupled systems, for which Dekker (2011) uses the metaphor "living organisms". In such systems, machine safety models are insufficient, and a different, more holistic approach is necessary while simultaneously considering all systems' interdependencies, internally and externally. However, there might be a potential for municipalities to learn from technical safety in the Norwegian Petroleum Industry regarding a holistic approach to barrier management, which will be discussed further in this thesis.

1.2. Motivation and Goal for Thesis

The motivation for this thesis was to look deeper into organizing public safety and preparedness in Norway on a municipal level, as municipalities are regarded as the closest governmental level to the citizens. In addition, the motivation is to understand if Stavanger municipality, regarded as a complex system, achieves a holistic approach to barrier management, balancing preventive and consequence-reducing measures and their interdependencies.

This thesis aims to investigate the distribution of the proposed measures in Stavanger municipality to determine if the current distribution enhances resilience and avoids drifting into failure. Enhancing resilience and avoiding drifting into failure is essential to address the challenges posed by hazards and threats. According to Aven & Thekdi (2022), resilience is a system's capacity to withstand disruptions and rapidly recover while minimizing societal impacts. It involves proactive measures to identify vulnerabilities, enhance preparedness, and establish effective response and recovery mechanisms. By incorporating redundancy, diversification, and robustness into critical infrastructure systems, their ability to resist and recover from various threats can be enhanced (Aven & Thekdi, 2022).

However, building resilient infrastructure alone is insufficient. It is crucial to prevent gradual deterioration and drifting into failure over time. Drifting into failure occurs when unnoticed and incremental changes accumulate, eventually leading to catastrophic events or system collapses (Dekker, 2011). Therefore, ongoing monitoring, maintenance, and proactive management of critical infrastructure are vital. Early warning signs must be identified, potential failures addressed, and appropriate corrective actions implemented to prevent the gradual deterioration that could compromise the resilience of these systems (Aven & Thekdi, 2022; Dekker, 2011).

Several issues are raised in this thesis; not all of them are meant to be answered but merely to be brought into the spotlight for further research. The thesis will delve into critical infrastructure, public safety, risk analysis and management (barrier management), aiming to explore some of the challenges, methodologies, and strategies involved. Specifically, it will examine the distribution of risk reduction measures, namely the preventive and consequence-reducing measures proposed in the Stavanger CRVA (2019b), as classified by the authors.

The main goal of the thesis is to look into the distribution of the Stavanger municipalities' proposed measures and, through the theoretical approach, understand 1. The current barrier balance, 2. If the barrier balance needs adjusting? 3. How can balance be achieved? and 4. If municipalities drifting into failure can be avoided by increasing resilience? The thesis title summarizes all the key aspects of the thesis.

"***Addressing the balance between preventive and consequences-reducing measures regarding avoiding drifting into failure while increasing resilience in municipalities.***"

Approaching the thesis through the chosen theoretical framework should give an insight into the difference between approaching barriers as a system as opposed to silo thinking and individually approaching each barrier. The following section will elaborate on the four research questions posed to address this thesis's main points, how they are approached, and to what end.

1.3.Research Questions

In order to build sound arguments and a deeper understanding of the thesis problem, four research questions are posed. The research questions are seen in the light of the theory in section 2. and empirical findings and results in section 4. and create the basis for answering the thesis problem statement. They are as follows:

1. *"What is the current distribution between the proposed preventive and consequence-reducing measures in Stavanger municipality?"*. The answer to this question is descriptive through reviewing the Stavanger Municipality's CRVA (2019b) document, specifically appendix C, and examining the distribution between proposed measures as categorized by the authors.

2. *"Should the measures balance be different from today, and if so, why?"* will discuss how important the balance of risk-reductive measures is both in the Stavanger municipality and generally as presented in the literature on the topic.

3. *"How can the measures balance be adjusted to provide a better fit for Stavanger municipality?"* Not much research has been conducted explicitly on the distribution of measures in municipalities. However, a normative approach through a literature study on the topic is suggested by combining generic risk science, risk management, and barrier management.
4. "*Is a holistic approach useful for adjusting the balance in complex organizations?".* Applying the systems thinking theory and perspective of drifting into failure in addition to the abovementioned literature will emphasize the importance of the holistic approach to barrier management in municipalities and why this type of organization should devote themselves to the same vision.

In order to adequately address these inquiries, it is imperative to take a multifaceted approach. The first answer is a descriptive discussion on Stavanger municipality's current balance of risk reduction measures. The second answer is the literature study discussion using various concepts to understand why achieving a holistic approach in bureaucratic organizations like Stavanger municipality is not so easy. The third and fourth answers are normative, as these answers are meant to increase awareness of the importance of a holistic view in risk management for complex systems.

1.4. Thesis Structure

This thesis will be structured to assist with answering the research questions.

Section 2. gives the theoretical framework for this thesis. First, a model reflecting the author's approach to the theory and discussion will be presented as an introduction to this section. Then, risk governance is presented, focusing on the Norwegian context.

In addition, the risk management part will be split into minor sections presenting the bow-tie model, barrier management and strategy, and the author's view on barrier balance.

Lastly, systems thinking and drifting into failure theory and perspective will be presented to elevate their importance in effective and efficient risk management.

The theory part can appear extensive. However, this can be due to relatively new risk science, where concepts, approaches, theories, and perspectives are still not consolidated and overlap. This thesis will not look into the conceptual issues but will merely shed light on the fact that there is more work to be done in the field of risk science, especially when it comes to complex systems of systems organizations, such as Stavanger municipality.

Section 3. describes and discusses the chosen research design and method strategy. Qualitative data collection methods and a section on the validity, reliability, and research ethics relevant to data collection are described. Lastly, this section will discuss the strengths and weaknesses of the research and the limitations of the results and discussion.

Section 4. presents the results in two parts. First are the data results - the overview of data collected from Appendix C of the Stavanger CRVA. Following this, a description and visual representation of the distribution of proposed measures and the organizations responsible for each measure will be presented. The document search is then presented, consisting of the Stavanger Municipality's CRVA (2019b), Norwegian laws and regulations, reports, guides, and other relevant national publications, creating the data basis for this thesis.

Section 5. presents and discusses the findings in Sections 3., and 4. through the theoretical framework in Section 2. The discussion aims to investigate the research questions thoroughly, determine whether the distribution of measures needs modification, and explore the most effective ways to achieve this, emphasizing the importance of adopting a holistic approach to managing complex organizational barriers, ergo, their balance. Lastly, a section presenting overall reflections from the research and discussion points is presented.

Section 6. presents a comprehensive conclusion summarizing the paper's key findings and proposing areas for further research.

2. Theory

The theoretical framework used in this section serves to present relevant existing concepts, models, and theories in five subsections. The first subsection addresses relevant concepts and provides definitions and explanations for risk, barriers, safety, security, vulnerability with robustness and resilience, critical infrastructure, and public safety concepts. The second subsection describes the thesis model created by the authors to present the steps of Norwegian public safety and preparedness (PSP) work that protect basic human needs, critical infrastructure, and functions, including risk management (with barrier management) and governance. The model is a circle placed between resilience and drifting into failure. Detailed reader guidance for the model is presented here as well. Risk governance, including Norway's approach, is described in subsection three. Risk management with tools and strategies, like the bow-tie model, risk assessment, barrier management, defense in depth, and the concept of barrier balance, comprise subsection four. Lastly, subsection five will describe systems thinking, including drifting into failure.

2.1. Concepts, Definitions, and Explanations

This subsection will briefly introduce the concepts of risk, barriers, safety, security, vulnerability, robustness, resilience, critical infrastructure, and public safety. These concepts are critical for the thesis discussion.

2.1.1. Risk and Risk Related Concepts

In the most general form, " Risk is the potential for undesirable consequences" or "Risk is the two-dimensional combination of the consequences C of the activity (with respect to something that humans value) and associated uncertainties about C". (Aven & Thekdi, 2022, p. 304)

Risk Source

A risk source is an element that can potentially create consequences for something humans value. Risk sources can be either an action, sub-action, component, system, or event, among other things, which can stand alone or combine with other elements. Risk sources usually bring adverse consequences (Aven & Thekdi, 2022, p. 304).

Hazard

"A risk source where the potential consequences relate to harm. Hazard could, for example, be associated with energy (e.g., explosion, fire), material (toxic or eco-toxic), biota (pathogens) and information (panic communication)". (Aven & Thekdi, 2022, p. 302)

Threat

A threat is a risk source usually used in security applications, but not exclusively, as it can be used in the threat of an earthquake. When used concerning an attack, the threat is defined as

follows: “A stated or inferred intention to initiate an attack with the intention to inflict harm, fear, pain or misery” (Aven & Thekdi, 2022, p. 305).

Risk Picture

“The risk picture is an understanding and overview of potential failure, hazard and accident situations and how to protect against them” (PSAN, 2017, p 9).

Event

“The occurrence or change of a particular set of circumstances such as a system failure, an earthquake, an explosion or an outbreak of a pandemic”; or “A specified change in the state of the world/affairs”. (Aven & Thekdi, 2022, p. 302)

Consequence

“The effect of the activity, with respect to the values defined (such as human life and health, environment, and economic assets), covering the totality of states, events, barriers and outcomes. The consequences are often seen in relation to some reference values (planned values, objectives, etc.), and the focus is often on negative, undesirable consequences.” (Aven & Thekdi, 2022, p. 302)

Uncertainty

An overall uncertainty concept definitions given by Aven & Thekdi (2022) are:

- “For a person or a group of persons, not knowing the true value of a quantity or the future consequences of an activity” (p. 305).
- “Imperfect or incomplete information/knowledge about hypothesis, a quantity or the occurrence of an event” (p. 305).

Knowledge

Aven & Thekdi (2022) list two types of knowledge:

- “Know-how (skills), and;
- know-that of propositional knowledge (justified beliefs).” (p. 302)

They also state that “knowledge is gained through scientific methodology, peer review experience and testing” (Aven &Thekdi, 2022, p.302)

Complex/complexity

“A system is complex if it is not possible to establish an accurate prediction model of the system based on knowing the specific functions and states of its individual components”. (Aven & Thekdi, 2022, p. 301)

“Complexity: A casual chain with many intervening variables and feedback loops that do not allow the understanding of prediction of the system’s behavior on the basis of each component’s behavior”. (Aven & Thekdi, 2022, p. 301)

2.1.2. Barriers and Related Concepts

According to the (PSAN, 2017), a barrier is defined as

> *“*A measure intended to identify conditions that may lead to failure, hazard, and accident situations, prevent an actual sequence of events occurring or developing, influence a sequence of events in a deliberate way or limit damage and/or loss.” (PSAN, 2017)

Barrier Function

“The task or role of a barrier” (PSAN, 2017).

Barrier Element

“Technical, operational and organizational measures or solutions involved in the realization of a barrier function” (PSAN, 2017).

Barrier strategy

“Plan for how barrier functions, on the basis of the risk picture, are implemented in order to reduce risk” (PSAN, 2017).

Barrier management

“Coordinated activities for establishing and maintaining barriers so that they fulfil their functions at all times” (PSAN, 2017).

Plan-Do-Check-Act Feedback loop

Williams (2020) states that the Plan-Do-Check-Act feedback loop is a useful management tool as it does not involve significant changes to the management system and can be incorporated into existing programs. The planning step refers to choosing goals and the means to achieve them. This is followed by actually doing what was planned. The next step is confirming that what was said would be done. Checks are important for avoiding surprises and can consist of formal audits for systems. The Act step is to review processes and change and adjust the plans. These steps are used in a loop of continual improvement (Williams, 2020).

Barrier Performance requirement

“Verifiable requirement for the properties of the barrier elements in order to ensure that the barrier is effective” (PSAN, 2017).

Barrier Performance- influencing factors

“Factors identified as having significance for barrier functions and the ability of barrier elements to function as intended” (PSAN, 2017).

2.1.3. Safety

Aven & Thekdi (2022) define safe as “without unacceptable risk” (p. 304). Further, they define safety as:

- “Interpreted in the same way as safe, and;
- The antonym of risk (the safety level is linked to the risk level; a high safety level means a low risk level, and vice versa)”. (p. 304)

2.1.4. Security & Security Management

One definition of security that includes the resilience aspect is given by Jore (2019):

> “Security can be defined as the perceived or actual ability to prepare for, adapt to, withstand, and recover from dangers and crises caused by people's deliberate, intentional, and malicious acts such as terrorism, sabotage, organized crime, or hacking.” (p. 169)

Security risk management, according to Jore (2019), "…includes assessing and reducing the likelihood and consequences of possible attacks by applying various types of risk-reducing measures. For example, by establishing critical infrastructure protection and by building organizational and societal resilience" (p. 169).

2.1.5. Vulnerability, Robustness & Resilience Concepts

Vulnerability

“Vulnerability is risk conditional on the occurrence of a risk source/agent” (Aven & Thekdi, 2022, p. 305). In addition, Engen et al. (2016) state that vulnerability can be seen as the system’s ability to function or be negatively affected by an adverse event. It can also be said that it is the weakness or ability of an organization, city, or country to resist, adapt or develop functionality after an adverse initiating event. Low vulnerability means the system can function even if a disruption occurs, while high vulnerability is the opposite. The vulnerability has reactive properties as it develops over a more extended period in a system without anyone noticing (Engen et al., 2016, p. 47).

Even though vulnerability can apply to any system, we can differentiate between technological and societal systems. The difference lies in the notion that a technological system's vulnerability

is about restoring the ability to function normally. On the other hand, in societal systems, the aspects of change and adaptation also apply in addition to the restoring aspect (Engen et al., 2016, p. 47). However, a more holistic and complex approach to vulnerability is necessary in socio-technological systems.

Robustness

Robustness is the antonym of vulnerability and has considerable magnitude and importance as a concept. It is also tightly linked to other important concepts for public safety, as adaptation, flexibility, and resilience (Engen et al., 2016, p. 48). It refers to how well we are prepared for known risks and "to the insensitivity of performance to deviation from normal conditions" (Aven, 2011, p. 12). However, robustness and vulnerability concepts are closely linked, and one should see them in connection as if they are on the opposite poles of an axis. These two concepts have a fluid relationship. When there is high robustness, the vulnerability is low, and vice versa.

Redundancy

According to Haimes et al. (2008), redundancy refers to having components take over for other damaged parts of the system seamlessly without affecting the system's performance. He continues by stating that maintaining redundancy and robustness can support the resiliency of a system. Both redundancy and robustness can serve as protective elements to increase the 'hardness' of a system.

Robustness & Resilience Strategy

Aven & Thekdi (2022) give a broad conceptual definition of resilience as follows: "Resilience is the ability of the system to sustain or restore its basic functionality following a risk source or an event (even unknown events) (p. 303)." They further define a resilient system as "…a system for which the resilience is judged high (this is a value judgment) (p. 303)". Resilience is an important objective when the desire is to build systems that can withstand surprising events and even tolerate them.

Further, Aven (2011) puts resilience in contrast to robustness, as robustness is a more proper strategy in case of known potential hazards and threats, while resilience "is a protective strategy against unknown or highly uncertain events" (p. 12). Thus, robustness and resilience are closely related but are not the same thing and require different processes and instruments (Aven, 2011, p. 13).

Furthermore, resilience is a crucial protective strategy against unforeseen or unthinkable events, and critical instruments for it include "the strengthening of the immune system, diversification of the means for approaching identical or similar ends, design of systems with flexible response options and the improvement of conditions for emergency management and system adaptation" (Aven & Renn, 2010, p. 129). The level of resilience in an organization or a system is directly linked to the ability to restore basic functions after the occurrence of an initiating event. Resilient systems can (Hollnagel, Woods, & Leveson 2006):

- respond to regular and irregular threats in a robust yet flexible (adaptive) manner,
- monitor what is going on, including its performance,
- anticipate risk events and opportunities,
- learn from experience

The EU defines resilience as "The ability of an individual, a household, a community, a country or a region to withstand, cope, adapt, and quickly recover from stresses and shocks such as violence, conflict, drought, and other natural disasters without compromising long term development" (EU, n.d.).

Haimes et al. (2008) describe resilience as the ability of systems to recover after an incident with acceptable time and cost and avoid damage to a reasonable amount. He further discusses two resilience perspectives, one static and the other dynamic. The static perspective of resilience describes the ability of a system to recover to an amount in line with performance goals after an incident while still avoiding significant losses (Haimes et al., 2008). The dynamic view of resilience is that an unavoidable period of disruption will follow an incident. If the recovery time comes at an acceptable cost, then resilience can be achieved; however, evaluating and measuring resilience can be complicated and complex (Haimes et al., 2008).

The concept of resilience is developing. When addressing resilience in socio-technological systems, such as resilience in municipal work with public safety and preparedness, we are addressing ***community resilience***, defined as "…the overarching attribute that reflects the degree of community preparedness and the ability to respond to and recover from a disaster" (O'Rourke, 2007). Bruneau et al. (2003) conceptualize resilience by having four distinct infrastructural qualities:

- **Robustness:** the inherent strength or resistance in a system to withstand external demands without degradation or loss of functionality.
- **Redundancy:** system properties that allow for alternate options, choices, and substitutions under stress.
- **Resourcefulness:** the capacity to mobilize needed resources and services in emergencies.
- **Rapidity:** the speed with which disruption can be overcome and safety, services, and financial stability restored.

2.1.6. Critical Infrastructure & Functions

The critical societal function is defined in the MEREPUV project as " a function of such importance that it is loss or severe disruption could entail major risks for the life and health of the population, the functionality of society or society's fundamental values" (NDCP, 2019b).

Critical infrastructure and functions refer to the essential facilities, systems, and services, or parts of these, necessary to maintain central societal functions. These are human health, safety, security, and financial or social welfare, including transportation networks, telecommunications, water supply, energy grids, waste disposal, and more. In other words, all

those parts of society where operational disruption or destruction could lead to large societal consequences (NDCP, 2012; NOU, 2006; O'Rourke, 2007; Civil Protection Act, 2010).

2.1.7. Public Safety

Public safety as a concept is ambiguous and debated politically and academically. There is an understanding in academia that public safety should be divided into safety and security. Safety denotes accidents from unintentional actions, while security denotes intentional actions by intelligent, adaptive perpetrators with political motives, malicious intent, and the capability to succeed with an attack (Jore, 2019). In Norway, public safety is defined in a way that it incorporates both safety and security as follows [original]:

> "Samfunnssikkerhet er samfunnets evne til å verne seg mot og håndtere hendelser som truer grunnleggende verdier og funksjoner og setter liv og helse i fare. Slike hendelser kan være utløst av naturen, være et utslag av tekniske eller menneskelige feil eller bevisste handlinger." (Meld. St. 10 (2016–2017), p. 9)

Translated by the authors:

> Public safety (civil protection) is the societal ability to confront, protect itself against and deal with events that threaten fundamental values and functions, and endanger life and health. Such events can be triggered by nature or can be the result of technical and human errors or deliberate actions. (Meld. St. 10 (2016–2017), p. 9)

The main goal of public safety, as per the definition above, is to maintain the ability of critical societal infrastructure and functions through preparedness and actions to return to normal functions after a significant crisis. Engen et al. (2016) state that societal ability means the institutional capacity and capability with all the material, organizational and human resources to deal with extraordinary events (p. 45).

A crucial aspect of public safety is that it cannot be seen as only a local issue in a modern complex global society. It is a matter of national governing as it closely relates to how the society is governed as a whole. There is a link between events that happen on the global and international level and consequences manifesting on a local level, where it is the municipalities' responsibility to be prepared for such events and mitigate their consequences.

Preparedness

Preparedness can be defined as all the measures for preventing, limiting, or mitigating unwanted extraordinary events (NOU, 2000: 24). The goal of preparedness is to predict possible threats and other challenges so that they can be effectively mitigated by establishing necessary resources and equipment (Engen et al., 2016, p. 280).

2.2. Risk Governance Influence on Civil Protection Model

The model presented in Figure 1. helps to guide the authors and readers in understanding the link between the various aspects presented in the theoretical framework, the results, and the discussion.

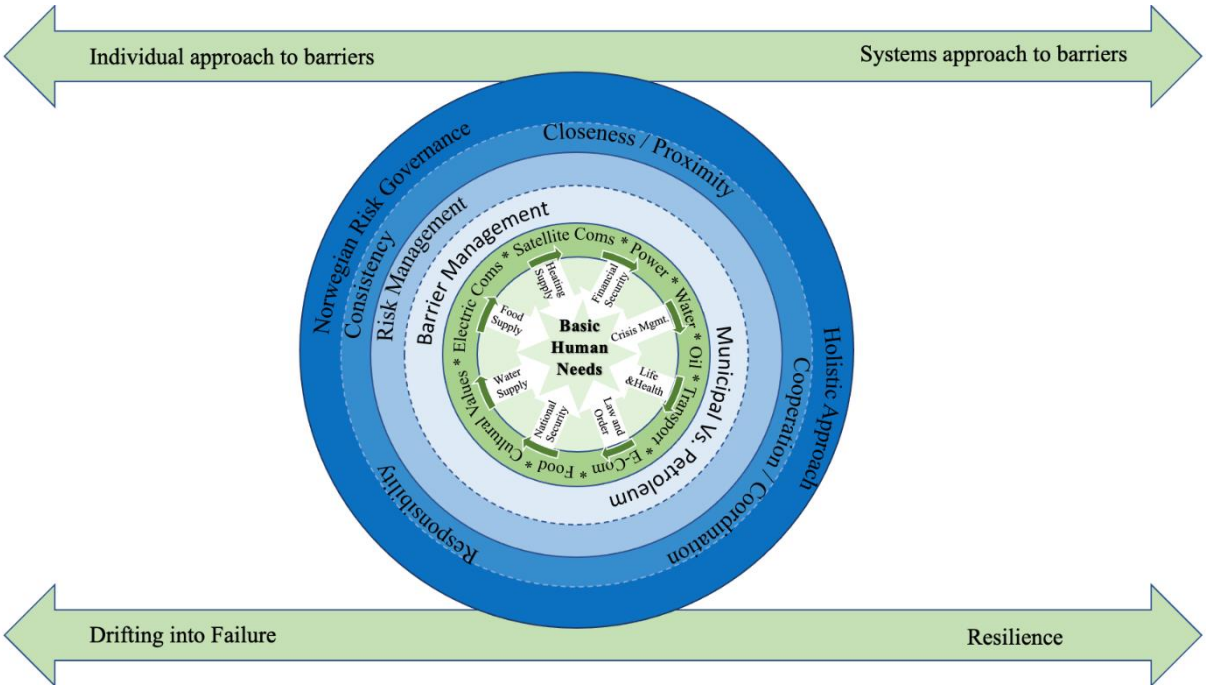

Figure 1. Risk Governance Influence on Civil Protection Model created by the authors. Representation of elements influencing public safety and preparedness work (broad risk management that includes governance) and how an individual barrier (static) approach drifts the organization into failure, while a holistic (dynamic) approach to barriers, inspired and adapted from (NDCP, 2012; PSAN, 2017).

Reader's Guidance of Figure 1

Figure 1. is a visualization of the theory used in this thesis. It represents all the elements the authors found relevant and dependent on each other in order to investigate and attempt to answer the complex question of what the municipality's approach to barrier management (individual or system) is, as well as to suggest norms on how to approach municipalities' barrier management so that to some level drifting into failure is avoided while resilience increases.

The figure should be read from the center of the circle and outwards. In the very center, the basic human needs are presented. In addition, the circle's center represents the critical infrastructure and functions needed to obtain these basic human needs. The green arrows visualize that there are interdependencies between these elements. The rings in Figure 1. are inspired by the KIKS project (2012) model, slightly modified and supplemented with the model from the Petroleum Safety Authority of Norway (PSAN) *Barrier Memorandum* (2017), and with what the authors regard as a holistic approach (NDCP, 2012).

Each ring from the center and outwards represents the next level of processes linked to Norway's PSP. The outer ring represents the Norwegian risk governance and aims to show how the governing model largely influences the balance of the measures and the PSP work. The

Community of Stavanger is governed under several laws, the Civil Protection Act (2010), the Regulation on Municipal Preparedness Duty (2011), the Planning and Building Act (PBA) (2009), and The Security Act (2019). As a public office, the municipality facilitates preparedness and protects the critical infrastructure and its citizens governed by the abovementioned laws and regulations, so removing the political aspect from public safety and preparedness work is impossible and must be considered in this thesis.

The interesting part is between Norwegian risk governance and protecting critical infrastructure and functions tending to basic human needs. This is where risk management finds its place, with all the tools and approaches. Barrier management is one of these tools. PSAN gives clear guidance on barrier management through the 2017 barrier memorandum for the petroleum industry (PSAN, 2017). On the other hand, the NDCP guides the PSP work and how CRVA should be conducted but does not explicitly guide barrier management. Regardless, the barrier management element is presented in the model, as it is assumed that municipalities do have a type of barrier management without naming it as such.

The model's center is a circle that can roll on each side of the axis based on the organization's approach to barriers and the political context. The model's axis represents the trajectory of PSP work considering the organizational risk management focus on barriers. The assumption is that more weight given to individual barriers leads the circle towards drifting into failure, while more weight to the holistic approach rolls the circle towards resilience.

2.3. Risk Governance

Risk management can be viewed narrowly or broadly (Aven & Thekdi, 2022, p. 201). Risk governance is a part of broad risk management, and this thesis is based on this view. Aven & Thekdi (2022) use the risk governance concept to refer to applying various governing principles for risk management. These principles include the aspects of participation, accountability, effectiveness, coherence, proportionality, and subsidiarity. Risk governance is the application of governance principles for handling risk, as all the actions, processes, traditions, and institutions have the authority to decide and implement risk-reducing measures (Aven & Thekdi, 2022).

On the other hand, Aven (2008) defines the narrow approach to risk management as focusing on the minutiae of the risk analysis procedure, including the identification, analysis, and strategies used to characterize risk and measures used to prevent it (p. 5). By focusing on both approaches to risk management, the risk situation can be addressed holistically.

Risk management is closely related to (public-) policy and governance. Aven (2016) states that policy is "… a principle or plan to guide decisions and achieve desirable outcomes, and the term applies to international organizations, governments, private sector organizations and groups, as well as individuals". In addition, Versluis et al. (2011) understand policy "…as a deliberate course of (in-)action selected from among available alternatives to achieve a certain outcome" (p. 11).

Versluis et al. (2011) consider public policy of modern society as closely linked to societal perception of governmental functions, meaning those areas that are socially acceptable and justifiable where the state should act, giving it some political legitimacy (p. 12). Thus, governance is central in politics and democratic societies.

The Organization for European Cooperation and Development (OECD, 2009) urged central governments to adopt a broader view on risk. Silo thinking, where hazards and consequences are addressed separately, should be avoided. A more holistic approach is desired to address multiple hazards and vulnerabilities and their interdependencies. This broader view, however, requires more complex coordination between the public and the private sector in terms of better risk governance. This broader view, however, requires more complex coordination between the public and the private sector in terms of better risk governance.

2.3.1. Norwegian Risk Governance & Public Safety and Preparedness

Risk management does not happen without any political aspect involved. Engen et al. (2016) state that decisions about risk usually have a political aspect (p. 167). Internationally the concept of governance is used for guiding state management and control. In Norway, Røiseland & Vabo (2016) use this concept to describe the non-hierarchical coordination and cooperation between the state, public actors, and their resources.

Risk management-related policies can be made by the private and the public sector. Making decisions politically, in enterprises, or various organizations and institutions and implementing these are usually denoted as governing. Figure 2. visualizes the overlapping influence of the parties involved in the risk governance process.

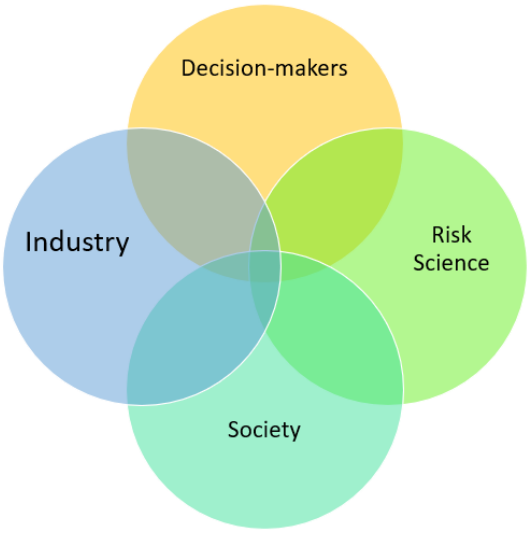

Figure 2. The overlapping influence of the parties concerned in risk governance processes. Created by the authors.

The Civil Protection Act (2010), the Regulation on Municipal Preparedness Duty (2011) together with the Guide on Municipal Preparedness Duty regulation (NDCP, 2021), and the PBA (2009) assign municipalities the responsibility and guidance for public safety and preparedness, where all the material, organizational and human resources must be available and accessible in crises, Figure 3 (Engen et al., 2016, p. 46).

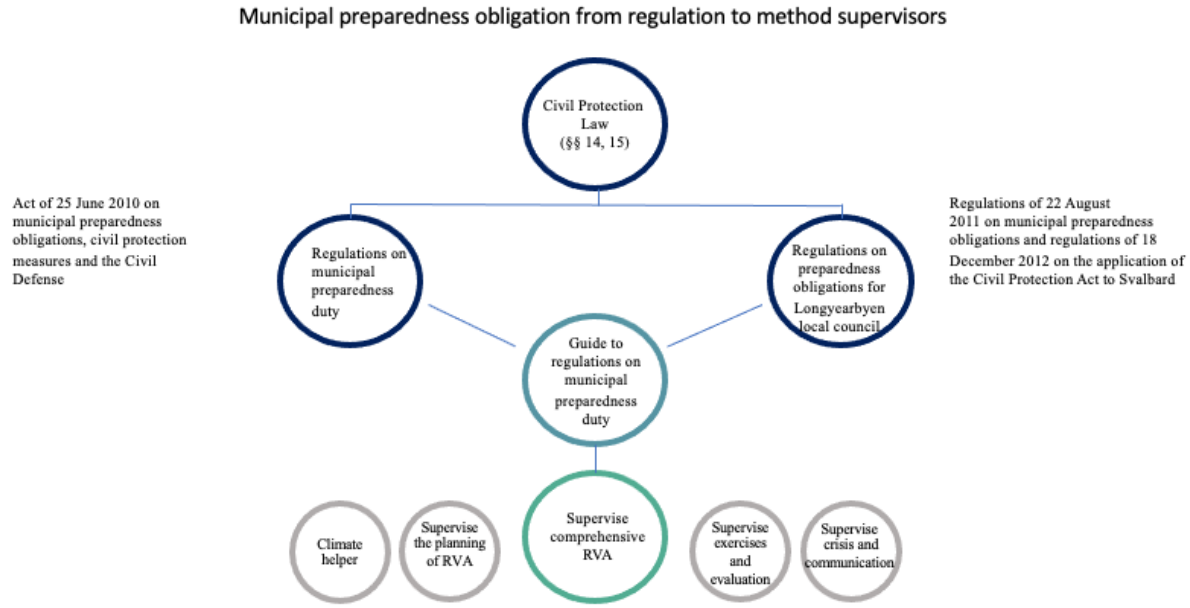

Figure 3. Model by NDCP of the laws and regulations influencing measures in Norwegian public safety and preparedness (NDCP, 2014)

PSP is a policy area that encompasses complex, cross-organizational, and administrative policy challenges related to specialization, coordination, and multi-level governance in the political-administrative system (Fimreite et al., 2014, p. 20). The work with PSP is linked to the national level (Engen et al., 2016, p. 46). Its goal is to prevent crises, prepare to cope and mitigate them and recover by protecting national infrastructure, functions, and citizens. However, we should be aware of the potential national crises have on influencing both the local and international levels because of value chains and interdependencies, and vice-versa (Engen et al., 2016, p. 46).

Norwegian PSP is managed by four main principles: responsibility, closeness (proximity), consistency, and cooperation/coordination (Engen et al., 2016; Fimreite et al., 2014; Stavanger Municipality, n.d.). These principles must be followed regardless of the level of authority from which a crisis is managed, and one must always be aware of the principles (Engen et al., 2016, p. 283).

First, NDCP supervises and regulates public safety through the ***responsibility principle***. This department provides a joint authority from the local level to the central level of fire, rescue, prevention, and preparedness (Fimreite et al., 2014, p. 16). The responsibility principle means that each government department and state authority is responsible for public safety within its jurisdiction (Fimreite et al., 2014, p. 16). This principle is problematic as it is based on the minister doctrine, and the specialization by sector is central (Fimreite et al., 2014, p. 16). The municipality of Stavanger has its own department for PSP work.

Secondly, according to Fimreite et al. (2014), ***the closeness (proximity) principle*** implies that mitigation should be done at the lowest possible level of the societal and organizational structure in crises, such as the municipalities and the county (Fimreite et al., 2014, p. 17). The logic behind this principle is that those authorities closest to the crises will have the best understanding of the situation and, with this, the best starting point for crisis mitigation (Engen et al., 2016, p. 51). The county governor's office is central in working with PSP as this office is responsible for coordinating vertically and horizontally to optimally use all the available and necessary resources for increasing public safety (Fimreite et al., 2014, p. 17). This principle is linked to local self-governing and is central to Norwegian municipalities' operations. This means that municipalities can govern public safety through their policy and measures, and in principle, the state cannot easily overturn them. It also means that the PSP work is bound by the territorial boundaries of the municipality (Fimreite et al., 2014, p. 17). An interesting aspect of this risk-governing principle is that it requires good cooperation/coordination horizontally and vertically (Fimreite et al., 2014, p. 17).

Third, ***the consistency principle*** implies that organizations must keep their structure under crises. Fimreite et al. (2014) state that implementing this principle is the most challenging (Fimreite et al., 2014, p. 17).

Last is ***the cooperation (coordination) principle***. Public safety is most effective if there is a cooperation between all relevant public and private stakeholders, in other words, vertically and horizontally (Fimreite et al., 2014, p. 17). This principle also entails that the authority or the organizations are responsible for creating and maintaining good cooperation with other relevant actors and organizations regarding prevention, preparedness, and crisis management (Engen et al., 2016, p. 51).

In addition, vertical coordination is sector-based coordination between levels of administration, either ministry and directorate or local and central state administration, but also between state and municipality. Horizontal coordination is between policy areas or sectors at the same level, as between policies for public safety and the various sector policies related to transport, energy, and health (Fimreite et al., 2014, p. 22).

It is ultimately up to the municipalities' political leadership to decide on the course of action regarding any identified risks and vulnerabilities (Aven et al., 2004, p. 105). Their leadership and decision-making skills will be crucial in ensuring the safety and well-being of their communities. The politicians must choose which of the proposed measures should be implemented and their prioritizations. It is also up to the political leadership of the municipality to decide on the distribution of safety and security measures. They are the ones who decide whether they should emphasize preventive or protective measures. Risk management in public safety is a political decision.

2.4. Risk Management and Strategies

To effectively manage risk, it is crucial to balance development and protection rather than simply strive for risk reduction. Taking a holistic approach and considering all relevant factors

is essential, as risk cannot be viewed in isolation (Aven & Thekdi, 2022). While it is hypothetically possible to achieve zero risk, this would require refraining from any actions toward development, which could hinder opportunities for value and benefits. At times, taking risks is imperative for achieving progress.

SRA (2018) defines the overall risk management process as follows:

> "…all measures and activities carried out to manage and govern risk, balancing developments and exploring opportunities on the one hand, and avoiding losses, accidents, and disasters on the other. In general, the proper risk level is a result of a value and evidence/knowledge-informed process, balancing different concerns. To generate value, risk-taking is needed. How much risk to accept in pursuit of value is context-dependent and depends on how values are weighted." (sec. 4)

Successfully managing risk involves generating value while minimizing incidents, accidents, or losses. While avoiding or preventing adverse events is ideal, it may not always be feasible, particularly in complex and interconnected systems (Aven & Thekdi, 2022, p. 201). In such systems, the potential for surprises is always present. Therefore, it is also critical to focus on decreasing vulnerability and handling the ramifications of any initial events (Aven & Thekdi, 2022, p. 201). Generally, the risk management process is about considering alternatives and evaluating their pros and cons to make a decision that will align with the decision-makers values and priorities (Aven & Thekdi, 2022, p. 202). Risk assessment is the input for decision makers who, through managerial review and judgment, will consider this input with other relevant issues not part of the assessment. Managerial review and judgment take in all important aspects to make a final decision, not only those raised in the risk assessment (Aven & Thekdi, 2022, p. 202). Stavanger Municipality systematically makes prevention and consequence-reduction decisions, supported by a risk-based approach regarding hazards and threats.

In addition, Aven & Thekdi (2022) categorize risk problems as simple, uncertain, and those that create value differences. Risk-management strategies are then categorized as risk avoidance, reduction, transfer, and acceptance (Aven & Thekdi, 2020, p. 206). All of these need different approaches to be mitigated. Choosing the appropriate risk management strategy is vital because all hazards and threats bring specific consequences and uncertainties. Not applying the correct strategy would lead to valuable information being lost in risk management and decision-making under uncertainty, leading to insufficient/inappropriate protection (Aven & Thekdi, 2022, pp. 205–208).

The choice of strategy is also directly linked to the choice of barriers. Not having the proper strategy will lead to not having the appropriate barriers. However, Aven (2015, 2016), Renn (2008), and Aven & Thekdi (2020, 2022) state that in many cases, a combination of the strategies would be the most appropriate approach to mitigating risk. The knowledge dimension is of utmost importance for making decisions about risk management strategies (Aven, 2015).

There are two fundamental and commonly used risk management strategies - risk-informed and the one based on the cautionary/precautionary principle. These strategies employ

robust/resilient measures to mitigate potential risks (Aven, 2015, 2016). The choice of strategy depends on the context, knowledge dimension, vulnerabilities, hazards, threats, consequences, and their magnitude. Further details on the abovementioned strategies are explained in the following section.

2.4.1. Risk-informed Strategy

The risk-informed strategy incorporates risk assessment (risk analysis + evaluation) and risk treatment (avoidance, reduction, transfer, and retention) (Aven, 2015). It is based on risk assessment in an absolute or relative way, and for this, we must be aware of the limitations this tool has, as it sometimes does not reflect all aspects of risk (Aven, 2016). Usually, these limitations are a poor reflection of uncertainties and a lack of knowledge (Aven & Kristensen, 2019).

Risk Assessment

Risk assessment is the systematic process of identifying risk sources, threats, hazards, and opportunities, their occurrence, and consequences represented through probabilities that describe the uncertainties to determine the risk significance using relevant criteria (Aven, 2016; Hansson & Aven, 2014). Risk assessments can also represent and describe the knowledge base, or for that matter, the lack of it, and other criteria necessary for evaluating the reliability and validity of the assessments' scientific weight (Aven, 2016; Hansson & Aven, 2014). Often, risk assessments are conducted so that regulatory requirements are met. If the sole reason for conducting a risk assessment is the regulatory requirements, the full potential of the assessment can be missed (Aven & Thekdi, 2022, p. 63).

According to Aven & Thekdi (2022), risk assessment is an analytical and guiding tool in risk management on which the decision-makers base their decision on balancing value creation and protection. The challenge for the decision-makers is understanding that risk assessments do not convey one most appropriate decision but reflect on aspects of the risk concept, making it easier to understand the risk picture (Aven & Thekdi, 2022, p. 195). The risk assessment is only one significant part of the risk management process, and it paints a picture of what we know, how well we know it or do not, and our options (Aven & Thekdi, 2022, p. 195). However, the risk assessment does not consider societal priorities, values, and preferences regarding specific risks, which are not always aligned with the risk assessment solutions. The balance between value creation and protection is not science per se but is about human values, ethics, management, and politics (Aven & Thekdi, 2022, p. 195).

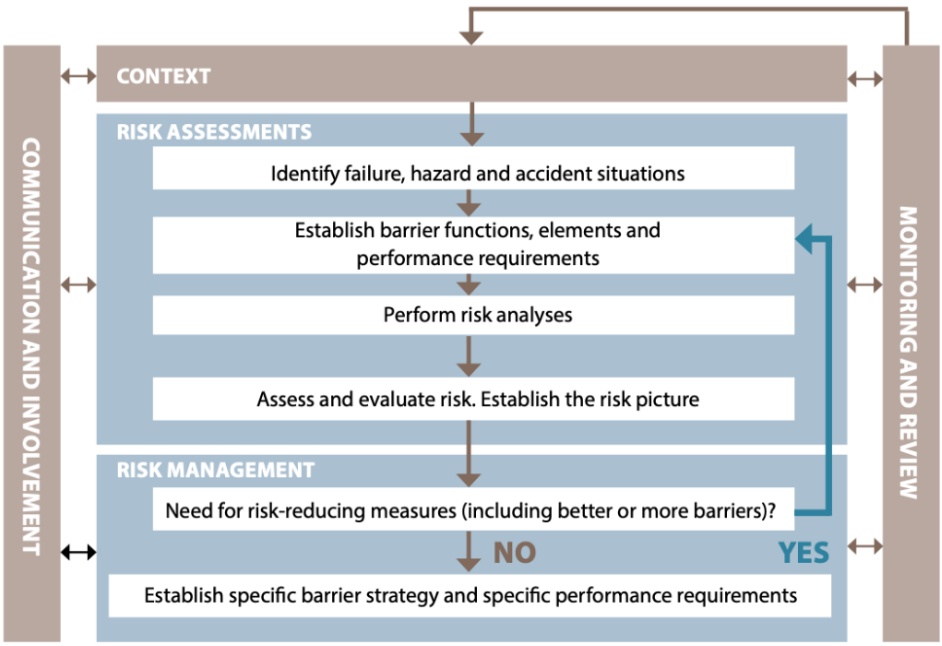

Figure 4. Risk assessment and management process considering barrier management from PSAN (2017)

The three components of a risk analysis process are planning, then risk assessment, followed by risk treatment (Aven, 2015). Looking closer, the risk assessment section can be divided further into identifying initial events, cause, and consequence analysis, portraying the risk picture, and finally, looking at alternatives and identifying and assessing measures. This is illustrated in Figure 4. In addition, this figure was explicitly chosen to visualize the risk assessment process that incorporates establishing barriers, functions, elements, and performance requirements, which is one of the focal points of this thesis.

The Cautionary and Precautionary Principles-Based Strategy

Traditional risk assessments based on causal chains and event analysis are meant more for linear systems, where historical data-based probabilities are calculated, are inadequate for complex systems, and present tools with strong limitations (Aven, 2016). However, broad risk assessments and management incorporate the resilience dimension and are suitable for situations of large or "deep" uncertainties. Aven (2016) asks what type of policies and decision-making schemes should be implemented in case of large or deep uncertainties. He answers this by discussing the need to use cautionary/precautionary principles based on risk management strategies, where robust and resilient approaches and methods are used (Aven, 2016).

The cautionary principle states that "…if the consequences of the activity could be serious and subject to uncertainties, then cautionary measures should be taken, or the activity should not be carried out" (Aven & Thekdi, 2022, p. 195). Aven & Thekdi (2022) say that the cautionary principle is not a decision rule but offers a guiding perspective when handling risk. Tools support development, but principles guide management in balancing the concerns regarding protecting people and the environment (Aven & Thekdi, 2022).

Similarly, the precautionary principle (a special case of the cautionary principle) states that "…if the consequences of an activity could be serious and subject to scientific uncertainties, then precautionary measures should be taken, or the activity should not be carried out" (Aven & Thekdi, 2022, p. 306). The difference between the precautionary and cautionary principles lies in the "scientific" uncertainties.

Some of the features that the cautionary/precautionary principle-based strategies have are:

> "…containment, the development of substitutes, safety factors, redundancy in designing safety devices, as well as strengthening of the immune system, diversification of the means for approaching identical or similar ends, design of systems with flexible response options and the improvement of conditions for emergency management and system adaptation." (Aven, 2016, p. 6)

The precautionary principle is used exclusively for protection and is widely adopted to protect values from unknown hazards and consequences. There have been critiques about using the precautionary principle, mainly due to its application, the definition of scientific uncertainty, and limiting progress through avoiding risk (Aven & Thekdi, 2022, pp. 216–217). The precautionary principle serves as a massive roadblock and barrier to the risk event occurring. If the precautionary principle is used, another tact must be taken, or significant scientific discoveries and research must prove that progress can happen (Aven & Thekdi, 2022, pp. 216–217).

2.4.2. Bow-tie Model

Bow-tie modeling stemmed from the late seventies and was later integrated into the business practices at Shell Oil (Center for Chemical Process Safety/AIChE, 2018, p. 2). By the 1990s, the use of the bow-tie model was common in risk management, showing a visual representation of risk measures and their link to the risk management system (Center for Chemical Process Safety/AIChE, 2018, p. 2). Bow-tie models can communicate a visual focus on operation aspects, measures, and their functionality to staff while keeping tabs on the effectiveness of barriers, Figure 5.

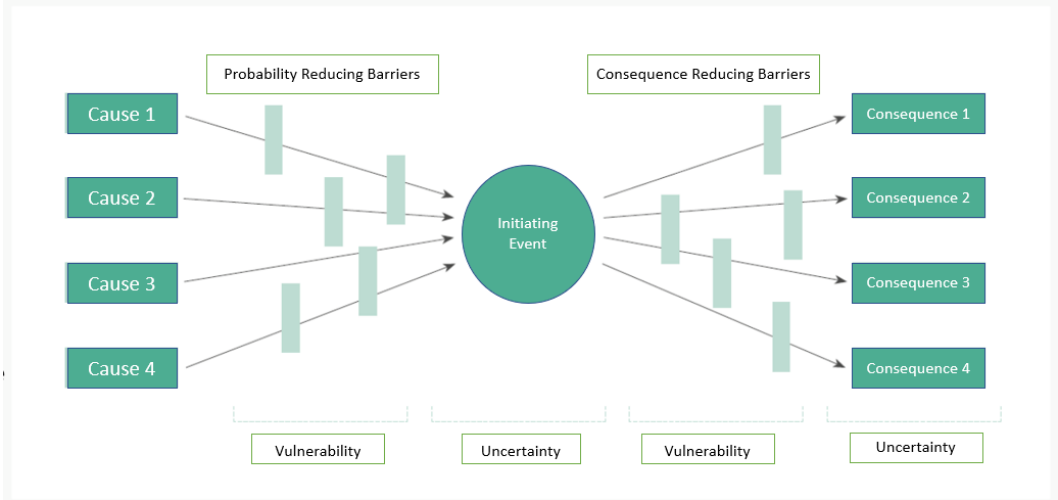

Figure 5. Bow-tie diagram as illustrated in the NDCP's guide on CRVA (2014)

The NDCP guide on CRVA and Stavanger municipality (2019b) utilized the Bow-Tie model as a valuable tool to evaluate and enhance the effectiveness of preventive and consequence-reducing measures. It is a risk management technique that visualizes the relationship between potential hazards, causes, initiating events, and preventive and consequence-reducing barriers in a diagrammatic format, yielding a holistic (yet static) risk picture for the system (Cockshott, 2005).

Bow-tie models can represent the risk assessment process and support risk management and communication. The focus on barrier management is of key importance in a bow-tie model and can strengthen accountability by documenting barrier owners and those responsible for them (Center for Chemical Process Safety/AIChE, 2018, p. 2).

The Center of the Bow-tie Model – Initiating Event

At the center of the bow-tie model shown in Figure 5. is the initiating event, which is also at the core of the risk assessment. One of the primary purposes of the risk assessment is identifying such initiating events, as it is the first step in risk reduction and a critical task (Aven, 2015, p.p.1-2). Identifying the initiating event must be a structured and systematic brainstorming session by persons with high competence in the field, guided by checklists and guidewords, tailor-made for the specific situation. The hazard identification process should be a creative process wherein one also attempts to identify unusual events (Aven, 2015, p.p.1-2).

Aven (2015) elaborates that the risk assessment process starts with identifying initiating events, which can be either hazards or threats. The importance of initiating event identification is eminent as events that are not identified cannot be mitigated. However, a precaution should be given in this phase as analyses are usually based on previously conducted ones. It is prevalent when similar analyses are conducted to reuse existing lists of initiating events. However, the issue here is that this can lead to overlooking important details and aspects of the system. This can be avoided by identifying the initiating event in a structured and systematic way in the presence of all the necessary and relevant experts involved (Aven, 2015, p. 38).

The initiating identification process is creative and should allow for identifying unusual events. The identification of the less possible events takes most of the time used at this phase, or as Aven (2015) says: it takes 20% of the time to come up with 80% of the events we are familiar with and have experience, while it takes 80% of the time to come up with those events that we are not experienced with or are regarded as unusual (p. 39). By being structured and systematic, one can avoid missing out on unusual events.

Causal Side – Preventive Measures

On the sides of the initiating event, we have the causal and the consequence picture. The left side lists the known factors responsible for potentially causing the initiating event. This happens when identifying several causes for one initiating event, prompting a new, more detailed analysis for each cause (Aven, 2015, p. 39). For this purpose, we can make a new bow-tie model specifically for that cause, which becomes an initiating event in this case, with both cause and consequences sides of the model potentially leading to a never-ending quest.

The cause analysis aims to identify initiating events, but this also depends on the analyst's starting point. For example, the analyst can consider security-born issues that adversely affect the power supply as a starting point (initiating event) for the analyses. Then when realizing that this disruption can potentially lead to a long-term failure of the power supply, the analyst can additionally analyze this event (long-term power supply), leading to several new "sub-risk analyses" with the new initiating event.

The barriers on this side of the bow-tie models are called likelihood-reducing measures, meaning that these measures reduce the likelihood of the initiating event occurring. These are also called probability-reducing or preventive barriers (Aven, 2015, p. 1). Barriers can also be vulnerability-reducing measures that reduce a system's vulnerability, specific component or asset vulnerability (Haimes et al., 2008).

Cause analysis is a qualitative evaluation to determine probable causes leading to the potential event (PSAN, 2017). According to the Barrier Memorandum (2017), preventive measures should always have priority over consequence-reducing measures. In addition, preventive barriers can help create understanding and awareness about local hazards, guide operating safely, and sound alarms when there is trouble (PSAN, 2017). However, measures are still needed on both sides of an event (PSAN, 2017).

Consequence Side – Consequence-Reducing Measures

The right side of the bow-tie model lists the possible consequences given that the initiating event has occurred. Each initiating event should get a consequence analysis (Aven & Thekdi, 2022, pp. 40–42). The dimensions and attributes of the consequences are various. For example, they can be financial, loss of life, environmental, or reputation. The number of steps in this analysis is proportional to the number of existing barriers (Aven, 2015, pp. 40–42). Consequence analysis can include quantifying the consequences of injuries and damage to personnel, environment, and assets and modeling accident sequences (Vinnem & Røed, 2020).

Barriers that reduce the possible consequences of an initiating event are called consequence-reducing barriers (Aven, 2015, p. 1). These measures can restore systems, contain hazards, and guide evacuation procedures (Aven & Thekdi, 2022). Consequence-reducing measures add resilience to the system, meaning measures that will enable the system to get back to its original state as much as possible, as soon as possible (Haimes et al., 2008). This is why one must ensure that the barriers are in place and working as intended (Aven, 2015, p. 41).

2.4.3. Barrier Management

The Barrier Memorandum by PSAN (2017) states that barrier management in the petroleum industry is the coordinated actions in establishing and maintaining barriers so that they function as they should at all times so that the risk will be reduced in case of failure, hazard, or accident (PSAN, 2017). The thesis uses the definitions and strategies the Petroleum Safety Authority of Norway put forth as they provide detailed descriptions of barriers, their functions, technical, organizational, and operational barrier elements, and their interactions in a system (PSAN, 2017).

Safety and security barriers are essential tools in risk management. Having efficient barriers also reduces consequences and limits costs (PSAN, 2017). Usually, the most preferred barriers are those that cost less but are most effective. The terms barrier and measures will be used interchangeably in this thesis.

Each barrier may have multiple barrier functions for a specific risk event. The barrier function is supported by elements that can be technical, organizational, operational, or a combination. Technical elements consist of equipment and systems. The organizational elements comprise the human dimension with specific roles and functions to ensure the effectiveness of the barriers. Lastly, the operational elements require personnel to operate and control the barrier's functionality (PSAN, 2017). Barriers are devised for a specific risk picture and should be managed to provide optimal protection (PSAN, 2017).

In order to understand if the barrier elements interact in a way that supports the barrier function, a barrier management strategy is imperative, Figure 6 (PSAN, 2017). The strategy ensures a clear connection between hazards, barrier functions, and elements. The barrier strategy serves as the plan for identifying functions and choosing and implementing elements to support risk management optimization (PSAN, 2017).

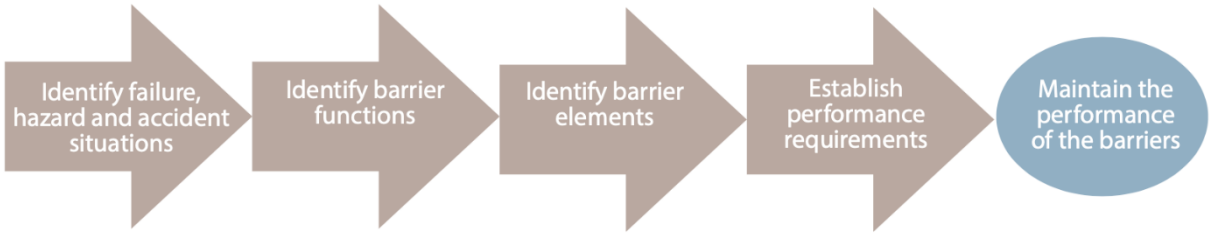

Figure 6. Main Features of Barrier Management from PSAN (2017)

Efficient barrier management can address risk by establishing and maintaining barriers. Accidents will always happen, but barriers can help to handle them. By referring to the management loop of Plan, Do, Check, Act, from the Barrier Memorandum (2017), barrier solutions can be kept up to date, continually monitored, and upgraded as needed while ensuring they are in place and functioning when necessary. Management tasks for barriers also include their "concepts and design, organization and manning, operation, and decommission and removal" (PSAN, 2017).

The first step in barrier management is identifying failure, hazard, and accident situations (e.g., Initiating events). This can be done preliminarily with a coarse risk assessment, as in the Stavanger CRVA. Once the situations have been identified, barrier functions can be proposed to prevent or mitigate the risk from the event. Barriers with their technical, operational, and organizational elements that are proposed or already existing should also be identified (PSAN, 2017). These elements should be functional, robust, and integral to the function of the barrier. Their job in supporting the barrier's functionality should be straightforward (Vinnem & Røed, 2020).

Additionally, barrier management helps the organization keep in line with the current government, industry, and performance requirements. Measuring the performance and availability of barriers is an essential step in barrier management (PSAN, 2017).

A holistic approach to barrier management in the petroleum industry that emphasizes the maintenance of all barrier elements, not just the technical, is described by (Øien et al., 2015). They acknowledge the importance of having staff on-site be familiar with which barriers exist, their functions and elements, and clearly know their performance requirements (Øien et al., 2015). The process of barrier management should be communicated to staff so that there is understanding across the board about barriers functions and why those responsible for them should be held accountable for their operations in the larger system (Øien et al., 2015).

Øien et al. (2015) describe that a holistic approach means that the barriers should function independently so that if one fails, it does not cause others to fail as well. This is especially important with operational and organizational barriers, as it can be challenging to establish performance requirements for them. These requirements must be specific and detailed, including how to reach operators and access data about the barriers (Øien et al., 2015).

Defence in Depth

The various barriers elements help to address the risk in a multifaceted manner and provide a defense in depth. The idea of "defences-in-depth" is defined by Reason (1997) as "…successive layers of protection, one behind the other, each guarding against the possible breakdown of the one in front." (p, 7). These can be either "Hard" or "Soft" defences or a combination of both, which is usually the optimal approach. Reason (1997) uses "Hard" defences, for example, when he addresses technical devices, physical barriers, alarms, interlocks, and keys, while "Soft" defences, when he addresses the combination of paper and people, such as legislation, regulations, rules, procedures, and front-line workers as some of the soft defences (p. 8).

Perfectly aligned "Hard" and "Soft" barriers should give optimal protection. However, defences have their weaknesses and gaps. He further distinguishes the nature of the gaps as "active" and "latent" failures. Reason (1997) sees "Active failures" as the errors and violations made by the front-line workers of the system, for example, a traffic controller not recognizing a dangerous situation that results in an airplane accident (p. 10). "Latent failures," on the other hand, are conditions that exist unnoticed until "…they combine with local circumstances and active failures to penetrate the system's many layers of defenses" (Reason, 1997, p. 10), resulting in an accident. This type of failure is due to "…strategic and other top-level decisions made by governments, regulators, manufacturers, designers and organizational managers" (Reason, 1997, p. 10).

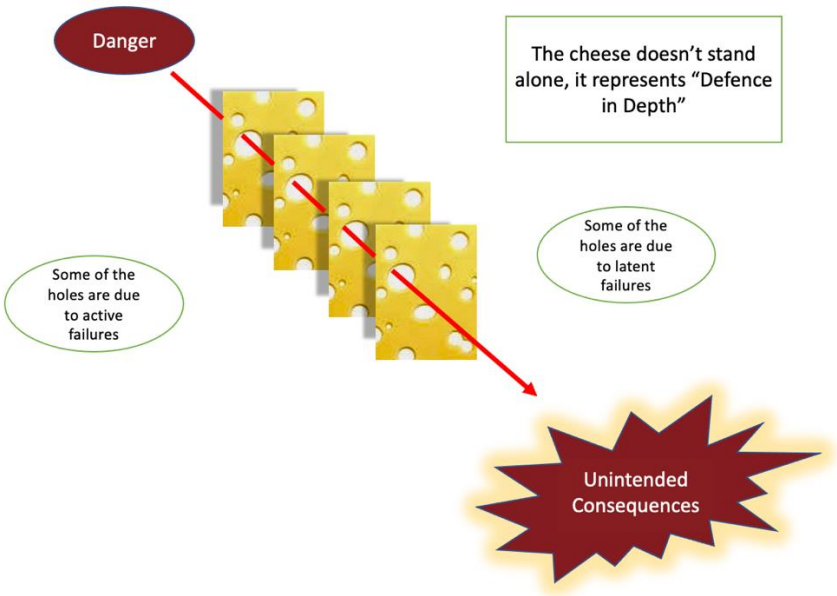

Figure 7. Reason's Swiss Cheese Model adopted by the authors (Reason, 1997, p. 12)Reason's Swiss Cheese Model adapted by the authors (Reason, 1997, p. 12)

The metaphor of Swiss cheese gives the impression that the gaps, being active or latent failures, are of static nature. However, this is not the case, and Reason (1997) describes the gaps as having a dynamic rather than static nature (p. 9). They move and shift due to maintenance, staff, scheduling, regulation, and oversight changes, making it harder to predict where a gap might be at a particular time (Reason, 1997).

2.4.4. Barrier Balance

To be able to judge whether preventive and consequence-reducing measures are balanced, we first must state what the concept of balance means in these circumstances. Having a static approach to balance where measures are fixed, rigid, and not frequently checked or assessed does not account for changes in the risk picture, Figure 8. This leaves little room to adjust barriers based on the scenario or initiating risk event. A dynamic approach to balance should be used to account for a more robust and resilient system that can deal with uncertainties and changes in the risk picture.

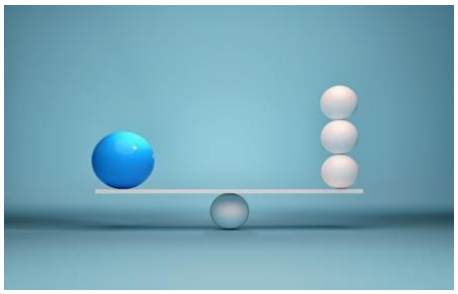

Figure 8. Illustrating 'static balance' between preventive and consequence-reducing measures. Source: Image from Word

Merriam-Webster (n.d.) defines the verb balance as "to bring into harmony or proportion". This definition can also apply to evaluating the balance between preventive and consequence-reducing measures. In this regard, one can envision the scales of justice. Figure 9. presents Lady Justice, who blindly compares right and wrong, implying that the balance is never level. It shifts and changes depending on the context.

Figure 9. Lady Justice. Source: Image from Word

In risk management, the balance depends on the dynamic risk picture, which can change at any time. For this reason, a dynamic approach to balance is needed, where the scales and measures can shift as needed in response to the risk picture. This approach to balance depends on constant monitoring of the situation and the risk picture to adjust the balance of measures as needed.

Balance as Represented in Literature

Balance among measures in literature is discussed using different terminology. For example, the thesis investigates balance in terms of preventive and consequence-reducing measures as defined by Aven (2015) and the Barrier Memorandum by PSAN (2017). In comparison, Baskerville et al. (2014) refer to the prevention and response paradigm used in information security. Haimes (2008) refers to protection and resilience measures. All of the abovementioned approaches can be visualized using the bow-tie model. Figure 10. illustrates differences in terminology among authors when referring to the measures and paradigms discussed in this thesis.

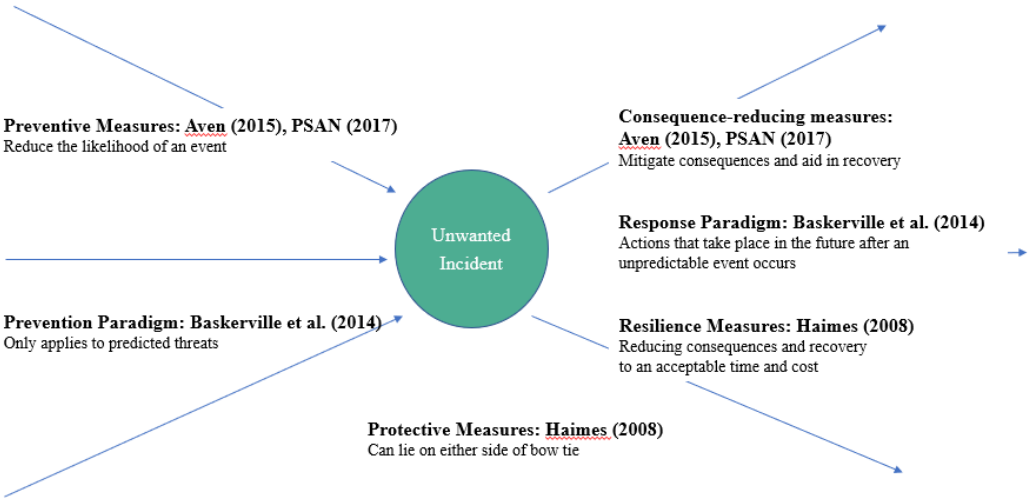

Figure 10. Various Approaches to Balance in Literature. Figure created by authors.

Baskerville et al. (2014) address balance as the prevention and response paradigms in the information security sector. This correlates to our understanding of uncertainty, complex systems, and the balance between measures. However, this approach differs from the approach to prevention used by the authors. Preventive measures are used in this thesis to prevent risk events from known, unknown, and ambiguous threats/hazards occurring, as opposed to the view of Baskerville et al. (2014), where the prevention paradigm only applies to predicted threats.

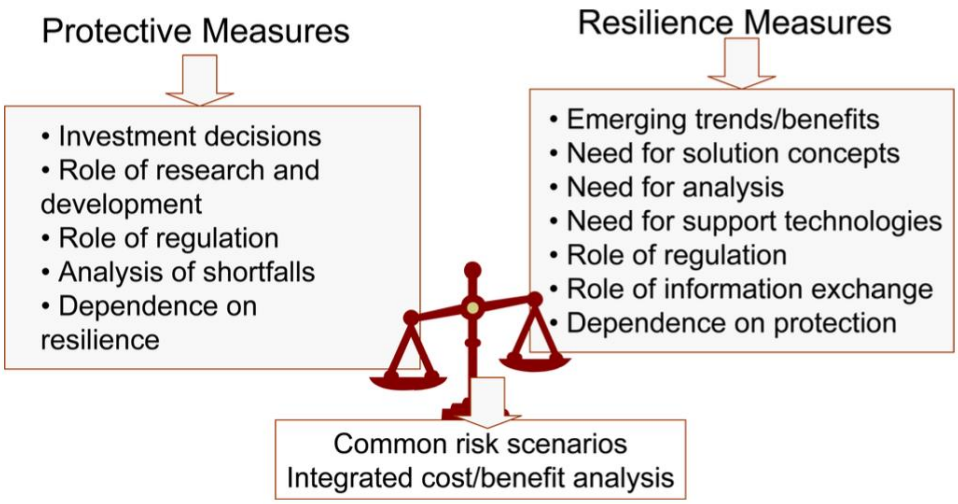

Figure 11. An integrated approach to risk management (Haimes et al., 2008)

On the other hand, Haimes et al. (2008) write about the balance between protective measures on both sides of the bow-tie model. Haimes et al. (2008) described that resilient measures lie on the right-hand side of the bow-tie model and tend to reduce consequences, recovery time, and costs. "Balancing protective and resilience action through system-level analysis will provide a means to improve the overall efficiency of regional and national preparedness" (p.

287). Thus, by obtaining a reasonable balance between measures, preparedness can increase and be more adaptable.

Ideally, the balance should reduce consequences from risks in the most cost-conscious way possible. Protection measures can be less effective and more expensive when there is increased uncertainty about risk events (Haimes et al., 2008). However, Haimes et al. (2008) elaborate that protection can be unproductive and shortsighted in the public and private sectors, and interconnection between operations can cause inadequate security. Concentrating more measures on one side over the other can lead to decreased ability to reduce risk. Balancing protection and resilient measures can be helpful to gain value in ordinary occurrences and resilience in the case of an emergency by balancing protection with investments to increase resilience. (Haimes et al., 2008). They state that resilience can be increased by adding robustness, redundancy, and improved maintenance.

2.5. Systems Thinking

Systems theory came around the 1930-40s as a response to classical analysis techniques' limitations regarding increasingly complex systems and was applied to different sectors (e. g., communications, biology) (Leveson, 2012, p. 61). However, the systems thinking paradigm became institutionalized in the 1950s (Checkland, 1999). Bertalanffy (1969), whose field was biology, suggested that all emerging ideas about systems thinking should be gathered and combined to create a general theory of systems.

Complex systems' emerging properties are important because they derive from the systems' parts relationship. The interaction between the various parts is the key point here. Leveson (2012) states that the foundation of systems theory lies on two pillars:

1. Emergence and hierarchy
2. Communication and control.

Socio-technical systems are diverse open systems where humans and machines interact and are named "living organizations" (Leplat, 1984). Leveson (2011) paraphrases Ramo (1973) that "in system theory, complex systems are modeled as a hierarchy of organizational levels, each level more complex than the one below" (p. 57). Humans are one element of these systems, playing a role by doing chores to accomplish their goals that might be different from the system's goal. This is truer for the lower levels of employees in an organization. The greater the distance between the worker and the executive, the greater the uncertainty and insecurity about the task performance (Leplat, 1984). In this case, the individuals can redefine their goals and the modus operandi for achieving those, making us aware of the distinction between prescribed and actual tasks (Hackman, 1969). According to Enderud (2003), in his presentation of the administrative man model for decision-making in organizations, individuals make satisfying solutions to their tasks instead of optimizing and maximizing. Finding the best solution is substituted with individuals' acceptance of a good enough one (p. 45).

Additionally, managing risks in complex socio-technical systems can be challenging due to unexpected potential accidents from emergent properties and their consequences. Experts have proposed systems thinking as a valuable approach to address these challenges. The systems approach has been discussed in various disciplines, including accident analysis, organizational theories, and quality discourse. Notable works in this area include those by Leplat (1984), Helbing (2013), Hollnagel (2016), Hollnagel et al. (2006), and Leveson (2011, 2012). By adopting a systems thinking mindset, risk analysts and managers can better anticipate and mitigate potential risks, promoting safety and reliability.

Leveson (2012) lists and discusses several issues arising from the fast technological development on which the traditional approaches for making systems safe are not applicable anymore. Leveson is addressing safety engineering. However, systems thinking can apply to any system consisting of humans, technology, and organization interaction. Leveson (2012) states that the changes that affect and are stretching the limits of safety engineering are:

- **The fast pace of technology change**: since our technology is developing rapidly, learning from past accidents is irrelevant or not helpful in every situation, especially when new emerging technology is at stake. “New technology introduces unknowns into our systems and creates paths to losses” (Leveson, 2012, p. 3).
- **Reduced ability to learn from experience:** the journey for a product, from technical discovery to becoming commercial, takes two or three years. In five years, the same product can even get obsolete. In comparison, this journey took thirty years at the beginning of the last century, focusing on carefully testing the system and design to gain knowledge on all the potential system behaviors and risks before the product is used.
- **Changing nature of accidents**: technology is not the only thing changing rapidly. Our societies do this as well. Digital technology plays a significant role in how systems operate now, and many approaches for preventing accidents are ineffective in controlling accidents from this digitalization.
- **The new type of hazards:** since technology develops very fast and societies change, it is okay to presume that new risks emerge. A good example is the use of antibiotics and how this led to resistant microbes. This asks for more advanced strategies for meeting these challenges.
- **Increasing complexity and coupling:** some systems have complex interactions and operations humans cannot intellectually manage. “In fact, complexity can be defined as intellectual unmanageability” (Leveson, 2012, p. 4).
- **Decreasing tolerance for single accidents:** the harmful potential of single accident dye to the systems’ complexity and dependencies is much higher now. A good example here is the nuclear power plants and the hazard they pose for society at present and future generations.
- **Difficulties in selecting priorities and making tradeoffs**: today, the pressure to take shortcuts to increase productivity and efficiencies is high, supporting more risk-seeking than safety-oriented behavior. This makes the information flow to the decision-maker even more critical.

- **Increase in the complexity of the relationship between humans and automation**: recently, automation is getting more responsibility for implementing higher-level decision-making shared between humans and automation. “All human behavior is influenced by the context in which it occurs, and operators in high-tech systems are often at the mercy of the design of the automation they use or the social and organizational environment in which they work” (Leveson, 2012, p. 5)
- **Changing regulatory and public views of safety**: in modern society, the responsibility for safety is moving away from the individual level and becomes the government’s responsibility. The risks the societies are exposed to are no longer possible for a single person to mitigate, and this is why citizens demand their governments take this responsibility and govern safety through laws, different forms of oversight, and regulations. Designing more effective regulatory strategies is very pressing and vital. The incremental safety improvements are not adequate anymore, and a paradigm shift is necessary. Systems thinking is more appropriate in understanding accident causes and prevention, providing a broader definition of safety and accident, including injuries and human death and losses of equipment, mission, finances, and information (Leveson, 2012, pp. 2–6).

Leveson (2011) discusses that systems can fail even though all the components are reliable and working as intended. It is not the components that are misfunctioned. It is the sum of these components and their interaction, or more clearly, the lack of understanding and communication. “A system design error can lead to an accident (unacceptable loss) without any component failures” (Leveson, 2011). Thus, system theory is a better approach to safety, providing a way forward to more prudent and effective risk analysis and management procedures (Leveson, 2012, p. 68).

However, the key point is that “…for complex systems, full control of the risks cannot be achieved. Surprises will occur. If complexity is not fully acknowledged, the result will be blind zones and poor understanding of uncertainty” (Aven & Thekdi, 2020, p. 25).

2.5.1. Drifting Into Failure

Dekker (2011) has worked on combining complexity and system thinking for more than three decades after becoming inspired by a “non-linear dynamic systems” class. This formed his view of organizations as dynamic, adaptive, complex, tightly coupled systems, which he compared with “living organisms”. For such systems, he claims, machine safety models are insufficient. The simplistic view of components failure as the sole reason for explaining accident occurrence, where “…something must break, something must give, something must malfunction” (Dekker, 2011, p. xiii), is an understanding “held hostage” by a Newtonian-Cartesian view, known as a cause and effect perspective of the worlds function. According to Dekker (2011), this line of thought applies to simple and linear systems but not to formal-bureaucratically organized risk management in a complex and tightly interconnected world (p. xiii).

Combining complexity theory and systems thinking resulted in Dekker's' development of drifting into failure perspective. He defines drift as "…a gradual, incremental decline into disaster driven by environmental pressure, unruly technology and social processes that normalize growing risk" (Dekker, 2011, p. xii). According to Dekker, drifting into failure originates from normal organizational functioning, structures, processes, and everyday tasks. When given enough time, uncertainties, and pressure, organizations drift inevitably into failure. The very same "organization's mandate will turn out to be responsible for undermining that mandate" (Dekker, 2011, p. xii). It is not whether drift will manifest itself but when.

One of the most significant aspects of Dekker's' perspective is that drifting into organizational failure is a slow, incremental process. This process is happening simultaneously as the organization uses all available resources to achieve its safety and security goals, among others, while encouraging development and freedom. The drift results from all the organizational processes, their complexity, interconnectivity, and interaction internally and externally. In other words, it results from the organizations pursuing their goals. Down the line, the organizations usually become victims of their pursuit due to stretching their available resources under the pressure of external and internal environmental factors, "…does things more efficiently, does more with less, perhaps taking greater risks" (Dekker, 2011, p. xiii).

Dekker (2011) claims that drifting into failure usually happens when organizations have good and steady performance, measured through predefined performance criteria. All the components and aspects of the organization can be in perfect order, and everything functions as it should, with no human error or rule violation (Dekker, 2011). The main reason for the inevitable drifting is that organizations are structured in sections and develop their technology, processes, and services in this way. What is built is usually understood in isolation. The holistic approach is missing, an approach that is especially important in a global world. When competition and operation space are more extensive, with organizations multiplying their connections, interactions, and interdependencies, complexity rapidly increases. The issue is that organizations cannot keep up with this rapid development. Because of the incremental nature of drift into failure, organizations are unaware of their drift until it manifests itself, becoming very challenging to detect and mitigate it early on (Dekker, 2011).

3. Research Design and Methods

This section will address the ways in which the research designs and methods have been used to elaborate on the topic of this thesis, "addressing the balance between preventive and consequences-reducing measures regarding avoiding drifting into failure while increasing resilience in municipalities". The process used to undertake this research study, as well as the constraints and challenges associated with data collection, design, and methods used, will be elaborated upon. The reliability and validity of the research study will be discussed, in addition to a sub-section on ethical considerations, accounting for bias and judgments. Lastly, a sub-section on the strengths and weaknesses of this research study will conclude this research design and methods section.

The research in this master's thesis has been designed to contain two parts in a mixed approach to data collection (Neuman, 2014, p. 50). By using a qualitative study of current data available for the primary source with a qualitative study of published documents as a secondary source, this thesis aims to provide consistent, credible, and valid results to address the balance between measures. Neuman (2014, p. 50) states that understanding, and credibility can be increased by using multiple data sources and the dependability of the results.

Conducting social research can help lead to understanding and decision support in municipalities by creating knowledge about the public, their needs, and concerns (Neuman, 2014, p. 8). This thesis aims to expand on that and make connections between how the municipality currently functions as a system and how improvements could be suggested.

3.1. Qualitative Method

In this research study, a qualitative method has been used for collecting data. The research includes collecting data from the Stavanger CRVA and displaying it numerically in the results section. This information was collected, assessed, and represented to assist in displaying the current situation in Stavanger. This data was supplemented through multiple qualitative sources in terms of a literature search to investigate the main topic of this thesis and to enhance the discussion of research questions.

3.2. Choice of Research Design and Strategy

The process of research design serves to link the collection of data to the main topic and questions investigated in the thesis. The design is a process and should be flexible to reflect changes and adjustments made throughout the study and serve as an anchor to guide the project along a consistent throughline (Hammond & Wellington, 2020, p. 213). Research strategies can assist in answering the proposed questions and consist of multiple methods. This study will focus on the abductive research strategy.

3.2.1. Abductive Research Strategy

An abductive research strategy can be seen as an exploratory, inductive approach and can lead to new ideas and suggestions that can be tested deductively later with further research (Hammond & Wellington, 2020, p. 11). By having an alternating focus between inductive and deductive strategies, the abductive strategy uses observations to propose the best explanation available among many different alternatives (Hammond & Wellington, 2020, p. 11). For this thesis, the abductive method can be useful in investigating the relationship between the measures, governance, and management put forth in the Stavanger CRVA and the holistic approach to systems. This research study is based on existing theories and documents, and new hypotheses will not be proposed nor tested. However, connections have been highlighted to put forth possible suggestions about how balance might be adjusted for a better fit with holistic systems management.

3.3. Data Collection, Reduction and Analysis

Data collection is a crucial aspect of the research study, and it is imperative that the methods used are clear. The decisions relating to what data is used and how it is collected are key to the research process. Using qualitative data collection methods, a researcher can make inferences from the data and observations studied (Neuman, 2014, p. 14). Stavanger municipality was asked to assist with this research study by allowing access to Appendix A of the Stavanger CRVA and staff interviews to get an insider's point of view. These requests were respectfully declined. Considering these circumstances, the authors used their knowledge of risk science and the associated NDCP guides to municipal risk analysis to classify the measures as preventive and consequence-reducing or a mix. In addition, the measures were classified by element type as operational, organizational, technical, or a mixture. This information was not supplied in the documents provided but rather produced by the authors, using criteria described in the Barrier Memorandum (PSAN, 2017) and their knowledge about the classification of measures. The data for this study was not first-hand data but was extracted from existing relevant documents and then reclassified to suit the needs and purposes of this study. This data will be regarded as a primary data source for this thesis. Document analysis is used as a secondary data source to bring another aspect to this study. Secondary data refers to data collected by analyzing published documents (Hammond & Wellington, 2020, p. 213). Data was collected for this study throughout the time frame of December 2022 through June 2023.

The data collection and content analysis of the proposed measures in Appendix C of the 2019 Stavanger CRVA is qualitative and regarded as this thesis's primary source of information (Hammond & Wellington, 2020, p. 213). This data collection and following interpretation and judgment of the measures by the authors to be preventive, consequence-reducing, or both serves to answer the research question about the distribution of measures in Stavanger municipality (Stavanger Municipality, 2019b). The 47 adverse risk events the municipality chose were numbered, and the measures associated with each were labeled with letters to assist in data analysis. Stavanger Municipality's CRVA (2019b) mentions a 48th risk event, however, this is not present in their list of measures from Appendix C and has no proposed measures associated

with it. Therefore, it is will not be represented in this study. Following the translation of the CRVA, guidelines were established to classify the proposed measures using a bow-tie model, Figure 13. to classify measures using the authors' judgment and knowledge of risk science, barrier management, and their understanding of the initiating events. The qualitative data collected from the municipality is interpreted, classified, and analyzed to present the results quantitatively.

3.3.1. Document Analysis

The secondary data source is a document study, using the thesis topic as a starting point and working backward. Reviewing the sources and input surrounding the primary data source led to discovering of additional documents. Examples of the documents used include meeting minutes, communication plans, action and financial plans, and surveys that would supplement the research.

The collection of documents reflects and strengthens discussions about the measures in the Stavanger CRVA. This type of study can be a suitable research method when seeking information on how others interpreted the process of creating and following up on the primary source (Hammond & Wellington, 2020, p. 213). Document studies can be less spontaneous than interviews but have the capacity to shine a light on the problem when it occurs (Hammond & Wellington, 2020, p. 66). Documents keep a record and timeline of the process in real-time, as opposed to interviews which could occur years after the process and reflection are complete. They provide a window into the concerns, opinions, and follow-ups regarding the primary source at the time it is happening. Therefore, in this case, a document search can potentially be a more relevant source than interviews.

The documents used have been chosen for their relevance in supporting this thesis's problem and clarifying the municipality's decision process surrounding the CRVA and their preparedness plan for increasing public safety in Stavanger municipality. The underlying factor was to search for common threads related to the CRVA and insights into whether the proposed measures were implemented, reflected, budgeted, or adjusted and, therefore, aligned with a holistic systems thinking approach with feedback loops. An overview of the documents used in this study is presented in Table 1.

Table 1. Secondary data sources used in the thesis. Table created by authors.

Article/Document	Publication Year	Website
Civil Protection Act	2010	lovdata.no
Regulation on Municipal Preparedness Duty	2011	lovdata.no
Planning and Building Act	2008	lovdata.no
Security Act	2018	lovdata.no
CRVA Guide by NDCP	2022	dsb.no
Guide to the regulation on municipal preparedness duty	2021	dsb.no
CRVA of Stavanger Municipality	2019	stavanger.commune.no
BAS3 project- A vulnerable electric power supply- Final report	2001	Norwegian Defence Research Establishment: https://www.ffi.no/en/publications-archive/en-sarbar-kraftforsyning-sluttrapport-etter-bas3
MEREPUV Project	2019	dsb.no
SINTEF report	2015	sintef.no
Barrier Memorandum	2017	https://www.ptil.no/contentassets/43fc402b97e64a7cbabdf91c64b349cb/barriers-memorandum-2017-eng.pdf
KIKS Project – Part 1 –	2012	dsb.no
RAV checklist	2018	stavanger.commune.no
NDCP municipality survey	2019	dsb.no
Report – Norwegian Municipalities Planning Implementation and Use of Risk and Vulnerability in Connection with Civil Protection	2017	Ebooks.uis.no: https://ebooks.uis.no/index.php/USPS/catalog/book/164 ISBN 978-82-7644-680-7

Stavanger municipality council case presentation- HROS	2019	https://einnsyn.no/api/v2/fil?iri=http://data.einnsyn.no/noark5/DOKOBJ-80B09C28-E586-4F87-9BC3-3F3E99181C8F1069443_4_1.pdf
Stavanger municipality council – approval of CRVA meeting minutes	2019	https://einnsyn.no/api/v2/fil?iri=http://data.einnsyn.no/89da076e-927d-46bb-b2fd-b5fe46a94d28
Stavanger municipality council meeting minutes regarding CRVA	2020	https://einnsyn.no/api/v2/fil?iri=http://data.einnsyn.no/db6f9e16-251d-41ba-bd8d-b59a4ba408ab
Stavanger municipality's action and financial plan	2019, 2020, 2021.2022	https://hop2019.stavanger.kommune.no/; https://hop2020.stavanger.kommune.no/; https://hop2021.stavanger.kommune.no/ https://hop2022.stavanger.kommune.no/

This search began with the NDCP website, where documents were found prescribing the format for municipal CRVAs in Norway. Surveys conducted by NDCP and the University of Stavanger are examined, reflecting on the process, administration, and follow-up of municipal CRVAs. Meeting minutes and documents from the municipal council were searched for risk and vulnerability assessment concepts and New Stavanger to find relevant results. From there, additional documents were found by working backward from the dates listed in the meetings. Finally, a search through the four action and financial plans, spanning from 2019 until 2025, was searched for the measures proposed in the CRVA and if they were being budgeted or reviewed. All documents were translated into English. The contents of the document search will be portrayed in the empirical findings section of this thesis.

3.4. Validity, Reliability and Research Ethics

3.4.1. Validity

Validity regards the appropriateness of the steps taken throughout the design and research process (Hammond & Wellington, 2020, p. 194). In terms of this thesis, internal validity will be discussed. Hammond and Wellington (2020) describe this as including the logic of the research, the clarity of the questions formed, the fit between the methodology, the questions being asked, and finally, conclusions drawn from the data.

As the request for access to interviews and secured documents from the municipality was declined, this thesis used publicly available data and sources as the basis for research. That said, the authors made conclusions and judgments that may not reflect the actual results. While best research practices and classifications were made with current risk science and governance strategies in mind, this thesis may not accurately represent the balance of preventive and consequence-reducing measures in Stavanger municipality. Instead, the identified distribution can be viewed as a representation that will be used to make connections about balance and how it can be adjusted to enable a more holistic (systems) view of Stavanger municipality. In this thesis, the current situation of the barrier elements is simplified. This is due to the fact that only the measures that were proposed in the Stavanger Municipality's CRVA (2019b) are analyzed.

The research study was completed logically, beginning with identifying the main topic and posing research questions to assist in clarifying the connection between measures, governance, and holistic systems. The questions formed were adjusted to adapt to the lack of assistance from Stavanger municipality. It was deemed that the topic could still be investigated. However, the theme of the research questions shifted slightly to focus less on the process in the municipality and more on the overall trends and reflections that the research study could address.

Using the qualitative method and data already published by the municipality with a document and literature search, this research study aimed to provide a multitude of sources that could serve as evidence for the discussion around the research questions. Currently, there are no unequivocally correct answers to the questions posed. They are meant to prompt a discussion and encourage future research into balance and systems thinking in municipalities.

In addition, a necessary disclaimer is that the data used from Appendix C from the Stavanger Municipality's CRVA (2019b) has been interpreted by the authors. However, Appendix C does not provide a picture of all measures in place, only the new proposed measures in this specific CRVA (2019b). The current balance can be shown by researching this data, but this is subjective and relies strongly on the author's judgment. It can be taken at face value to discuss the concept of balance. Additionally, this research intends to prompt critical thinking about what barrier balance means for holistically viewing the risk governance of Stavanger municipality.

3.5.2. Reliability

Reliability is often used to describe measurements relating to consistency and stability in repeated data collection (Hammond & Wellington, 2020, p. 163). In this thesis, measurements were not collected; however, data reliability can still be discussed regarding the consistency of the collection and methods and the reliable production of results found. Collecting the data from the Stavanger CRVA (2019b) was as consistent as possible given the situation. When classifying the measures as preventive, consequence-reducing, or both and later defining their technical, organizational, or operational barrier element type, the authors use a template provided by the Barrier memorandum (PSAN, 2017). The template was used consistently so all judgments about the data would be as reliable as possible. At times it was unclear what was meant by a certain risk event or measure, and it was interpreted and classified as well as could be possible without the background knowledge needed to explain what was meant by the municipality.

The results section shows graphs and charts used to illustrate the findings from the data collected. These figures are systematically created to show the results in a consistent representation and to capture the aspects of the data the authors believe to be most important in addressing the main topic of this thesis.

3.5. Process with Delimitation

Process

In order to adequately address these inquiries, it is imperative to take a multifaceted approach. The whole process of conducting this thesis is illustrated in Figure 1. The first step is a descriptive discussion on Stavanger Municipality's current balance of risk reduction measures assuming that it is operating as usual at the time of the risk event and that no extreme security circumstances were occurring. For this purpose, the authors categorized the proposed measures in Stavanger Municipality's CRVA (2019b) as either preventive, consequence-reducing, or a combination based on the available information and the author's background knowledge of barriers. In order to investigate additional aspects of the measures, they were categorized as operational, technical, organizational, or both, in line with the Norwegian Petroleum Safety Authorities Barrier Memorandum (PSAN, 2017). Currently, the municipality does not classify measures in this way, yet in the future, it might be fortuitous to do so. Following this categorization, the results are quantified in a tally and percentages, presented in the results section.

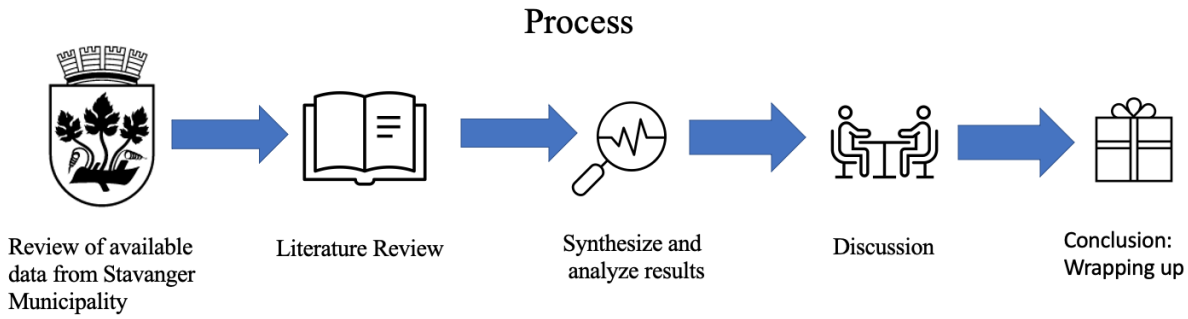

Figure 12. The process of conducting this thesis

The second step is the literature review of available and relevant literature. As information regarding the nature of barriers in the Stavanger Municipality's CRVA (2019b) is unavailable, a document search helped find additional relevant sources. Meeting minutes are examined for comments and notices about measures before and after the Stavanger Municipality's (2019b) was published. Lastly, the Action and Financial plans for the following years are investigated for signs of investment in the measures (Stavanger Municipality, 2019a, 2020, 2021, 2022). The extensive list of literature used as secondary data sources in this thesis is presented in Table 1.

Following the data review from Stavanger Municipality, a literature review of available theory is also conducted. The literature sources were used to expand on risk science, management, governance, barrier management, balance, systems thinking, and drift. These subjects are presented in the theory section of this thesis and will be used with the empirical contribution to address the main topic and research questions.

The third step is synthesizing and analyzing the results, leading to the fourth step of discussing the findings through the relevant theoretical contribution. Lastly, a concluding comment on the findings will be presented.

Delimitation

Some delimitations were necessary to answer the thesis problem and research questions in a compressed and timely matter. The study examined the Stavanger municipality's risk and vulnerability assessment and barrier balance work. Other municipalities were not considered and are not part of this study, even though the comparison between various municipalities' barrier balance is a fascinating topic to look into.

The methodological delimitation is around data collection. Initially, the research design was planned to revolve around interviews with employees of the Municipal Department of Public Safety and Preparedness (MDPSP) in Stavanger, supplemented with documents of their whole CRVA process, as well as meeting minutes where barriers were decided upon. However, the delimitation of the sources happened naturally after the Stavanger municipality respectfully declined to provide interviews and disclose relevant and necessary documents not accessible to the public with the argument that the current situation does not allow it. This was then understood as the sensitiveness of the material in times of increased security threats in Norway is an issue, as the thesis looks at both safety and security measures (ETJ, 2022; NSM, 2022; The Security Act, 2019). The authors' focus then changed to literature and available document analysis as the primary data source. Appendix C from the Stavanger Municipality's CRVA (2019b) listed 47 risk events identified as areas of concern. In order to prevent and mitigate risk from the chosen events, 278 measures are proposed. Appendix C is the basis of this research, although information regarding categorizing measures as preventive or consequence-reducing by Stavanger municipality is unavailable. Since only the published information is available, the events are taken at face value and categorized as such by the authors relying on guidance from the Barrier Memorandum (PSAN, 2017).

In addition, the document analysis investigates laws, regulations, project reports, and national publications relevant to the public safety and preparedness sector. The timeframe given to conduct this study also gave a natural delimitation of the scope and scale of data collection.

3.6. Strengths & Weaknesses of the Design and Project

Taking a qualitative approach to the research design was imperative as it best captured the current situation and the desire for deeper explanations, connections, and descriptions. While interviews with municipality employees involved in the CRVA would have strengthened the research, it was not possible. Interviews would have helped understand the process around proposing, classifying, and following up on measures. As these were not available, the reliance on government documents, guides, and meeting minutes helped to fill in the gaps. However, these did not fully answer all questions on the implantation of the measures.

Regarding the document search, there were many municipal documents to review from the time frame surrounding the Stavanger Municipality's CRVA (2019b). While Stavanger's action and financial plans listed budgeting for the coming year, it was challenging to correlate the line item in the budget to a specific measure proposed in the Stavanger CRVA.

It is essential to keep an open mind when conducting research and not to get locked into a single point of view but to look at the problem holistically and through multiple perspectives. This brings hidden assumptions to light and creates awareness of biases or implications (Neuman, 2013, p. 8). This research study was strengthened by collecting and considering multiple sources.

4. Results

The following section describing results consists of two subsections. The first is reviewing the results obtained from the data classified from the Stavanger CRVA. The second source of results is from a document search, reviewing laws, regulations, municipal guides, meeting minutes, and budget reports relevant to this thesis.

4.1. Data Results

Description of the Current Barriers Distribution

Investigating the current balance of measures required translating the list of proposed measures in Appendix C of Stavanger's CRVA (2019b), presented in Appendix 1. at the end of this thesis. The 47 risk events chosen by Stavanger municipality were numbered, and the measures associated with each were labeled with letters to assist in the data analysis. Following the translation, guidelines were established to classify the proposed measures as preventive, consequence-reducing, or both. The bow-tie model presented in Figure 13. was used to classify measures using the authors' judgment and knowledge of risk science, barrier management, and their understanding of the initiating events. The results of this classification can be seen in Appendix 1.

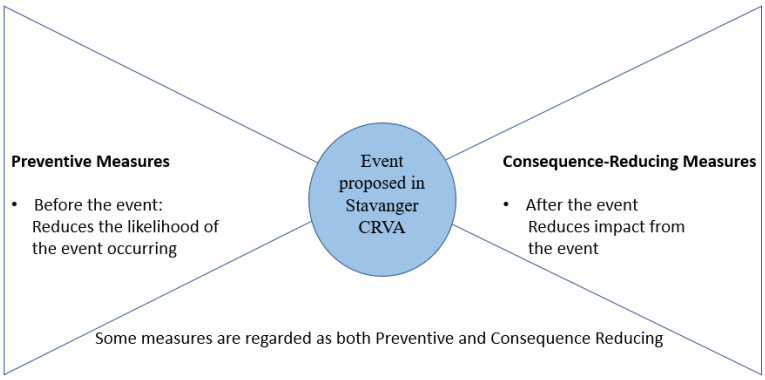

Figure 13. Depiction of the bow-tie model used to classify measures in Stavanger CRVA

Measures judged to reduce the likelihood of the event are considered preventive. Citing an example from the event of a long-term power supply failure, the proposed measure stating to – "ensure that infrastructure and facilities that are critical to the power supply are taken care of according to regulatory plans"- was deemed to be a preventive measure (Stavanger Municipality, 2019b).

Measures mainly focusing on mitigating the event's consequences are categorized as consequence-reducing measures. For example, for the long-term power failure the - Stavanger

72 campaign, residents must be able to care for themselves for up to 72 hours regarding food and water supply (Stavanger Municipality, 2019b). This measure can reduce the consequences of the risk event by ensuring that residents are prepared to be self-sufficient for 72 hours without power. This measure allows local officials to focus on more critical needs.

Some measures had elements of both preventive and consequence-reducing measures, such as the proposed measure - Municipal service areas should have power supply failures included in risk and vulnerability analysis (RVA) and emergency plans - (Stavanger Municipality, 2019b). The proposed emergency plans would guide citizens and government officials on steps to take after the power outage to mitigate the consequences.

Distribution of Preventive/Consequence-Reducing Measures

To calculate the distribution, a table was used to create a tally of the 278 measures proposed in the Stavanger CRVA (2019b). This table can be viewed in Appendix 2. The tally was used to calculate the percentages of the proposed measures, as presented in Figure 14.

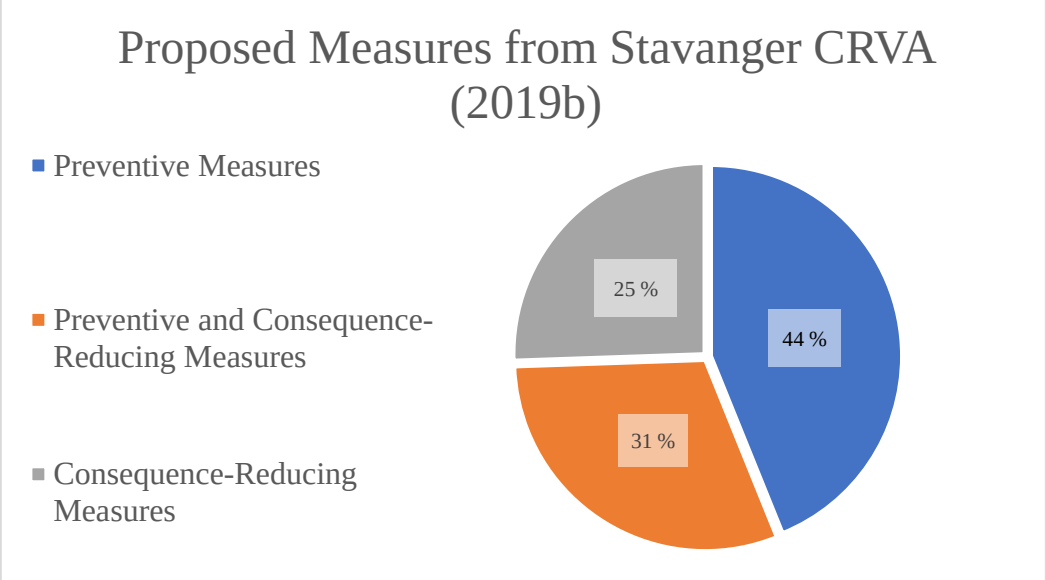

Figure 14. Pie Chart showing the percentage of the type of proposed measures represented in the Stavanger municipality CRVA as defined by the authors of this thesis. Figure created by the authors

The percentages in Figure 14 show the proposed measures in the CRVA (2019b) as they were judged preventive, consequence-reducing, and a mixture of both by the authors. The preventive measures comprise the majority at 44 percent. Consequence-reducing measures are substantially lower at 25 percent, and measures that are a mixture of preventive and consequence-reducing measures fall in the middle at 31 percent. These numbers represent a static interpretation of the measures at the moment the CRVA was completed and serve to identify the measure's proportions and their relation to one another.

The proposed measures are additionally identified by their barrier element type. The authors categorized the barriers element type as organizational, operational, technical, or citizen action using a template shown in Table 2. to guide the decision.

Technical elements support barrier functions with specialized equipment and systems. For example, in the event of a fire in a nursing home or other institution, a proposed measure was to install a sprinkler system throughout. This measure is deemed to have technical elements as it used equipment and systems to prevent and mitigate consequences after a fire started. Organizational elements support a barriers function with staff with defined roles, functions, and specific training. Going back to the event of a nursing home fire, the proposed measure of informing Rogaland Fire and Rescue about the municipal housing that is currently occupied is an organizational element type, as informing them is a defined role that must be completed. Operational elements support barrier functions with actions and activities. An example of this for the risk event of a nursing home fire is the proposed measure of holding practical exercises to test competence, preparedness, and staffing in the event of a fire. The barrier element type of Citizen Action has been added to account for measures like the Stavanger 72 hours self-sufficiency measure that relies on residents to act for themselves.

Table 2. Categorization chart used by authors when deciding on the barrier element type

Barrier Element Type	Relying on:
Operational	Actions and activities
Organizational	Personnel with defined roles and functions
Technical	Equipment and systems
Citizen Action	Residents to take action themselves

However, the distinction between the operational and technical classification is not always that clear as sometimes they can be closely related, such as an operator pressing an alarm or emergency brake button.

Distribution of Barrier Element Types in Measures

Following this categorization by barrier element types, the results were tallied (see Appendix 2.) to display as the pie chart in Figure 15 displaying the percentages of each barrier element type represented in the Stavanger CRVA (2019b) proposed measures.

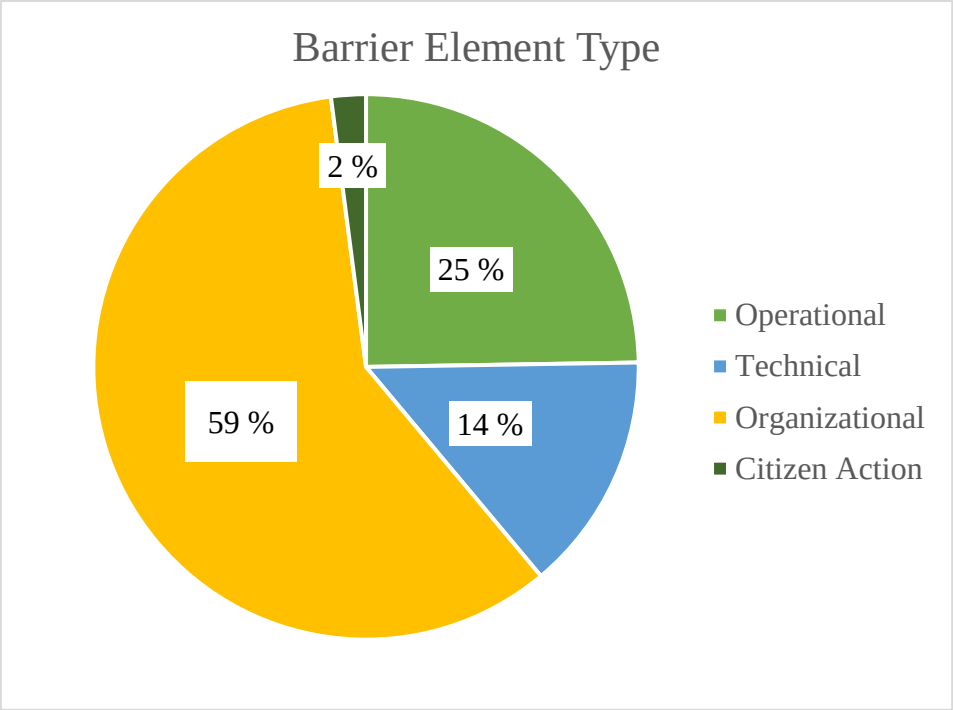

Figure 15. Distribution of barrier types in measures identified in the Stavanger CRVA(2019b) as classified by the authors. Figure created by the authors

Departmental Responsibility for Measures

A table in Appendix 3. presents the organizations responsible for the proposed measures and the distribution of measures in terms of preventive, consequence-reducing, or both. This is complex to present, as multiple organizations are sometimes responsible for an individual measure. In Figure 16., the distribution of measures each organizational group was responsible for is represented in a horizontal bar chart. The Municipal Department of Public Safety and Preparedness (MDPSP) has overwhelming responsibility for the proposed measures. The Department of Urban Environment and Development, Departments of Health, Citizen Services, and IT also have responsibility for many of the measures.

Figure 16. Organizations and the measures they are responsible for, and their distribution of balance as identified by the authors from the Stavanger CRVA (2019b). Figure created by the authors

Figure 17. is a simplified version of Figure 16., presenting the organizations sharing the responsibility for measures, consolidated, as shown in Appendix 3.

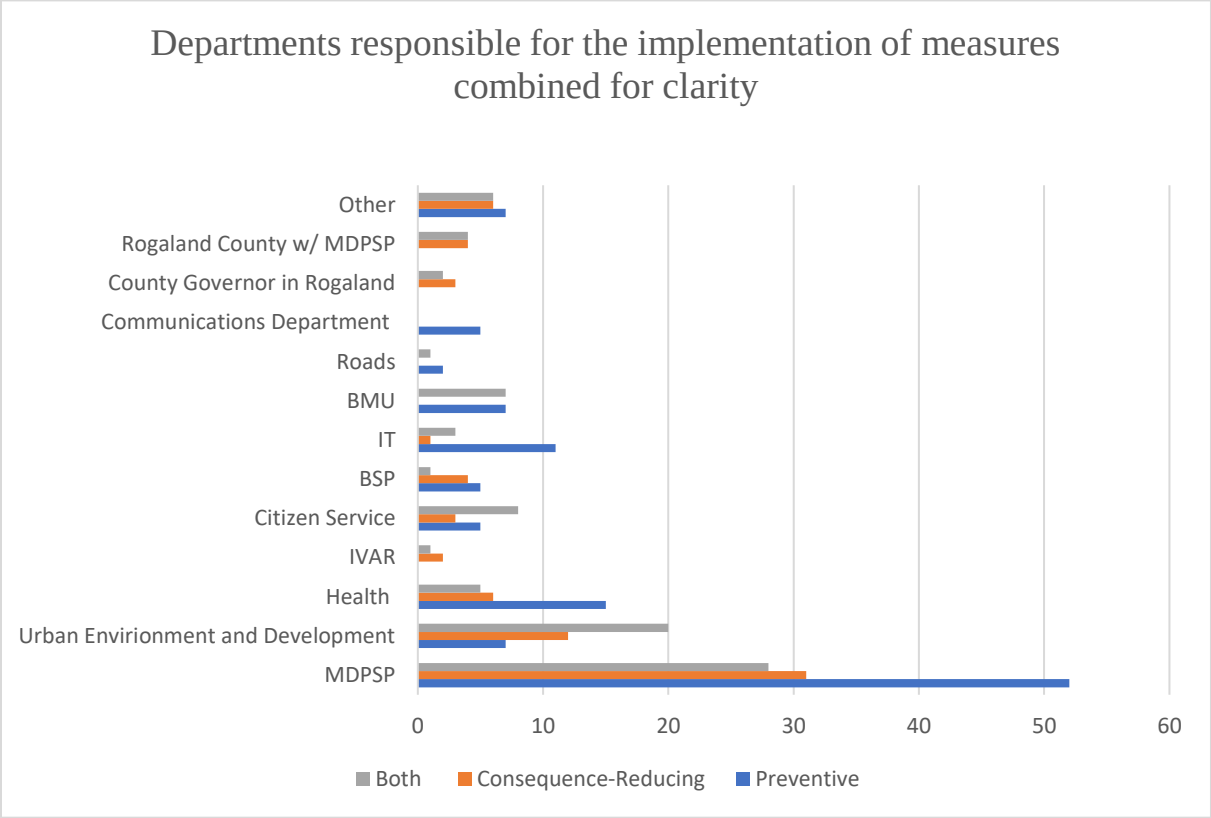

Figure 17. Departments responsible for the implementation of measures combined for clarity. Figure created by the authors

The overlap of these organizations and the size of their responsibility is portrayed in Figure 18.

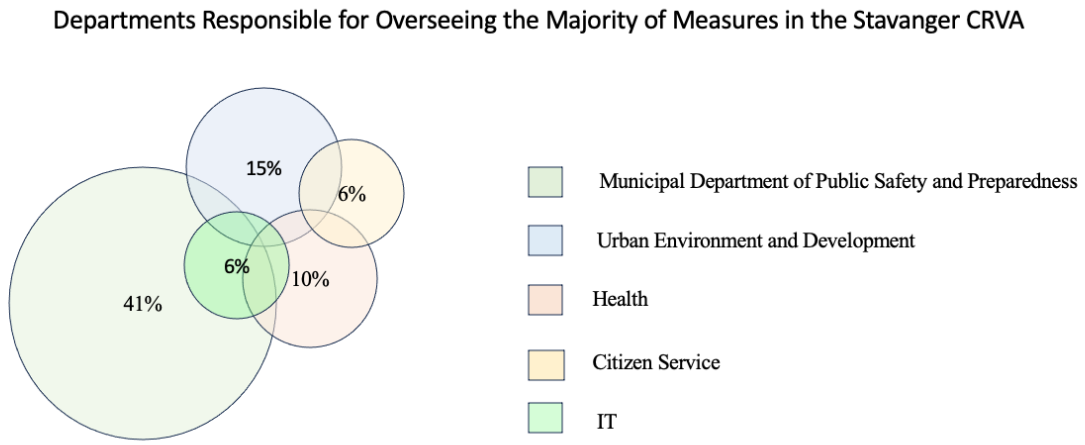

Figure 18. Departments responsible for overseeing the majority of proposed measures identified in the Stavanger CRVA (2019b). Figure created by the authors

Critical Societal Infrastructure/Function and Measures

An additional table was made to show the events and measures in the Stavanger CRVA (2019b) sorted by societal function. When the events and measures were initially displayed in Appendix C of the CRVA (2019b), they were grouped by societal function. However, it was not easy to see the correlation. In the tables shown in Appendix 4. the events and measures were grouped in sections to relate to their societal functions. The tallies of preventive, consequence-reducing, and measures that were both were added to this chart as the barrier element types, which can be seen in Appendix 2. These tallies are used to create Figure 1. and Figure 20.

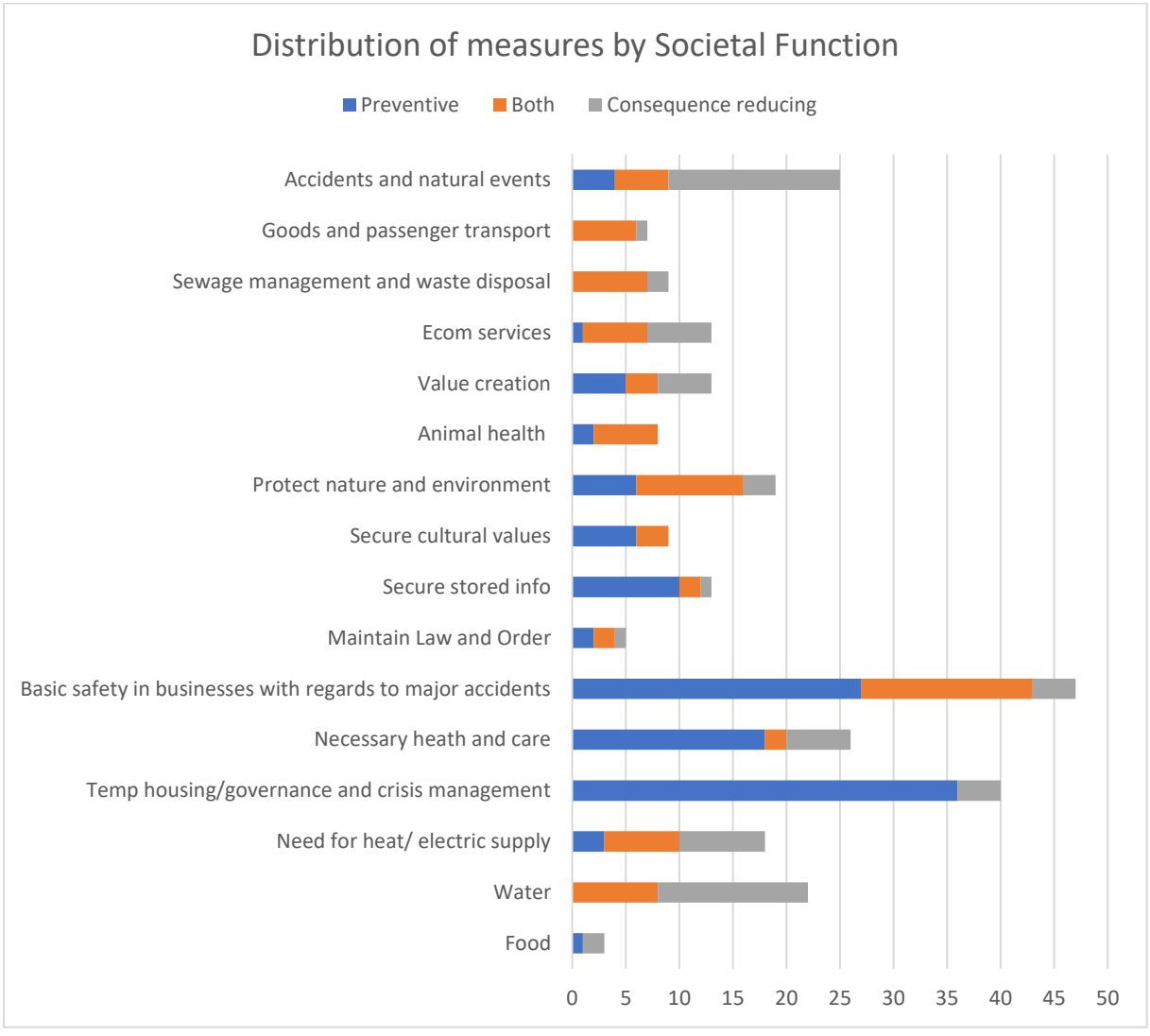

Figure 19. Distribution of measures by societal function as identified by the authors from Stavanger CRVA (2019b). Figure created by the authors

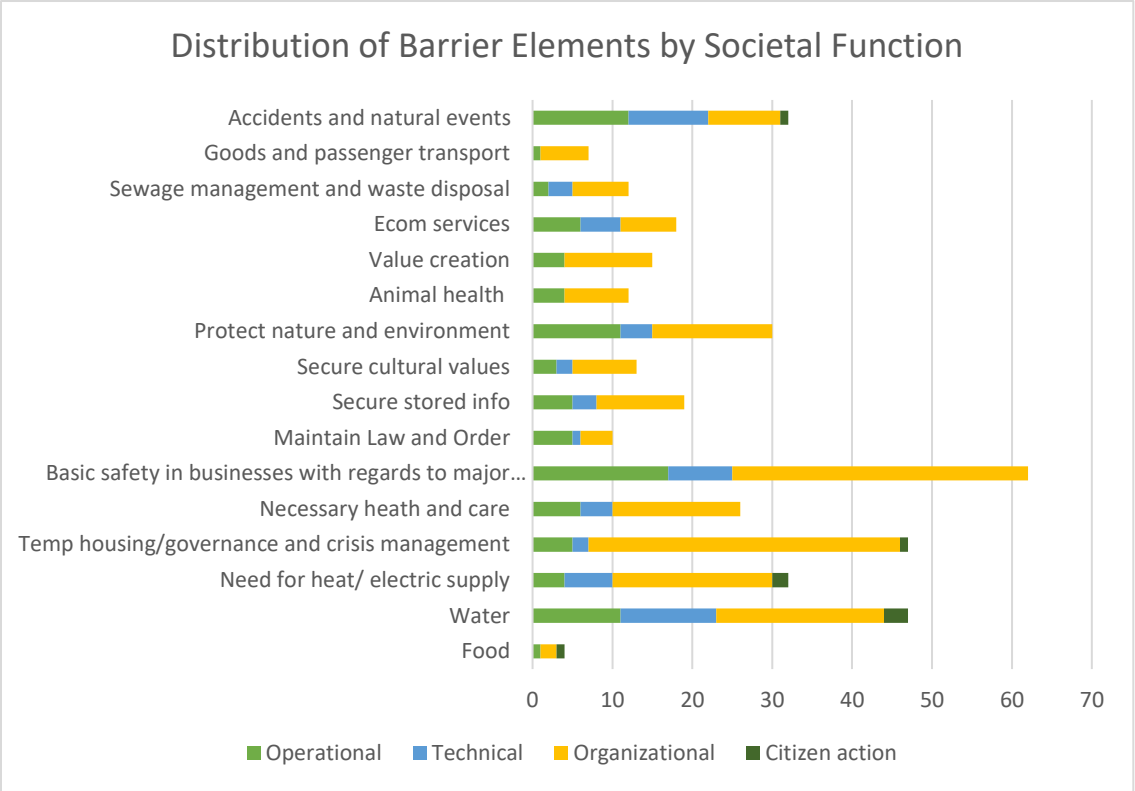

Figure 20. Distribution of Barrier Elements by societal function as identified by the authors

4.2. Document Search

The following section accounts for the data collected through government laws and regulations, national publications, the Stavanger Municipality's CRVA (2019b), various projects, surveys, and checklists. This is supplemented by accounts taken from the meeting minutes and an overview of the Action and Financial plans for the years surrounding the creation of the Stavanger CRVA.

4.2.1. Laws and regulation

Public safety and preparedness in Norway are very well regulated. In the discussion about the balance of measures in Stavanger municipality, it is inevitable to mention the overall national approach to risk governance and the relevant laws and guidelines.

Civil Protection Act

The Civil Protection Act (2010) encourages municipalities to appraise their public safety holistically. The act imposes the conduction of comprehensive risk and vulnerability analyses. In this way, potentially adverse events can be systematically mapped out as their occurrence probabilities and their effect on the citizens of these municipalities. The results of these analyses are then used for creating and implementing a preparedness plan for the municipality. The county governor will then coordinate the civil preparedness in the county between the municipalities and have an oversight, advisory, and guidance role in all questions related to

creating and implementing their preparedness plan (Fimreite et al., 2014, p. 51; Civil Protection Act, 2010).

Some of the most valuable paragraphs of the Civil Protection Act (2010) for this thesis are:

§1. states that the purpose of this act is to protect life, health, environment, material assets, and critical infrastructure and functions are protected through the use of non-military force in times of war, or when war threatens, when the kingdom's independence or security is in danger, and in the case of unwanted incidents occurring in peacetime.

§12. that states in detail the municipalities duties.

§14. The municipality's duty for preparedness & risk and vulnerability analysis

§15. Municipal preparedness duty – preparedness plan for the municipality

Regulation on Municipal Preparedness Duty

The regulation on municipal preparedness duty (2011) aims to ensure that the municipal work on public safety and preparedness (civil protection) is systematically and holistically implemented across municipal sectors, aiming to reduce the risk of loss of life or damage to health, the environment, and material assets. The preparedness duty gives every Norwegian municipality the role of authority within the public safety and preparedness work in their geographical area, as business, and as facilitator and motivator for other actors.

§2. states that every Norwegian municipality must conduct CRVA, including mapping, systematizing, and assessing the probability of adverse events occurring and their effects. The municipal council must approve the CRVA.

The municipality must also ensure that all relevant public and private actors are invited when RVA is conducted. In case of discovering the need for further, more detailed risk analysis, the municipality must follow through or make sure that the relevant actors will conduct this analysis. The municipality must also stimulate the relevant actors in implementing preventive and consequence-reducing measures.

§3. states that the municipality, based on its CRVA, will:

- Prepare long-term goals, strategies, and priorities and plan for follow-up of public safety and preparedness work.
- Assess conditions that should be integrated into plans and processes per Act 27 June 2008 no. 71 on planning and building proceedings (PBA, 2009).

§4. States the municipality’s responsibility to be prepared to mitigate adverse events through a comprehensive preparedness plan that coordinates and integrates all other preparedness plans of the municipality based on their CRVA. In addition, the preparedness plan should be coordinated with all other relevant public and private crisis and preparedness plans. The

preparedness plan should be conducted as an action plan of the municipal sub-plan per the Act 27 June 2008 no. 71 on planning and building proceedings (PBA, 2009).

§5. states that as possible, there should be established cooperation between municipalities, with local and regional preventive and preparedness solutions, so that resources are used most effectively.

§6. states that the CRVA must be updated in line with the revision of the sub-plans as per Act of 27 June 2008 no. 71 on planning and building proceedings PBA (2009) § 11-4 first paragraph, and otherwise in case of changes in the risk and vulnerability picture. The preparedness plan must continuously be updated and, as a requirement, at least once a year. The plan should clearly state who has the responsibility of following the plan updates and the work of updating it.

§7. states that the preparedness plan must be exercised every second year through the scenarios listed in the municipality CRVA, with other relevant municipalities and actors from these scenarios in the most helpful form. The municipality should have a system for training that ensures that people with a role in the municipality crisis management have sufficient qualifications.

§8. states that municipalities, through their exercise of the relevant scenarios, evaluate their crisis management, and if necessary, based on these, the CRVA and the preparedness plan should be adjusted.

§9. states that the municipalities must in writing document that the regulation demands are met.

§10. states that the county governor supervises that municipalities follow up on their duty given by the Regulation on Municipal Preparedness Duty (2011, Chapter 30).

Security Act

§1-1 of the Security Act (2019) states the purpose of this act is to contribute to:

a) Securing Norway's sovereignty, territorial integrity and democratic form of government, and other national security interests.
b) Prevent, uncover, and counter activities that threaten security.
c) Security measures are carried out in accordance with the basic legal principles and values of a democratic society.

§1-2 clarify that this Act applies to any state, county, and municipal body.

The Security Act is very detailed and consists of 12 chapters. However, for the scope of this paper, § 1-1. from Chapter 1. is sufficient.

4.2.2. National Publications

In the following sections, a general overview of national publications is given. The publications listed in this section have relevance in addressing the main topic and research questions posed in this thesis.

CRVA Guide by NDCP

The NDCP (2014) guide to municipal CRVAs assists municipalities in meeting regulations and creating consistency. In addition, it stipulates that information from past events and experts can be used, but unexpected issues should be accounted for. Intentional and unintentional events should be assessed for probability and consequences similarly. When assessing probability, consequences, and vulnerability, the knowledge base should be strong, there should be agreement among assessors, and it should be acknowledged that the risk picture can change. To reduce uncertainty: more knowledge must be gathered, understand that there is always uncertainty, and propose measures to take uncertainty into account (NDCP, 2014).

The process recommended by NDCP for conducting CRVA is clearly defined as follows:

1. Clearly describe the incident, contributing factors, and existing measures.

2. Vulnerability assessment: Are there distinctive features of the municipality that could contribute to the undesirable event developing for the worse? (Natural conditions, demography, etc.)
    - Could the unwanted event lead to the consequential event and failure of critical societal functions and services?
    - How will long-term lapses affect other critical community functions and services?
    - How will the unwanted event affect the municipality's management and crisis management capabilities?

3. Impact assessment: (community value, consequence type, consequence category, justification).

4. Uncertainty assessment to list the uncertainties.
    - Identify potential measures by listing probability and consequence-reducing classifications.
    - Governance: Assessment of controllability (low, medium, and high) Are the measures in place, and are they effective?

5. Risk Description: low, medium, high, justification
    - Based on the ratings above, low to high
    - Possible Measures: Probability reducing, Consequence reducing.

6. Governance: low, medium, high, justification
    - Assessment of controllability

Description of Stavanger Municipality CRVA

Stavanger municipality, on the 1st of January 2020, merged the smaller municipalities of Finnøy and Rennesøy into its jurisdiction. This created the need for a new and updated comprehensive

risk and vulnerability analysis (CRVA), reflecting the public needs of these two smaller communities and the risks emerging from these interdependencies.

The Stavanger Municipality's CRVA (2019b) has been prepared for scenarios occurring in normal operating conditions throughout the year. The analysis gives a systematic evaluation of the municipalities geographical area and operation, aiming to map out risk and vulnerability, which includes:

- unwanted incidents that are of such a nature or extent that it involves the municipality's management in the assessment of preventive measures, as well as preparedness and crisis management.
- adverse events affecting several sectors.
- uncover cross-sectoral vulnerabilities and interdependencies.
- avoid risk and vulnerability where possible.
- reduce risk and vulnerability through preventive and damage-limiting measures.
- handle any residual risk with preparedness.

This CRVA is conducted as a project consisting of representatives from the three municipalities that merged and is based on the analysis of the meeting and audit rounds carried out over several years, consistent with several documents. Appendix H of the Stavanger Municipality's CRVA (2019b) shows the complete overview of the revision history.

The Norwegian Directorate for Civil Protection - NDCP (2014) CRVA guide is used for conducting the CRVA of the merged Stavanger municipality. The NDCP CRVA guide is supplemented by adding NS 5814 standard, which deals with requirements for risk assessments. The risk assessment process is based on the ISO3100 standard (Stavanger Municipality, 2019b, app. 1). In addition, this analysis builds on the previous relevant municipalities' risk and vulnerability assessments (RVAs). In a project group with representatives of all three municipalities, revision on the existing RVA's was made, and it was decided that the previous RVA (2017) of Stavanger's should be used as a starting point for the new CRVA. The 2017 Stavanger RVA was judged to be eligible both methodologically and by its content (Stavanger Municipality, 2019b).

Following, a gap analysis was carried out to detect the differences in the existing analyses, ensuring that the new CRVA of the merged Stavanger municipality includes all relevant risk elements, including those of the new areas. Because of the high quality of the 2017 RVA, the new CRVA is a revision of it, adding various other activities that were not present previously. It was decided that major changes in adverse events identified in RVAs 2017 should be emphasized, in addition to the changes caused by the merger. The revision was based on the ISO 31000: 18 standard and the following criteria:

- The barriers/measures status
- New knowledge
- Knowledge acquired through previous adverse events

- Change in framework conditions (the internal/external context)
- New adverse events (Stavanger Municipality, 2019b).

The adverse events were identified in the project meetings, as well as the risk description and vulnerabilities present in the societal functions, basic capabilities, performance, and infrastructure. All events were assessed through the criteria mentioned above, and those with major changes were additionally analyzed based on the bow-tie diagram – Figure 5. This diagram was used to illustrate the various aspects of risk analyses, where adverse (initiating) events are identified, and a description of the risk and vulnerability linked to the societal infrastructure and functions.

The risk sources were also assessed, and the probability (preventive)- and consequence-reducing barriers/measures were identified for existing and new proposed barriers/measures. The analysis was built on the assumption that the existing measures and barriers are working as intended (Stavanger Municipality, 2019b).

Following, for the identified adverse events was conducted an assessment of the:

- The consequences of an adverse event occurring are as follows:
    - Expected consequences given an event has occurred
    - The potential for significant deviation from the expected and actual consequences.
- The likelihood of an adverse event occurring is based on the description of the adverse events and their risk sources, consequences, and probabilities. These probabilities are justified by referring to data basis, statistics, previous risk assessment, etc.
- The strength of knowledge (SoK) base for the events' likelihood and expected consequences.
- The controllability of risks linked to the event (Stavanger Municipality, 2019b).

The societal values that the Stavanger municipality wants to protect with associated type of consequences are presented in Table 3.

Table 3. Societal values and their associated consequence type as presented in the Stavanger Municipality's CRVA (2019b)

Societal values	Type of consequence	Observable sizes
1. Life and health	1.1 Death	• Number of deaths • Time of death
	1.2. Injuries and illness	• Number of injured • Number of sick
	1.3. Physical stress	• Number of affected individuals • Duration
	1.4. Mental health issues	• Number of individuals that need follow-up
2. Nature and environment	2.1. Long-term damage to nature and environment	• Geographic distribution • Duration
3. Economy	3.1. Financial and material loss	• Damage on property, financial loss, as well as mitigating, handling and restoring
4. Societal stability	4.1. Social unrest	• Number of individuals with behavioral reactions • Duration
	4.2. Disturbance in daily life	• Number of affected individuals • Duration
5. Governance and territorial control*	5.1. Weakened national governance	• Number of relevant indicators • Duration
	5.2. Weakened territory control *	• The size of the geographical area that is affected • Duration
6. Cultural values	6.1. Loss of cultural values **	• Qualitative criteria

* Governance and territorial control are a national matter and thus not the municipality's responsibility, but the municipality will be affected by, and must deal with, the consequences of weakened national governance.

Appendix B of the Stavanger Municipality's CRVA (2019b) contains all the risk characterization categories, such as categorizing the consequences, probability, uncertainty, and controllability.

Appendix C of the Stavanger Municipality's CRVA (2019b) presents identified measures for assessing short- and long-term applicability. Table 4. presents these new adverse events. In addition, it presents the societal function/basic capability the events affect. The measures are suggested to be prioritized and generally implemented based on a cost-benefit assessment. The extensive analysis log is given in Appendix A of the Stavanger Municipality's CRVA (2019b), which is covered by Norwegian Security law and made unavailable to the public.

Table 4. List of adverse events as presented in the Stavanger Municipality CRVA (2019b)

ID	Event	Social Function/Basic Capability
1	Failure of Food Supply	1. Provide necessary food supply.
2	Distribution of Hazardous Food	
3	Failure/ Interruption of Drinking Water Supply (long-term)	2. Provide necessary (drinking) water supply. C. Water supply.
4	Distribution of Contaminated Drinking Water	
5	Contaminated Drinking Water, Air, Food etc. Due to Radioactive Fallout	
6	Power Supply Failure (long-term)	3. Provide society needs for heating. B. Electricity Supply.
7	Failure of Gas Distribution (long-term)	
8	Failure of District Heating (long-term)	
9	Failure to Provide the Necessary Shelter and Population Notification/ Evacuation**	3.2. Ability to provide temporary housing. 2. Enable governance and crisis management.
10	Failure of Regional Coordination and Crisis Management	
11	Failure of Local Crisis Management	
12	Failure of Population Information Regarding Prevailing Risks, Crises, and Crisis Management	
13	Failure in Health and Care Services	7.1. The ability to maintain necessary health and care services
14	Epidemic / Pandemic	
15	Hospital Fire/Explosion	
16	Hospital Sabotage/Terrorist Attack	
17	Nursing Home/Institution Fire	
18	Failure of Emergency Services - General	
19	Major Accident- Industry	7.3. Ability to maintain basic safety levels in businesses with the potential for major accidents
20	Major Accident - Aviation	
21	Major Accident - Sea	
22	Major Accident - Road	
23	Major Accident - Railway	
24	Dam break	
25	Offshore Accident	
26	Fire in Buildings With Many People	
27	Serious Crime – including terrorism and ongoing life-threatening violence	8. Maintain law and order
28	Failure in Information Security	10. Secure stored information
29	Damage to Cultural Heritage/Cultural Environment	11. Secure cultural values
30	Fire in the Wooden Town - Old Stavanger	
31	Release of Hazardous Goods	12. Protect the nature and the environment
32	Emission of Diesel etc. From Tank Facilities/pipelines	
33	Acute Air-pollution	
34	Nuclear Accident	
35	Failure of Animal Health	12.2 Take care of animal health
36	Infectious Plant Disease	
37	Dramatic and Lasting Drop in Oil Prices / Phasing Out of Fossil Energy Sources	13. Maintain value creation
38	Failure of Banking and Payment Solutions	
39	Incident that Requires the Evacuation of the Forus Area	
40	Failure of Ecom (e-communications)	A. Ecom-services
41	Failure of Sewage/Sewage services/Ability to Handle Sewage	D. Sewage management and waste disposal
42	Failure in Renovation	
43	Failure in Goods/Passenger Transport	F. Goods and passenger transport
44	Extreme Weather / Natural Event	5.1 Ability to monitor and limit the risk of accidents and natural events
45	Natural and Forest Fire	
46	Social Security Challenges Related to Immigration **	
47	Hybrid Events**	

** Events not analyzed

In Stavanger's CRVA, the risk picture is illustrated with risk matrices, showing the probability and consequences for each risk event. The amount the consequences may deviate from the expected value is also represented, along with an indication of weak background knowledge where applicable. These risk matrices illustrate the risk picture and are not solely used to guide decisions about reducing, mitigating, or preparing risks (Stavanger Municipality, 2019b).

The municipality has an enormous role in public safety and preparedness, as it "owns" the events occurring on its territory and their mitigation. The Stavanger Municipality's CRVA (2019b) accounts for this and specifies that if an event occurs in a neighboring municipality, such as a power outage for example, Stavanger will be adversely affected because critical infrastructure is damaged or in defect, or because citizens of the Stavanger municipality are directly and indirectly involved. The county governor gets the central role if the power outage affects the whole region. However, Stavanger municipality must contribute to mitigating the adverse situation. Even in case of events outside Norwegian borders that affect Norwegian citizens, the municipality must be prepared to help.

Chapter 5.4 from the Stavanger CRVA (2019b) reflects on the implication of the loss of critical infrastructure. In Table 4. critical infrastructure is marked with capital letters A, B, C, D, and F. The E-com services marked with A and the electricity supply marked with B are regarded as the most critical infrastructures in the CRVA. Figure 21 visualizes the interdependencies of these critical infrastructures.

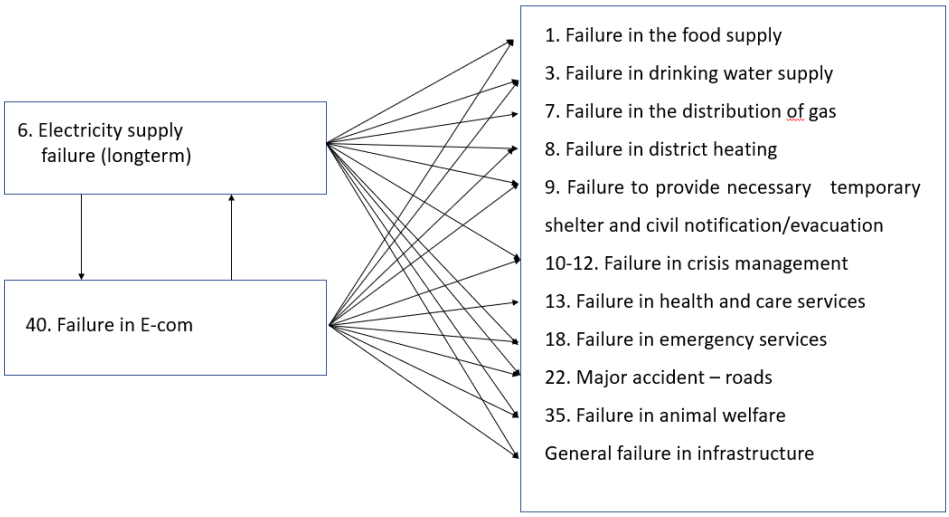

Figure 21. Interdependencies between the critical infrastructures of electricity supply and E-com and their potential adverse events as presented in NDCP (2014) and the Stavanger Municipality's CRVA (2019b)

Several measures are already in place, such as a reserve supply of electricity, more robust communication solutions if the E-com is disabled, and plans to relocate crisis management leaders if the administration offices are disabled/destroyed (Stavanger Municipality, 2019b).

Chapter 6 of the Stavanger Municipality's CRVA (2019b) states clearly that the responsibility of following through with the CRVA and prioritization of the measures lies with the municipal council and that it is in line with §2 of the Regulation on Municipal Preparedness Duty (2011).

Some of the measures are general and can be applied to any region municipality, while others are specifically created for the new Stavanger region. It is suggested that the prioritization of the measures should be based on cost-benefit analysis.

BAS 3 Project

A few decades back, The Norwegian Directorate for Civil Protection (NDCP) recognized this and commissioned the Norwegian Defense Research Institute (FFI) to improve knowledge about vulnerabilities and interdependencies in electricity production and distribution. The BAS3 final report - "A Vulnerable Electric Power Supply" (1999-2001) – summarizes the research conducted by the FFI on this topic (Fridheim et al., 2001). The report emphasizes the critical role of electricity in Norwegian society and highlights the mutual dependencies among various public sectors. For example, in a situation where telecommunication and electronic payment systems are both dependent on electricity and each other, any disruption would have a cascading effect, impairing multiple aspects of society's normal functioning. The report also states that the consequences for society are high in a long-term power outage. However, even short outages affect society's normal functioning to some degree. BAS3 concludes that the vulnerabilities in the Norwegian electricity supply will only increase in the future due to the society's dependency on electricity and uncertainties of the security picture (Fridheim et al., 2001).

MEREPUV Project

The “Methods and measures to enhance resilience against electrical power outage in urban vital societal functions” - MEREPUV project (NDCP, 2019b), funded by the EU Commission (DG ECHO), explored the vulnerabilities of power outages in cities. The beneficiaries were stakeholders from Norway, Netherlands, and Latvia. The goal was to reveal vulnerabilities and interdependencies that have not come forward in previous risk assessments through hypothetical power outage situations. The New York City, Argentina, and Uruguay power outages are events that remind society of scenarios with low probability and high consequence combination of relevance and importance (Bogost, 2019; Byrne & Henao, 2019; NDCP, 2019b).

Three Norwegian cities were involved in the MEREPUV project – Oslo, Bergen, and Stavanger. Each municipality was required to conduct a risk and vulnerability assessment (RVA) of power outages for three vital societal functions (health services, emergency services, and critical communication systems), which were then summarized in national working papers. Each city focused on one of the vital societal functions, with Stavanger focusing on e-com services (NDCP, 2019b). This project aimed to increase cities' (community) resilience in case of a power outage by:

- “improving knowledge of cities’ role in protecting their vital societal functions from such disruptions;
- and by identifying efficient measures available at the local level for protecting citizens against severe consequences of power outage.” (NDCP, 2019b)

In today's interconnected world, disruptions to critical infrastructure can have far-reaching consequences. For instance, according to the MEREPUV project and the NDCP guide on comprehensive risk and vulnerability assessment, failure in electricity supply will adversely affect the e-com services and vice versa. This can lead to:

- failure in supply of food, warmth, and medicine,
- failure in accommodating evacuated citizens,
- failure in energy, fuel, and gas supply, water supply and waste services,
- failure in transport,
- failure in supporting vulnerable groups,
- failure in performing necessary health and care functions,
- failure in social services,
- failure in providing emergency and rescue services,
- failure in governance, crisis management and communications (NDCP, 2019b, 2014).

The list is extensive, Figure 21. Such disruptions can lead to major social and economic disturbances, compromising public safety and the ability to respond effectively and efficiently to emergencies (NDCP, 2019b, 2014).

Barrier Memorandum

The authors regard the Barrier Memorandum by PSAN (2017) as the most crucial literature for this thesis. This publication aims to clarify the interaction between technical, operational, and organizational barrier elements and how these can be planned and monitored over time. “Who does what with which equipment in failure, hazard and accident situation” is developed as an instructional phrase for clarifying the interaction and importance of each barrier element (PSAN, 2017, p. 8). PSAN has, throughout many years, focused on barrier management in the petroleum industry, leading to increased competence and understanding of the importance of the barrier in case of accidents and optimizing companies' barrier management systems (PSAN, 2017, p. 8).

In this publication, PSAN's conclusion based on audits and inspections was that companies had identified the human factor “to providing barrier functionality only to a limited extent” (PSAN, 2017, p. 8). Technical barriers seem to be in focus, while operational and organizational have been “identified and emphasized to a lesser degree” (PSAN, 2017, p. 8).

Municipal Survey by NDCP - 2019

In their municipal survey of municipalities in Norway, the NDCP (2019a) reflects that the Planning and building act is rarely used to safeguard public safety. The work in the CRVA should be reflected with follow-up plans, maps, and provisions and the work with public safety should be comprehensive and systematic, as illustrated in the figure (NDCP, 2019a).

Figure 22. Components in the quality cycle as described in the Municipal survey by NDCP (2019a)

The survey explains that at a minimum, the CRVA should include:

- Existing and future risk and vulnerability factors in the municipality
- Risk and vulnerability outside the municipality in the geographic area that has the most importance to the municipality
- How different risk and vulnerability factors affect each other
- Special challenges linked to critical social functions and loss of critical infrastructure
- Ability to maintain its business when exposed to an unwanted event and the ability to resume business after an event has occurred. (Resilience)

Stavanger Risk and Vulnerability Checklist for Regulatory Plans

Stavanger Municipalities' (2018) checklist reviews requirements from the NDCP checklist while adding that there must be a conclusion, including the follow-up of measures suggested in the CRVA. If necessary, the measures must be followed up with an analysis and a conclusion. This document also emphasizes that mitigation measures must be specific and followed up in the plans and regulations (Stavanger Municipality, 2018).

Report on Norwegian Municipalities Planning, Implementation and Use of Risk and Vulnerability Analysis in Connection with Security Work

The study conducted by Njå & Vastveit (2016) analyzed data collected regarding understanding planning, presenting and implementing the RVA process specific to a selection of municipalities in Norway. This survey aimed to identify how the municipality works with holistic understanding and thinking in social security work. The municipalities surveyed were not directly identified, therefor results could only be used for this thesis in general terms.

Njå & Vastveit (2016) identified a trend in the survey that showed municipalities found it difficult to ensure the implementation of measures and that proper departments took control of implementing and following up. Too many organizations in charge of the measures make

claiming responsibility for implementing, checking, and following up on measures challenging. And overall, the measures proposed were very general (Njå &Vastveit, 2016).

The survey conducted by Njå & Vastveit (2016) aimed to identify how the municipality works with holistic understanding and thinking in public safety work. Municipalities are complex systems and thus require vigilance and system understanding (Njå & Vastveit, 2016). Njå & Vastveit (2016) conclude that there is a need for active learning efforts. Normal learning work after dramatic events is an immediate reaction and prompts self-examination in organizations. Nancy Leveson says simple risk-based governance is not suitable for complex systems. Systems theory applies as there are so many who work in a municipality (Leveson, 2011).

The Civil Protection Act (2010) and Regulation on Municipal Preparedness Duty (2011) set requirements for the Municipality's RVA analysis and public safety work in general (Njå &Vastveit, 2016). These requirements significantly demand the knowledge and competence of the municipality employees to interpret what these mean for the municipality and how employees should work with the requirements (Njå & Vastveit, 2016). Risk-informed management and risk thinking are challenging. It is easier for municipalities to specify preparedness over public safety (Njå & Vastveit, 2016).

Meeting Minutes from Municipal Council

These meeting minutes reflect the thoughts and actions of the Municipal Council in the time surrounding the creation, approval, and implementation of the Stavanger CRVA, which was completed as the municipality expanded to include Finnøy and Rennesøy into New Stavanger. The merger of Finnøy and Rennesøy to Stavanger prompted the Stavanger Municipality's CRVA (2019b) as there was a need for more knowledge and more detailed analyses. The municipality's risk practice changes continuously to reflect the features and concerns of society.

On November 19th, 2019, the Stavanger Municipality Council was presented with a briefing and case description of the Comprehensive Risk and Vulnerability Analysis for Stavanger Municipality (Stavanger Municipality Council, 2019). The Stavanger Municipality Council mentioned the need for municipalities to have a central role in Public Safety within Norway, as local communities should be safe and robust (Stavanger Municipality Council, 2019). At this meeting, it was discussed that the Stavanger Municipality's CRVA (2019b) is based on previous important foundational documents. Such as the County Governor Office's RVA (2018) and the police security service's (PST) (2019) annual threat assessment, among others (Stavanger Municipality Council, 2019).

The municipal board unanimously approved the Comprehensive Risk and Vulnerability Assessment for the new Stavanger municipality on December 12th, 2019 (Stavanger Municipal Council, 2019). It was stipulated that the report should be revised every four years at a minimum.

The final report for New Stavanger was presented to the council on January 5th, 2022 (Stavanger Municipal Council, 2021). This report details that New Stavanger Municipality was officially established on January 1st, 2020. The planning and preparations leading up to this occurred over

2014-2020, intending to strengthen the three municipalities and make them more robust together. It was decided that the roles and responsibilities in situations with many management lines, resources, and interactions must be clearly assessed for risk and uncertainty (Stavanger Municipal Council, 2021). This report mentioned that risks should be identified and followed up with dialogue between the individual project manager and program staff. A second RVA was completed in the second half of 2019 to identify important harmonization tasks and the risk of delays (Stavanger Municipal Council, 2021).

Budget Reports

The Action and Financial plans for Stavanger from 2019-2024 do not specifically address the measures proposed in the CRVA, their funding, implementation, or review (Stavanger Municipality, 2019a, 2020, 2021, 2022). However, sections appeared in these budget documents that could be assumed to address the proposed measures indirectly for the risk events of failure and contamination of drinking water supply, sewage, and failure of information security. The sections in the action and financial plan that appear to correlate with these events are described below.

In the city and community planning section, of the Action and Financial Plan for the years 2019 -2022 there is an investment in a new emergency network, including procurement and operation. In addition, an external review of IT infrastructure with a security perspective was budgeted, along with investments in privacy and security (Stavanger Municipality, 2019a). In the Action and Financial plan for 2020-2023, preparedness and community development are budgeted for each of the next four years (Stavanger Municipality, 2020). Funding in the budget for a new emergency center and ICT upgrades for Rennesøy were present in the Action and Financial Plan for 2021- 2024 (Stavanger Municipality, 2021). Measures to upgrade waterworks in Rennesøy and Finnøy, upgrade sewage in Rennesøy and add additional upgrades to reduce water leakage with reinforcements to secure the supply were funded. Backflow protection against pollution in the water supply and sewage with the renewal of pipes was present under the budget heading of urban transformation (Stavanger Municipality, 2021).

The merger brings new agricultural concerns, as emissions from Rennesøy and Finnøy are more extensive than for Stavanger. The measures to address this will be included in the climate budget. There are uncertainties to consider with regulations about emissions and political concerns changing. Stavanger Municipality relies on publicly available data, assessments, and budget improvement to reduce uncertainties (Stavanger Municipality, 2021).

5. Discussion

Throughout this research study, the goal has been to investigate the balance of measures in Stavanger municipality and the connection between this balance, government requirements for public safety and preparedness, and how Stavanger municipality as a system works on increasing resilience while avoiding drifting into failure. This section will present parallels between theory, data from the Stavanger Municipality's CRVA (2019b), and empirical findings by attempting to answer four sub-sections, one to address each research question posed in section 1. in order to gain more insight on municipal work on measures.

5.1. What is the Current Distribution of Measures?

The answer to this question is descriptive and achieved through reviewing the Stavanger Municipality's CRVA (2019b) document, specifically Appendix C, to examine the distribution between proposed measures. Appendix C presents the gap analysis results conducted when the three municipalities of Stavanger, Finnøy, and Rennesøy merged. This means that the proposed measures are considered missing, not an overview of all measures. As the data consistent with all the measures in the Stavanger municipality is not available, the authors can not know what is implemented. In this case, the interpretation is based on what is stated in the Stavanger Municipality's CRVA (2019) document.

Section 4. shows the current distribution, where multiple charts can be viewed. For the question posed, the distribution concept was better suited than balance as the main goal is to represent the measures spread between the preventive and consequence-reducing sides of the bow-tie model. In a way, the distribution is a measurement of balance. In this thesis, the term distribution applies to a more static representation of the measures when they are proposed or analyzed. However, the concept of balance describes a shifting scale where measures can be addressed dynamically on both sides of the bow-tie model, with the potential for adjustment for optimal functioning. This section will discuss the results portrayed in Section 4. and elaborate on limitations faced when representing this distribution.

Distribution of Preventive/Consequence-Reducing Measures

The preliminary category examined in the results is the distribution of preventive and consequence-reducing measures from the Stavanger Municipality's CRVA (2019b). The results are categorized as either preventive, consequence-reducing, or both, and the distribution is displayed in a pie chart, Figure 14. This chart shows that most measures are preventive at 44%, while consequence-reducing measures are only at 25%.

The NDCP guide to municipal CRVA (2014) prescribes classifying measures as preventive or consequence-reducing. Stavanger has followed this guide when proposing measures. A key difference in the distribution of the measures presented by the authors is that they classified many of the measures as both preventive and consequence-reducing, which is 31% of the total. For example, in the event of a long-term drinking water failure, one of the measures proposed is a "Third main water line is being planned in the Stavanger region". The authors have

interpreted this measure to both prevent a failure and mitigate the consequences, depending on what the measure entails. Because the specific knowledge and context of the measure are lacking, it presents a challenge for the authors to classify it as solely preventive or consequence-reducing. The authors regard many of the measures proposed in Appendix C of the Stavanger Municipality's CRVA (2019b) as too generally formulated and thus challenging for precise interpretation and classification.

The measures classified as both preventive and consequence-reducing bring up the concept of barriers doing dual duty on both sides of the bow-tie. This classification of measures as "both" opened up a new avenue to consider barriers, as they can be adaptable and applied to different risk sources. For example, take the measure of "Third main water line is being planned in the Stavanger region". The authors considered having a third water line an excellent preventive (redundant) measure in case the other water lines are damaged, as it prevents the initiating event of "failure in water supply" from occurring significantly. However, they also considered it a consequence-reducing measure, as having this third water line will also significantly reduce society's consequences from the "failure in water supply" initiating event. Identifying and implementing barriers as "both" could potentially have merit to the municipality moving forward.

Table 4. lists the 47 initiating events from Appendix C of the Stavanger Municipality's CRVA (2019b) discovered in the gap analyses. However, the root causes of these are not specified in the available documents. The Stavanger Municipality's CRVA (2019b) states that they used the bow-tie model for risk assessment. This led to an understanding that risk sources have been listed, but a decision has been made on what will be presented in the document and available to the public.

Looking at the new proposed measures listed in Table 4. the author's impression is that the Appendix C of the Stavanger Municipality's CRVA (2019b) does not specify the risk source but seems more focused on the initiating events than their causes. They also appear more focused on the vulnerabilities of the critical infrastructure, or more specifically, on reducing those, as opposed to what causes failures in their critical infrastructure. This claim is based on the available documents and the authors' interpretation. In addition, this conclusion cannot be used for generalization as it is based on very small part of the actual measures considered and implemented by Stavanger Municipality. Without interviews from those conducting the Stavanger CRVA, it is difficult to discuss how they decided where to have their focus when presenting their risk analysis results, which initiating events to focus on, if the measures are so broadly formulated to account for both hazard and threat born issues if they focus more on preventive or consequence-reducing measures, and if the vulnerability is the aspect actually where they focus the most.

The relativeness of a barrier doing a dual duty is something that Hollnagel (2016) addresses. He states that the issue of determining barriers as either preventive or consequence-reducing is "…relative to the occurrence of the initiating event in the sense that the very same barrier in some cases may be preventive and in some protective" (p. 78). He gives the example of a door into a room full of hazardous materials as both a preventive and protective barrier depending

on the initiating event. As a preventive measure, this door restricts people's entry into this room, so people will not be exposed to hazardous materials. The door can also serve as protection to contain a fire in the room so it does not spread outside, therefore reducing consequences (Hollnagel, 2016, p. 79). This can also apply in the case of initiating event being a result of a previous initiating event occurring (e. g., 1. gas leakage leading to 2. explosion). In this case, a wall is a consequence-reducing measure for the gas leak, stopping it from spreading, while it is also a preventive measure, containing the gas in a space where no ignition can occur. The approach to measures shifts depending on the initiating event and, with this, the distribution, or more specifically, the balance of the measures.

In addition, Hollnagel (2016) also regards barriers as permanent and temporary (p. 76). An example of this type of measure can be the temporary measures enforced by the Stavanger municipality at the peak of the Covid-19 pandemic. The relevance of the Covid-19 measures for this thesis is not their preventive or protective classification but their timeframe, as temporary measures skew the balance. Consequently, all the above-mentioned examples play a significant role in figuring out the balance of measures in Stavanger municipality, presenting an issue that could be challenging, extensive, resource and expertise-demanding, and exhausting for the employees.

Woodruff (2005) discusses that risk-based decisions in Health, Safety and Environment (HSE) are often more influenced by the consequences than the overall risk. He further discusses that the hazard affects the event's severity. However, the event's nature and context are fundamental, maybe even more than the hazard itself. Woodruff (2005) suggests that practitioners in any risk-based maintenance program should focus more on identifying events as the first building block of an effective risk assessment program, not the hazard per se. Woodruff's (2005) point of view is something that this thesis agrees with, especially because Norwegian municipalities must account for both hazards and threats. In that case, we recognize that focusing predominantly on the initiating event and its context is of great importance and should have precedence. Jore (2019) further states that despite the differences, like the hazard and threat-born risk sources leading to an initiating event, the consequences for society can often be similar (e.g., as in the power outage from the 1.1. section of this paper).

On the other hand, the root cause for the initiating event is important for prevention and the decision-making process. According to Jore (2019), the approach to preventive measures shifts depending on whether it is a hazard or threat-induced initiating event. For example, if we consider that the risk source for the power outage was hazard induced, especially in the case of a well-known phenomenon on which we have high knowledge and experience, the preventive measures would be much different than if the risk source was a malicious attacker that we had not encountered before and the knowledge base is generally low (Jore, 2019). In the case of not knowing what to protect from, the measures would focus on reducing the vulnerability. In security risk analysis supported by the Norwegian Security Act (2019), the risk is seen as the three-factor model of threats, values (assets), and vulnerabilities (NS 5814: 2021; NS 5832: 2014). On the other hand, in safety, the risk is regarded as the"…two-dimensional combination

of the consequences C of the activity (with respect to something that humans value) and associated uncertainties about C" (Aven & Thekdi, 2022, p. 304).

However, in the case of a power outage, the same consequence-reducing measures (e. g., a generator with a backup, sufficient fuel supply, and a 72-hour campaign) will mitigate the consequences, regardless of if the risk source was a hazard or a threat (Jore, 2019). In addition, many of the same consequence-reducing measures can often reduce both security and safety threats (e.g., a fire extinguisher, 72-hour campaign), although this is not always the case, as some measures have different effects on security and safety (Jore, 2019). This means that from an organizational perspective, it is necessary to see security and safety in relation to each other so that security measures do not threaten safety or vice versa (Jore, 2019). Thus, the consequence-reducing measures proposed should be adjusted depending on the risk source and the initiating event, accounting for Jore's (2019) argument that safety measures could sometimes affect security and vice versa. However, this discussion is not the center of this thesis and therefore will not be discussed further here.

Going back to Woodruff (2016), we agree with his statement that identifying events in complex systems is imperative, especially because complex systems have emergent properties from the interaction between the system's components and the interaction of the system's barriers. However, focusing on the causes of the initiating event does not and should not exclude the focus given on identifying possible events. We understand this as risk analysis should be supplemented with an additional focus on identifying events, especially those potentially arising from the emergent properties of complex systems.

In addition, the Stavanger Municipality's CRVA (2019b) has proposed generic measures that seem to fit a wide range of events and consequences. The document has stated that these measures and events are assumed to occur during a period of normal operation and not a time of war. However, even the magnitude of an event could bring a need to adjust measures. For example, if power is cut due to a landslide, the size and location of the landslide would have implications for the consequence-reducing measures. There is a difference in how a landslide would be mitigated in the countryside than in a densely populated city. Cities have more vulnerabilities as the infrastructure is interdependent because of physical proximity, operational interaction (O'Rourke, 2007), and all the other assets and values humans want to protect.

Distribution of Barrier Element Types in Measures

Jore (2019) states that regardless of the hazard or threat cause of an initiating event, major organizational accidents involve the failure of different technical, organizational, and operational (human) barriers. In addition to categorizing the measures as preventive, consequence-reducing, or both, the authors categorized the measures by barrier element type. This was done to discuss the distribution of technical, operational, organizational, and citizen action barrier elements type within the measures. The Barrier Memorandum from the PSAN (2017) is used to guide this classification, and the criterion used by the authors can be seen in Table 2. Measures were sometimes classified as having mixed types of elements as there was some overlap in the description of the measures. For example, the measure "Reduce the

consequences of failure in the electricity supply by setting up alternative heating in new homes (a requirement in legislation) and informing about people's/organizations'/companies' own responsibilities" is judged to have all barrier element types present - technical, operational, organizational and citizen action. However, some measures only had one associated barrier element type, such as "Municipal service areas should have power supply failures included in RVA analyses and emergency plans," which was classified by the authors as an organizational barrier element type.

The distribution of these measures shows that Stavanger municipality has the majority of 59% associated with organizational barrier element types. Operational element types represent 25% of the total, while technical 14%. Citizen action accounts for 2%, where participation from residents was relied on to implement preparedness measures, such as the Stavanger 72 plan, to ensure that residents can provide for themselves without power for 72 hours.

Departmental Responsibility for Measures

One aspect of the Stavanger Municipality's CRVA (2019b) that stands out is the amount of overlap regarding who is in charge of implementing and following up on measures. Looking more closely at the measures and the actors responsible, we can see that MDPSP has the most responsibility for the proposed measures overall. The urban environment and development and health and welfare followed this. These three departments were involved with the majority of proposed measures, as seen in Figure 18. On the other hand, very few measures had only one department responsible for them, such as health and welfare and communications. Most measures had anywhere from two to five different private and public actors that shared responsibility for them. The departments responsible for measures are from Stavanger Municipality and other private companies such as IVAR and Bane Nor. The authors believe this makes a holistic approach to barrier management within the municipality somewhat challenging, more so in the case of poor cooperation and coordination between the risk governance levels, both vertically and horizontally.

In addition, Njå & Vastveit (2016) identified a trend in their survey that showed municipalities found it challenging to ensure the implementation of measures. Too many organizations in charge of the measures make claiming responsibility for implementing, checking, and monitoring challenging (Njå & Vastveit, 2016). Stavanger Municipality's CRVA (2019b) had a column in Appendix C representing completed measures and the date. Only six of the 278 measures are completed, and 35 have a status update at this point. While originally published in November 2019, the Stavanger CRVA was updated in December 2020 and again in October 2021. If the measures have been completed in the time frame following the CRVA, it was not reflected in the updated versions.

Critical Societal Infrastructure/Function and Measures

The events and proposed measures described in Appendix C of the Stavanger Municipality's CRVA (2019b) are arranged according to the critical infrastructure and functions, see Table 4. The results based on the authors' interpretation show that measures are predominately

preventive in these particular societal critical infrastructures and functions: Temp housing/governance and crisis management; Necessary health care; Basic safety in business with regards to major accidents (which had the most measures overall); securing stored info; and securing cultural values, see Figure 19.

Providing "basic safety in business with regard to major accidents" had many preventive measures. This could be because the measures' requirements stem from outside sources (laws and regulations). The petroleum industry is one of the leading industries in Norway and is associated with the most significant industrial accidents – The Bravo blowout (environmental) and the Alexander Kielland accidents (mass casualties) (Smith-Solbakken, 2023; Smith-Solbakken & Dahle, 2023). These accidents consolidated the tripartite " The Norwegian Model" of close cooperation between the workers, employers, and the authorities in Norway, which increased the overall offshore technical safety (Rosness & Forseth, 2014, p. 314). However, the risk events for this category are all due to major accidents from the petroleum industry and any other industry, in addition to major accidents in aviation, sea, roadways, railways, offshore accidents, or a fire in a building with many people. Planning for these types of risk events involves a lot of collaboration with other actors, preparation, and exercise of these types of scenarios.

On the other hand, the critical social infrastructure and functions with the most consequence-reducing measures were: Food supply; Water supply; The need for heat; E-com services; and Accidents and natural events, Figure 19. Most consequence-reducing measures are associated with "accidents and natural events". This would include events for extreme weather, nature, and fire events (hazards), as these types of events are highly likely to occur based on previous experience. Such events usually have known consequences. However, their magnitude may vary. While prevention is important in these events, such as prohibiting disposable grills in exposed areas, most measures are consequence-reducing, such as having call lists at the ready. Even though this measure may seem preventive at first glance, it will not prevent the adverse event. However, it will reduce the event's impact and therefore is categorized as consequence-reducing.

5.2. Should the Measures Balance be Different From Today and Why?

The section below focuses on the laws, guides, and regulations and how these can potentially affect the balance of municipal measures. The issue of cost is also reflected. Lastly, the importance of barrier balance is discussed.

Regulations in place

Figure 3. presents the laws and regulations that create the municipal obligation for civil protection and preparedness. Stavanger Municipality's CRVA (2019b) must be anchored through these laws and regulations. In addition, Stavanger Municipality must comply simultaneously with the four PSP principles of responsibility, consistency, closeness, and cooperation/coordination. These requirements are the frame in which Stavanger municipality

must work. The authors' interpretation of the frame is presented in Figure 1. where all important aspects protecting basic human values are shown.

As mentioned in Section 2.3.1., the work with PSP primarily lies at the national level (Engen et al., 2016, p. 46). However, Engen et al. (2016) state that for optimal PSP, several levels of state authorities, municipalities, and private organizations must be involved and cooperate (p. 52). This is a problem, as such a structure gives fragmented responsibility, potentially leading to confusion. The biggest dilemma is between the top-down approach in citizen protection – centralization - with a holistic view, consistent governing, and more effective allocation of resources; and the bottom-up approach to citizen protection - decentralization - that utilizes the full potential of the local resources and the possibility of improvisation if the situation requires it (Engen et al., 2016, p. 52). However, decentralization creates an environment where innovative ways of dealing with PSP can be fostered if enough resources are allocated for such work. This leads us to conclude that good vertical coordination is essential in Norwegian risk governance and PSP work.

As described in Section 2.4. risk management is not only about risk reduction but is more about finding an appropriate balance (tradeoffs) between protection and value creation (SRA, 2018). Risk management in Norwegian municipalities must be based on a risk-informed strategy, meaning based on risk assessments. The requirements for the CRVA are put in place by the Civil Protection Act (2010). Emergency plans and exercise drills are mandatory requirements of the Regulation on Municipal Preparedness Duty (2011, § 7 & 8), and 24 of the measures proposed dealt directly with conducting exercises to increase preparedness. The CRVA guide for municipalities by NDCP (2014) states that information from past events can be used as a basis for the CRVA, but uncertainties should be accounted for. Having a strong knowledge base and agreement that the risk picture can change, resulting in the need for new risk assessments, is also recommended by the NDCPs CRVA Guide (2014).

However, risk assessments are often conducted so that regulatory requirements are met. If the sole reason for conducting a risk assessment is the regulatory requirements, the full potential of the assessment can be missed (Aven & Thekdi, 2022, p. 63). The authors' impression is that the Stavanger Municipality goes beyond the regulatory requirements based on their interpretation of the proposed measures in Appendix 1. This shows that the municipality plans to invest resources in discovering gaps and acquiring more knowledge through new RVAs. However, such a conclusion is impossible at this point. First, because generalization should not be based on such a small sample of measures. Second, most of the proposed measures are not yet implemented, as shown in Appendix C of the Stavanger Municipalities CRVA (2019b).

In addition, the Stavanger Municipality's CRVA (2019b) builds on previously conducted RVAs and is then supplemented with a gap-analyses. As previously mentioned, new risk analyses often build on past analyses. This leaves room for surprising events to arise as conducting the CRVA using accumulated knowledge from previous risk assessments can systematically oversee aspects passed on in such a build-up of risk analysis. Even though knowledge accumulation is required, necessary, and time and resource saving, it does not always allow the risk assessment of such a complex system to start anew, discovering aspects relevant to the

present risk picture. One of the most significant issues is if previous oversight is continuously moved forward in the risk analysis. Another issue is that the risk analysis does not adapt as quickly as the risk picture changes, and with this, the appropriate measures (balance) are lacking.

An essential aspect of risk management is implementing appropriate measures in order to mitigate the risk while development is encouraged. Too many barriers can crowd each other and even be counterproductive to overall civil protection, as discussed in section 5.1. Abrahamsen et al. (2018) state that too many measures are not feasible in organizations with a limited budget. This can lead to suboptimal overall protection, as older measures can be neglected or deprioritized by implementing new measures (Abrahamsen et al., 2018). This is why a tool such as a barrier management/strategy is important. The Barrier Memorandum by PSAN (2017) states that barrier management in the petroleum industry is the coordinated actions in establishing and maintaining barriers so that they function as they should at all times so that the risk will be reduced in case of a failure, hazard, or accident (PSAN, 2017). We believe that a sound barrier management strategy can even help organizations adjust their measures' balance. Having few well-functioning measures is better than having many dysfunctional or sub-optimal ones, making barrier management important for organizations.

The Issue of Cost

One approach in this thesis is searching for public documents to see which proposed measures from the Stavanger municipality were budgeted for. We tried to understand if Stavanger Municipality is following up on its proposed measures and if the Municipal Council approves funding. The logic behind this is that the price of measures influences what is recommended, enforced, and followed up and thus is an important aspect of adjusting the balance. If the municipal budget does not explicitly account for measures, it is difficult to check if they are in place. The same can be said for the maintenance of existing measures.

What we found by reviewing the Stavanger Municipality's CRVA (2019b) is that the proposed measures should be based on a cost-benefit assessment. The document's Appendix C has a column for the price to be presented, which is still empty. The Action and Financial plans of Stavanger Municipality (2019a, 2020, 2021, 2022) and meeting minutes were searched to find evidence that the measures listed in their CRVA are budgeted for. There are line items listed for an external review of IT infrastructure with a security perspective, in addition to investments in privacy and security and ICT upgrades for Rennesøy. The budget items appear to align with the measures proposed in the CRVA for an event dealing with a failure in information security (Stavanger Municipality, 2019a). However, no correlation is shown in the Action and Financial plans to connect the measures proposed in the CRVA with their associated budget. Urban transformation is budgeted for 65 million NOK, but external actors control these projects, and there is significant uncertainty about the costs and progress. These measures for urban transformation are mandated by law and obligation in the roads act and are prioritized (Stavanger Municipality, 2021).

Water and Sewage improvements that have been budgeted for in Stavanger's Action and Financial plan (2021) include measures to upgrade waterworks in Rennesøy and Finnøy and upgrades to sewage in Rennesøy as well as upgrades to reduce water leakage and reinforcements to the security of the supply. In addition, backflow protection against pollution in the water supply and renewal pipes have a price budgeted for them in Stavanger's Action and Financial plan (2021). These budgeted measures are perceived to be in line with the "failure in the drinking water supply and the distribution of contaminated drinking water" event from the Stavanger Municipality's CRVA (2019b). Again, based on the available data, we cannot find a direct correlation between the budget and the CRVA.

It is challenging, solely based on the publicly available data, to follow up on the measures in the budget. The authors did not find documentation for the budget of all measures. This can be because such documents are not made available to the public or because these measures are still a work in progress. Only six of the 278 measures have been presented as being completed in the Stavanger Municipality's CRVA (2019b).

Balance

Balance can be equated to maintaining control. Achieving a balance between preventive and consequence-reducing measures is paramount for municipalities in ensuring adequate protection and preparedness. Striking the right balance between these measures is crucial for comprehensive risk management. Too much on any side can cause control to slip, resulting in chaos. However, control does not have to be rigid and unyielding, nor does balance. As viewed by the authors, balance is about maintaining control to best prevent risk events from occurring and mitigate consequences in any given situation. This means that Stavanger Municipality must vigilantly follow the changes in the risk picture globally, regionally, locally, and within the organization itself and adjust the balance of the measures accordingly. When too many measures are on either side of the bow-tie, the control can slip, and events, incidents, and hazards can come through, much like the concept of maintaining a defence in depth (Reason, 1997). If measures focus only on one side, the system approach and the emerging properties created by the measures interacting within the system are not considered (Leveson, 2011). Therefore, a well-rounded approach combining proactive prevention with robust response and recovery strategies is essential. By appropriately allocating resources and implementing a diverse range of measures, municipalities can foster a resilient system that not only reduces the risk of initiating events occurring but also effectively manages their consequences, safeguarding critical infrastructure and ensuring the safety and well-being of the community.

As described in the previous question, the distribution of the proposed measures is predominately preventive in Stavanger Municipality, Figure 14. According to the Barrier Memorandum by PSAN (2017), preventive measures should always have priority over consequence-reducing measures. However, measures are often needed on both sides of an initiating event (PSAN, 2017). Stopping an adverse event from occurring is always better than mitigating the consequences. By increasing robustness through preparedness measures, we can also increase resilience and reduce vulnerability. However, achieving this might not be as simple when information about the phenomena is unavailable, and the measures are mainly

organizational and depend on human interaction to function. Regardless, prevention is not always possible. In that case, protection is necessary. Focusing too much on preventive measures will lead away from a critical aspect of risk management – reducing consequences.

On the other hand, Figure 14. shows that 25% of the distribution of the measures is consequence-reducing. These measures add resilience to the system, meaning measures that will enable the system to get back to its original state as much as possible, as soon as possible (Haimes et al., 2008). Not applying a holistic view on risk reduction measures can present its challenges, which will be discussed in Section 5.4.

A fragmented approach, focusing solely on either side of the bow-tie model, regarding the measures individually may lead to a lack of coordination, redundancy, or even conflicting strategies, as discussed previously in this thesis, Section 5.1. and by Jore (2019). For example, focusing solely or predominantly on preventive measures may result in neglecting the importance of consequence management, leaving municipalities ill-prepared to respond effectively when an incident occurs. On the other hand, solely or predominantly focusing on consequence-reduction measures may overlook the underlying causes and fail to address the roots of the initiating event before it manifests. A holistic approach is necessary, one that integrates preventive, consequence-reducing, and resilience-building measures to create robust and adaptive risk management (Haimes et al., 2008).

Therefore, a well-rounded approach that combines prevention with robust/resilience strategies is essential. By appropriately allocating resources and implementing a diverse range of measures, municipalities can foster a resilient system that reduces the risk and effectively manages their consequences, safeguarding critical infrastructure and ensuring the safety and well-being of the citizens.

Literature on barrier balance is rarely presented in a national context. However, Haimes et al. (2008) have written on *Homeland Security Preparedness: Balancing Protection with Resilience in Emergent Systems*. Their article addresses that one must look beyond component systems and their assets and include the study of emergent system-level attributes by adding resilience to the system (Haimes et al., 2008). This article is considered an essential contribution to this thesis, even though it does not straightforwardly discuss the balance between preventive and consequence-reducing measures. The authors agree with Haimes et al. (2008) that adding resilience and focusing on a holistic approach can achieve more balanced risk management where the emerging properties of the system components and measurement interaction are considered. This approach can potentially improve governmental preparedness for civil protection (Haimes et al., 2008).

Preventive measures, and for that matter, consequence-reducing measures, being implemented is not enough. One must consider the interdependencies and interaction between the various implemented ***preventive vs. preventive*** or ***consequence-reducing vs. consequence-reducing measures***, as well as between these two different types (***preventive vs. consequence-reducing***) of measures. Simply said, one must be aware of the emergent properties of these measures interacting. Haimes et al. (2008) claim that by adding resilience to a system, emergent properties

that can impact the overall system must be addressed appropriately (Haimes et al., 2008). A system can become more robust if the system design is hardened, but this is not the same as the system becoming resilient. Resilience goes beyond robustness. This is because "…resilience requires attention to the system structure, architecture, and component system interdependencies" (Haimes et al., 2008, p. 291). Aven (2011) is of a similar view and states that a robust strategy is more proper in case of known potential hazards and threats, while a resilience strategy "is a proactive strategy against unknown or highly uncertain events" (p. 12). The emerging properties of barriers and system elements interacting can be regarded as highly uncertain events, especially if the organization does not have the focus or expertise to discover these emerging properties. The aspects of resilience presented in Section 2.1.5., are of great importance when discussing a holistic approach to risk management (barrier management) in organizations, specifically for such complex organizations as the Stavanger municipality. This would also help create an appropriate balance for the specific risk picture. However, the holistic approach and the importance of resilience in a system of systems type of organization will be more profoundly discussed in Section 5.4.

5.3. How can the Measures Balance be Adjusted to Provide a Better Fit?

A few different methods and approaches will be discussed in discussing how the balance of measures can be adjusted for a better fit. This will begin with showing departmental accountability for the measures, their follow-up, and finally, discussing the aspects of barrier management from the petroleum industry.

Departmental Accountability for Measures

The results from the gathered data on measures from Stavanger Municipality show that MDPSP is responsible for the most proposed measures, Figure 18. The majority of the measures the MDPSP is responsible for are preventive measures, Figures 16, 17. This makes sense, as this department is responsible for the preparedness part of the civil protection in the municipality. However, a focus on consequence reduction does not appear to be lacking either. The authors read from the results that the distribution of the measure is mostly on preventive measures, but the rationale here is understood as solid. The Barrier Memorandum by PSAN (2017) does state that preventive measures are preferred over consequence-reducing.

However, having one department responsible for most of the measures can be both positive and negative. The positive is that when one department is responsible for measures. The study conducted by Njå & Vastveit (2016) on various *Norwegian Municipalities Planning, Implementation, and Use of Risk and Vulnerability Analysis in Connection with Security Work* showed that municipalities found it challenging to ensure the implementation of measures and to decide which is the adequate department to take control of implementing, checking and following up on the measures. This responsibility is mostly in MDPSP at Stavanger municipality, with 41% of the measures. This is presumed to make the work with barriers implementation and follow-up easier for the Stavanger Municipality.

The study by Njå & Vastveit (2016) also pointed out that the governmental requirements from the Civil Protection Act (2010) and Regulation on Municipal Preparedness Duty (2011) place a great demand on the municipality's resources and expertise. Having one department dealing with most of the PSP work and implementing barriers, as in the case of the MDPSP of Stavanger Municipality, would help this problem.

The authors also recognize that having one department responsible for most measures helps the municipality maintain a holistic approach to the implemented measures, as there can be better accountability. The learning potential, in this case, is also more significant.

On the other hand, the negative side of having one department responsible for most of the measures is that it can be challenging to view the system holistically without input and oversight from all the departments involved with the CRVA. Key insights and observations may not be shared among all the actors involved, which can be critical to maintaining both barrier functionality and civil protection.

Follow-up on Proposed Measures

The Stavanger Municipality Risk and Vulnerability Checklist for Regulatory Plans (2018) states that measures must be followed up with analysis and, if necessary, documented. The checklist also emphasizes that mitigation measures must be specific and followed up in the plans and regulations (Stavanger Municipality, 2018). Despite revisions in 2020 and 2021, of the Stavanger Municipality's CRVA (2019b), for the authors, it is not apparent that the proposed measures have been documented nor reflected in Stavanger Municipality's Action and Financial plans (2019a, 2020, 2021, 2022).

Ideally, a paper trail should prove that barriers were budgeted, initiated, completed, monitored, and reviewed to increase accountability. By checking up on the measures and accounting for them, the municipality will have a more accurate picture of their level of civil protection and can identify gaps. Without this accounting, the authors find no reliable way to address and check the balance of the proposed measures.

The authors believe that accounting for measures through documentation and departmental oversight can better represent the measure's distribution, further providing a better understanding of the balance in the municipality. However, this might be the case internally in Stavanger Municipality, but data on this is not available to the public.

Barrier Management

By incorporating strategies of barrier management into the Stavanger Municipality's CRVA (2019b), the municipality could potentially adjust the distribution and balance of measures better. Stavanger lies in an oil-rich area where much research and funding goes into the petroleum industry. The Petroleum Safety Authority of Norway has studied the process of barriers and management for years and has published an extensive report called the Barrier Memorandum (PSAN, 2017).

Stavanger Municipality does not use concepts from barrier management, but it might benefit from them. It appears that the municipality understands and implements risk management well in practice. Barrier management lies under the umbrella of risk management and risk governance, Figure 1. It incorporates the concepts already in place in standard risk management and elaborates on the aspects of functionality, barrier strategies, their elements, and performance requirements to ensure barriers are in place and working as expected (PSAN, 2017).

Barrier management in the petroleum sector refers to systematically keeping the organization in line with the current government, industry, and performance requirements. Barriers are devised for a specific risk picture and should be managed to provide optimal (holistic) protection (PSAN, 2017). If the risk picture changes, it would require an adjustment of the barriers. Managing barriers systematically through a barrier management strategy should be of greater importance in a municipal setting where the risk picture can change quickly, especially in cases with high uncertainty. However, this view is based on the assumption that Stavanger Municipality does not have such a system in place.

The Barrier Memorandum suggests that organizations (municipalities) should identify the performance requirements to check that the barrier elements function as they should. They should also be investigated by reviewing past incidents and interviewing current staff to see if barriers work properly/efficiently. The organization should communicate these requirements (Vinnem & Røed, 2020, p. 406).

Maintenance of the barrier performance should be established to ensure the barriers are working as they should and are monitored to address adjustments to the changes in the risk picture (PSAN, 2017). The performance of barriers can be characterized by their robustness, integrity, availability, functionality, and capacity (Vinnem & Røed, 2020). To improve barrier reliability, increased knowledge should be gathered about barrier performance (Vinnem & Røed, 2020). PSAN (2017) states that management judgment and review of barrier functionality need to be revised often. Technical barriers should be inspected and maintained, while organizational and operational barriers need to be frequently practiced and appropriately trained with safety drills and training evaluations. The authors identified that 59% of the proposed measures in Stavanger Municipality are organizational, Figure 15.

Safety measures are usually addressed individually, making seeing dependencies and common cause failures challenging. The Norwegian regulations require independence between barriers when there is more than one (Vinnem & Røed, 2020, p.405). To view the system holistically, any short-term, long-term, or even organizational changes should be considered for impact on barrier functionality (PSAN, 2017). A holistic view of the barrier system should be taken, but this must be systematically documented and internalized in the organizational culture.

The Holistic Approach to Barriers

Øien et al. (2015) describe a holistic approach to barrier management in the petroleum industry that emphasizes the maintenance of all barriers, not just those with technical components,

acknowledge the importance of having staff on-site be familiar with which barriers are there, what their functions are, and have a clear knowledge of their performance requirements. The process of barrier management should be communicated to staff so that there is understanding across the board about barriers functions and why those responsible for them should be held accountable for their operation in the larger system (Øien et al., 2015).

Such devotion and approach to barrier management are challenging in a municipal setting as organizational barriers depend on various factors, such as that employees must have defined roles and functions. This would require many people with very distinct roles attached to monitoring each measure. However, it is not impossible. The Regulation on Municipal Preparedness Duty (2011) §7 requires that municipalities have an education system that ensures employees with crisis management roles have the necessary qualifications. This leads to the conclusion that maybe in order to achieve a good holistic approach to barriers in complex socio-technical systems that ensure public safety and preparedness, people with high expertise in barrier management should be employed. The knowledge gathered from the petroleum industry is valuable for the municipalities, but applying it directly can be challenging as municipalities must also adhere to the four principles of PSP work.

In addition, Øien et al. (2015) describe that to achieve a holistic approach in the petroleum industry (technical safety), barriers should function independently so that if one fails, it does not cause others to fail as well. This is especially important with operational and organizational barriers, as it can be challenging to establish performance requirements for them (Øien et al., 2015). Organizational barriers are defined by the Barrier Memorandum (2017) as relying on the person with defined roles and functions. These requirements need to be specific and detailed, including how to reach operators and access data about the barriers (Øien et al., 2015). Hypothetically, this can be achieved if the organization is devoted, has the culture for it, and is very precise in assigning the requirements to the employees (department) responsible for that specific organizational barrier. However, this requires enormous resources, and organizations may not have the proper motivation to achieve this.

5.4. Is a Holistic Approach Necessary for Barrier Balance in Complex Organizations?

Njå & Vastveit (2016) identified municipalities as complex systems that require vigilance and system understanding. Stavanger municipality is a complex socio-technical system with numerous interdependencies. One might even say that it is a system of systems. Implementing systems thinking can enhance resilience and provide significant benefits, as risk management with a systems thinking approach involves understanding a system's intricate connections and complexities to reduce risks and create value. The resilience strategy is a cost-effective way to address risks in complex socio-technical systems, as suggested by Leveson (2012, p.6).

In a socio-technological system, barriers can be regarded as one type of system component. Barriers must fulfill their function to prevent or mitigate an initiating event. The barrier doing its function should straightforwardly increase the safety of the system. Having many barriers

would, by this logic, mean that the system is safer. However, this is not that simple, and is why complex systems must focus on a holistic approach to barrier balance.

As discussed in Section 5.2., barrier balance is important for optimal protection. This leads to the understanding that barriers on each side of the bow-tie should be adjusted according to the risk picture, in some cases more preventive measures, while in others more consequences-reducing. One must apply a holistic approach to the distribution of measures so neither side is favored, and with this miss relevant aspects for increasing citizen protection. However, the holistic approach for barrier balance based on the systems theory logic presents a different level of a holistic approach, focusing on the emerging properties of the barrier interactions.

Systems theory claims that accidents in complex systems are usually due to the interaction of system components. These components, sometimes being barriers, when operating individually fulfill their function without issues (Leveson, 2012, p. 9). Barrier interaction can create emerging properties that organizations did not account for, as these interactions are usually not obvious. They are a type of latent failure that Reason (1997) talks about in organizational accidents.

Another interesting aspect of the systems theory is that reliability and safety are regarded as different properties. This theory points out that reliability is a component property while safety is an emerging property of systems: Safety can be determined only in the context of the whole (Leveson, 2012, pp. 64, 75). One barrier can be reliable, but this should not be mistaken as the barrier directly increasing safety. These two properties, in some cases, can even be conflicting. Making the system safer may decrease reliability and vice versa. One must account for the context barriers operate in (Leveson, 2012, p. 64). Aven is of a similar view and states that while measures should work independently, they should not be considered in isolation, as there can be trade-offs for the entire system (Aven & Thekdi, 2022). Placing preference on one measure can impact the effectiveness of others in the system in unpredictable ways.

When combining systems theory and the holistic approach to barrier balance, the focus is on what Leveson (2011, 2012) calls emerging properties. Systems like the Stavanger municipality are presumed to benefit from focusing on emerging properties in their barrier management. In this case, the emerging properties are regarded as the effects the various measures have on each other, the specific parts of the system, and the system as a whole. We should not individually focus on each barrier's reliability and effectiveness and speak about safety or security. We must look at all of them simultaneously and make assumptions about emerging properties of the barriers interacting within that system (Leveson, 2011).

Resilience is a proper strategy for dealing with emergent properties of the systems and leading the organization away from drifting into failure. By incorporating resilience strategy and means, we are better suited to learn from previous experiences and try to be better. Resilience can be improved in many ways, including adding safety barriers, layers of protection through redundancy, and diversification of protection types (Aven & Thekdi, 2022, p. 115).

However, increasing resilience does not straightforwardly mean that drifting into failure can be avoided. Dekker (2011) describes drifting into failure as inevitable, as increasing complexity and interconnectivity lead to drift. He continues to describe that the main reason for drift to occur is that organizations are structured sectorally and develop their technology and processes similarly. What is built is understood in isolation, and a holistic approach is missing. Dekker (2011) states that "drifting into failure is not so much about breakdowns or malfunctioning of components as it is about an organization not adapting effectively to cope with the complexity with some structure and environment" (p. 121). Only by strong devotion by the organization and all the other relevant stakeholders' and constant focus on increasing resilience and cooperation/coordination both vertically and horizontally can potentially lead to moving away the organization from drifting into failure

5.5. Overall Reflections

Since the results of the thesis are based on a small pool of the overall municipal data, some reflections must be given. The Appendix C of the Stavanger Municipality's CRVA (2019b) results from the gap analyses because of the municipal merger. Only six of these measures are confirmed by Stavanger Municipality as completed. This thesis's results do not represent the overall balance of measures in the municipality. However, the data pool still identifies some trends, such as where the focus of the municipality is, their devotion to protecting the critical infrastructure, and increasing community resilience.

6. Conclusion

This thesis aims to understand better how barriers are distributed and balanced within Stavanger Municipality. This allows for an investigation and discussion of the main topic of the thesis, which is:

"Addressing the balance between preventive and consequences-reducing measures regarding avoiding drifting into failure while increasing resilience in municipalities."

While it was challenging to accurately portray the balance due to a lack of access to data, and a lack of literature on the balance between measures, the authors were able to address the balance regarding the main topic through the four research questions posed.

1. "What is the current distribution between the proposed preventive and consequence-reducing measures in Stavanger municipality?"

While this is hard to accurately represent without access to more data, the authors have judged the distribution to be predominantly prevention measures and organizational barrier element types. A third classification was included, which the municipality does not address, measures that serve as both preventive and consequence-reducing. These measures were too generally formulated and thus challenging for precise classification and interpretation. Measures that can serve to prevent an event from occurring or reduce consequences might have merit as they could be adaptable for different risk sources and initiating events. In answering this question, the authors could not accurately represent the current distribution of measures. The distribution of the proposed measures is based on the authors' classifications. This data was then used to investigate the distribution of these measures in terms of barrier element types, departmental oversight, and critical infrastructure. It appears the municipality is focused on reducing vulnerabilities and this can lead to increased resilience, this is demonstrated by their use of gap analysis.

2. "Should the measures balance be different from today, and if so, why?"

Without more information on the balance of measures from the municipality, it is challenging to conclude whether the balance should differ. In answering this question, the authors discussed the concept of balance through the results and previous literature. The regulations guiding Norwegian risk governance were used to set the frame that potentially affects the barrier balance. Additionally, the measures' cost and budget were investigated to gain deeper insight into the state of barrier balance in Stavanger Municipality. However, this information was insufficient, and a conclusion could not be reached. It is hard to determine if the measures balance should differ from today, as access to all the data was unavailable. The proposed measures of the municipality should not and could not be used as the sole data to answer this question.

3. "How can the measures balance be adjusted to provide a better fit for Stavanger municipality?"

The balance of measures can potentially be adjusted for Stavanger Municipality by increasing departmental accountability and follow-up of the measures with responsibilities and roles regarding follow-up for measures clearly defined. Stavanger Municipality can take a more holistic view of the measures in place by incorporating concepts of barrier management from the petroleum industry. Employing concepts from barrier management in a municipal setting can increase focus on barrier element type, their interactions, and viewing the system holistically.

4. "*Is a holistic approach useful for adjusting the balance in complex organizations?"*

A holistic approach through systems theory can increase awareness of the emergent properties of barrier interaction. The holistic approach is essential for managing complex systems, which is why it is imperative for adjusting the barrier balance. Resilience is a valuable strategy for dealing with emergent properties in systems and moving away from drifting into failure.

Barrier balance is a new concept in risk science and a challenging one to address. However, by adapting the concept of barrier management from the petroleum industry to better fit the complex municipality system, the concept of balance can be represented more dynamically. By crafting measures to fit within a system with strong organizational, governmental, and industrial influence, they can increase accountability, reliability, and holistic thinking.

Opportunities for Further Research

While Norwegian Municipalities have ample guidance from the NDCP on conducting a comprehensive risk and vulnerability assessment using current risk science techniques and addressing uncertainty and knowledge, this leaves room for advancement in their approach to barrier management. It would be beneficial to conduct further research into creating a Municipal specific barrier management framework based on the work already conducted on the subject by the Norwegian Petroleum Safety Authority in their barrier memorandum.

Additional research could also be conducted on how holistic barrier management and systems thinking could be combined with the current approaches to risk management in the commune to strengthen resilience.

Further research on the effect of the four principles of civil protection on the barrier balance of preventive and consequence-reducing measures would also be helpful for the municipalities as some of the principles contradict each other. The thesis states that barrier balance is essential for achieving optimal protection.

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ID	Event	Variable	Proposed new measures/ barriers	Preventive Measure	Consequence Reducing Measure	Operational, Organizational, or Technical Barrier, Citizen Action	Coordination and follow-up responsible	Status/ Date
1	Failure of Food Supply	a	Proposal from the Norwegian Food Safety Authority (At a meeting in December 2018) to practice emergency plans together		yes	Operational	Municipal Department of Public Safety and Preparedness together with the new agricultural office	
		b	Stavanger 72 campaign, residents must be able to take care of themselves and for up to 72 hours in terms of food and water supply		yes	Organizational, Citizen Action	Municipal Department of Public Safety and Preparedness	Followed up in March and October 2019
2	Distribution of Hazardous Food	a	A new agricultural office is being established for the new Stavanger municipality	yes		Organizational	Citizens and Public Relations	January 1st 2020
3	Failure/ Interruption of Drinking Water Supply (long-term)	a	Assessment of whether Stavanger Municipality has the capacity/ robustness to handle an emergency situation in the event of a long-term failure/interruption of the drinking water supply		yes	Organizational	Urban Environment and Development w/ WA	
		b	Assess whether there is a gap between actual delivery capacity and needs requirements for functional water mains systems in the event of a pipe break in the leading network, then assess whether any gaps should be closed by IVAR and/or the municipality itself.	yes	yes	Organizational, Operational	Urban Environment and Development w/ WA	
		c	Ensure that contingency plans drawn up in each service area also take care of tasks in the event of a water loss	yes	yes	Organizational and Operational	All Service Areas in Stavanger Municipality	
		d	Obtain an overview of private wells on cottage plots and with farmers in the municipality	yes	yes	Organizational	Assessed by urban environment and development w/ WA	
		e	As of today the water authority has a plan for where water tanks are to be placed (in schoolyards after school's opening hours, in church car parks, etc.) Consider preparing a map where the various water tanks will be. Here it may be appropriate to use some backup solutions if the preferred location is not available (e.g. schoolyard @school during operating hours.		yes	Operational, Organizational and Technical	Urban Environment and Development w/ WA	

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		f	Third Main water line is being planned in the Stavanger region	yes	yes	Technical, organizational, operational	IVAR	
		g	IVAR and VA should have each other's numbers available on the emergency network to facilitate communication in the event of major incidents. Consider creating a separate joint emergency network channel between IVAR and VA for use in major incidents. Have clearly clarified when this channel is to be used and practice this.		yes	Technical, Organizational, Operational	Clarification; IVAR and Stavanger Municipality w/ WA	
		h	Conduct Joint exercises to test plans		yes	Organizational, Operational	Municipal Department of Public Safety and Preparedness in Collaboration with IVAR and WA	
		i	Stavanger 72 campaign, residents must be able to take care of themselves and for up to 72 hours in terms of food and water supply		yes	Organizational, Citizen Action	Municipal Department of Public Safety and Preparedness	Followed up in March and October 2019
4	Distribution of Contaminated Drinking Water	a	Connect the water network across municipal boundaries to compensate for contaminated drinking water in one of the municipalities in the region	yes	yes	Technical, Organizational, Operational	Urban Environment and Development w/ WA	
		b	Follow up that the water works in the area have good conduit models that show the water's flow direction, so that contaminated drinking water is not distributed. Such a system exists but one should follow this up	yes	yes	Technical, Organizational, Operational	Urban Environment and Development w/ WA	
		c	Follow up that fresh zonal water supply and assessment of source capacity in the event of serious pollution on the main water line and the distribution network is taken care of in IVAR's and the municipality's water RVA		yes	Organizational	Urban Environment and Development w/ WA	
		d	Several households/farms have their own water sources/wells on Finnøy. It should be mapped where these water sources/ wells are.	yes	yes	Organizational and Technical	Urban Environment and Development w/ WA	
		e	Communication/ Information to the population if the drinking water becomes contaminated. This message must be the same for all municipalities involved.		yes	Organizational, Operational	Urban Environment and Development w/ WA	
		f	Joint exercises should be held to test the planning system	yes	yes	Organizational	Urban Environment and Development w/ WA	
		g	Stavanger 72 campaign, residents must be able to take care of themselves for up to 72 hours in terms of food and water supply		yes	Organizational, Citizen Action	Municipal Department of Public Safety and Preparedness	Followed up in March and October 2019
5	Contaminated Drinking	a	Ensure that the municipality has enough water tanks assessed against IVAR's capacity for contaminated drinking water due to radioactive fallout		yes	Organizational Technical Operational	Clarification, IVAR and Stavanger municipality w/ WA	

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	Water, Air, Food etc. Due to Radioactive Fallout	b	Information and knowledge about iodine shall be distributed in municipal schools and kindergartens		yes	Organizational and Operational	Health and Welfare w/ the Head of Health	
		c	Consider obtaining an overview of low radioactive sources		yes	Organizational	Health and Welfare w/ the Head of Health	
		d	Coordinated communication and messages between organizations and agencies in the region		yes	Organizational	Municipal Department of Public Safety and Preparedness together with the Communications department	
		e	Cross sectoral communication/collaboration between organizations and agencies in the region to handle this type of incident, as well as establish a common risk picture		yes	Organizational	All Service Areas in Stavanger Municipality, Municipal Department of Public Safety and Preparedness	
		f	Stavanger 72 campaign, residents must be able to take care of themselves for up to 72 hours in terms of food and water supply		yes	Organizational, Citizen Action	Municipal Department of Public Safety and Preparedness	Followed up in March and October 2019
6	Power Supply Failure (long-term)	a	Consider whether strengthening the security of supply with a new central line in the region (Lyse-Fagrafjell) entails a change in CRVA for Stavanger	yes		Organizational, Technical	Municipal Department of Public Safety and Preparedness	
		b	Own RVA Analysis for electricity/energy must be prepared/ revised (applies to all service areas)	yes		Organizational	All Service Areas in Stavanger Municipality	
		c	Map the vulnerability of water supply in event of power failure		yes	Organizational, Technical	Urban Environment and Development w/ WA, Municipal Department of Public Safety and Preparedness	
		d	Information about which municipal services are to be prioritized in the event of a failure in the power supply, as well as information about what the individual must ensure and be aware of, must be communicated to those affected by the prioritization.		yes	Organizational, Operational	All service areas must map their services	
		e	Ensure that institutions / businesses that are critically dependent on electricity have the option of self-supply (e.g. generator) - with a back-up solution - in the event of a failure in the power supply.		yes	Organizational, Technical, Operational	Health and Welfare	
		f	Reduce the consequences of failure in the electricity supply by setting up alternative heating in new homes (requirement in legislation) and informing about people's / organizations' / companies' own responsibilities.		yes	Organizational Operational, Technical and Citizen Action	Stavanger Municipality at the Planning Department	
		g	Ensure that infrastructure and facilities that are critical to the power supply are taken care of according to regulatory plans.	yes		Organizational	Stavanger Municipality at the Planning Department	

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		h	Use the power RVA to revise Lyse and the municipality's plans for power rationing in the event of a failure in the power supply.		yes	Organizational	Municipal Department of Public Safety and Preparedness	
		i	Consequence assessment in the service areas/businesses to map vulnerability in the event of power failure		yes	Organizational, Technical	All service areas/businesses must map their own vulnerabilities	
		j	Municipal service areas should have power supply failures included in RVA analyzes and emergency plans	yes	yes	Organizational	All Service Areas	
		k	Project, Fuel Supply		yes	Organizational	Municipal Department of Public Safety and Preparedness	During 2020
		l	Stavanger 72 campaign, residents must be able to take care of themselves for up to 72 hours in terms of food and water supply.		yes	Organizational, Citizen Action	Municipal Department of Public Safety and Preparedness	Followed up in March and October 2019
7	Failure of Gas Distribution (long-term)	a	Cooperation Lyse/the municipality. Ensure that gas supply is taken care of in the municipality's overall RVA analysis and is included in the municipality's emergency plans	yes	yes	Organizational	Municipal Department of Public Safety and Preparedness	During 2020
		b	Carry out a detailed impact assessment in the service areas' ROS to map the vulnerability of failure in gas distribution	yes	yes	Organizational	All Service Areas in Stavanger Municipality	
		c	Prepare emergency plans for nursing homes and other municipal institutions that depend on gas supply.		yes	Organizational	Health and Welfare	
		d	Develop a strategy for alternative solutions in the event of sabotage or other breaches of heat supply in the strategic plan for regional energy and heat solutions in the municipal plan.		yes	Organizational	Municipal Department of Public Safety and Preparedness	
		e	Systematic learning and evaluation of incidents/exercises will give us better and more robust preparedness in relation to all types of events.	yes	yes	Organizational	Municipal Department of Public Safety and Preparedness	
8	Failure of District Heating (long-term)	a	Updated maps with recorded district heating route (if digging)	yes	yes	Organizational, Technical	Urban Environment and development	Consecutively
		b	Regular contact meetings between Lyse and the municipality for mutual updates	yes	yes	Organizational, Operational	Municipal Department of Public Safety and Preparedness	Yearly
		c	Systematic learning and evaluation of incidents/exercises will give us better and more robust preparedness in relation to all types of events.	yes	yes	Organizational	Municipal Department of Public Safety and Preparedness	
9	Failure to Provide the Necessary Shelter	a	Prepare overall plans (principles) for population notification and evacuation	yes		Organizational	Municipal Department of Public Safety and Preparedness	Completed
		b	Prepare plans for the organization of temporary shelter and ensure that the necessary materials are available	yes		Organizational	Municipal Department of Public Safety and Preparedness	During 2020

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	and Population Notification/ Evacuation	c	Coordination between the municipality, neighboring municipalities, voluntary organizations and emergency services	yes		Organizational	Municipal Department of Public Safety and Preparedness	Continuous work
		d	Exercises, to test whether competence, routines, skills and staffing are in place for a desired level of preparedness.	yes	?	Organizational	Municipal Department of Public Safety and Preparedness	Continuous work
		e	The Stavanger72 campaign Residents must be able to take care of themselves for up to 72 hours in terms of food and water supply		yes	Organizational, Citizen action	Municipal Department of Public Safety and Preparedness	Mar-19
10	Failure of Regional Coordination and Crisis Management	a	Prepare a new emergency plan for New Stavanger based on the Comprehensive Risk and Vulnerability Analysis (CRVA) to be distributed to cooperation actors.	yes		Organizational	Municipal Department of Public Safety and Preparedness	June – October 2019 Completed
		b	Prepare notification lists and resource lists to be distributed to cooperative actors.	yes		Organizational	Municipal Department of Public Safety and Preparedness	June – October 2019 Completed
		c	Clarify a joint speaking group between municipalities and the emergency services in a crisis situation	yes		Organizational	Municipal Department of Public Safety and Preparedness	June – October 2019 Completed
		d	Revision of the Plan for communication during crises to include Rennesøy and Finnøy.	yes		Organizational	The Communications Department in collaboration with Municipal Department of Public Safety and Preparedness	June – October 2019 Completed
		e	The EPS plan must be updated to include Rennesøy and Finnøy.	yes		Organizational	Health and welfare v/EPS management	During 2019
		f	Clarify the meeting point/node for municipalities, FM and emergency services in the event of a power and e-communications failure	yes		Organizational	Municipal Department of Public Safety and Preparedness	The "Information Centers" project is ongoing
		g	Arrange orientation meeting to ensure that emergency agencies and cooperating municipalities (other agencies/organizations) are informed about our new plans, notification lists and resource lists	yes		Organizational	Municipal Department of Public Safety and Preparedness	Community Safety Day 2020 February 2020
		h	Continuity planning to safeguard critical societal functions	yes		Organizational	Mapped in HROS in the individual service areas in New Stavanger municipality	
		i	Prepare and sign a new cooperation agreement between the cooperation municipalities in Nord-Jæren	yes		Organizational	Municipal Department of Public Safety and Preparedness	During 2020
		j	Organize internal orientation meetings to ensure that all service areas in New Stavanger Municipality are aware of new plans, notification lists and resource lists	yes		Organizational	Municipal Department of Public Safety and Preparedness	Continuous work

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		k	Exercises, to test whether competence, routines, skills and staffing are in place for a desired level of preparedness.	yes		Organizational, Operational	Responsibility at the strategic and operational level: Municipal Department of Public Safety and Preparedness. Responsibility at the tactical level: The service areas in New Stavanger municipality	Continuous work (see own competence and training plan for this work)
11	Failure of Local Crisis Management	a	Arrange that the municipal service areas/enterprises must have an: *RVA analysis and emergency plan for the service areas/enterprises *regular exercises	yes		Organizational	Municipal Department of Public Safety and Preparedness developing templates	Mar-19
		b		yes		Organizational	The emergency coordinators in New Stavanger municipality carry out HROS, emergency plans and exercises in their own service area	During 2019
		c	Review and update the municipality's emergency plan to ensure that communication / interfaces with relevant actors / agencies / businesses for each of the causes of failure in local crisis management that have been identified are taken care of (e.g. loss of power, e-communications, ICT system failure, etc.).	yes		Organizational	Municipal Department of Public Safety and Preparedness	June – October 2019
		d	Coordinate and establish a common understanding of the situation with other municipalities in the region, the emergency services, etc. through e.g. a joint Co-operative Centre	yes		Organizational	Municipal Department of Public Safety and Preparedness	June – October 2019
		e	Include scenarios related to the failure of emergency response staff in the municipality's exercise plan (loss of central resources or loss of large parts of the municipality's emergency response staff)	yes		Organizational	Municipal Department of Public Safety and Preparedness	June – October 2019
		f	Clarify expectations from main stakeholders regarding availability and capacity for performance for emergency response staff and strategic crisis management in Stavanger municipality	yes		Organizational	Municipal Department of Public Safety and Preparedness	June – October 2019
		g	Prepare a new emergency plan for Stavanger municipality with action cards (based on a proactive method)	yes		Organizational	Municipal Department of Public Safety and Preparedness	June – October 2019
		h	The regional emergency plan must be revised in collaboration with our partner municipalities	yes		Organizational	Municipal Department of Public Safety and Preparedness	June – October 2019
		i	Develop good routines in connection with travel under the authority of the municipality (domestic/abroad) SOS International	yes		Organizational	Municipal Department of Public Safety and Preparedness	June – October 2019
		j	A notification list must be drawn up	yes		Organizational	Municipal Department of Public Safety and Preparedness	June – October 2019

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		k	Competence requirements, education, courses, training and exercises (mapping)	yes		Operational, organizational	Municipal Department of Public Safety and Preparedness	June – October 2019
		l	Regular exercises (includes deputy mayor, councilor, etc.)	yes		Operational, organizational	Municipal Department of Public Safety and Preparedness	June – October 2019
		m	Include a long-term scenario in the municipality's exercise plan	yes		Organizational	Municipal Department of Public Safety and Preparedness	June – October 2019
12	Failure of Population Information Regarding Prevailing Risks, Crises, and Crisis Management	a	Revise the regional plan for crisis management	yes		Organizational	Municipal Department of Public Safety and Preparedness	June – October 2019
		b	Ensure that important information is made available in different ways, including for the blind and partially sighted, and in different languages	yes		Organizational	Communications Dept	
		c	Establish a chat function for Citizen Service	yes		Organizational, Technical	Citizen service	2019
		d	Clarify expectations for availability and capacity for performance for crisis staff and crisis management, including crisis communication, in Stavanger municipality	yes		Operational, organizational	Municipal Department of Public Safety and Preparedness	June – October 2019
		e	Establish an on-call system for communication in Stavanger municipality. Alternatively, establish a scalable on-call system for communication in Stavanger municipality if necessary	yes		Organizational	Communications Department	
		f	Include scenarios that affect regional crisis communication / cooperation in the regional plan for exercises	yes		Organizational	Communications Department	
		g	Establish a project that will look at the use of public houses/schools/assembly centers as information centers in the event of crises. In addition to a clear mandate, this group must be interdisciplinary/interagency.		yes	Organizational	Municipal Department of Public Safety and Preparedness	June – October 2019
		h	Map out alternative communication methods in the event of a power outage	yes		Organizational Technical	Communications Department	
		i	Cooperation/communication - in peacetime (network building)	yes		Technical, Organizational, Operational	Communications Department	
13	Failure in Health and Care Services	a	Ensure that an arena for good interaction between the agencies/organizations is established/continued	yes		Organizational	Health and Welfare	
		b	Updating RVA analyzes and emergency plans for the municipal home-based services.	yes		Organizational	Health and Welfare	
		c	Routines in all municipal home-based services to have important information available also on paper.	yes		Organizational	Health and Welfare	

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		d	Assess the need for a credit system / municipal guarantee for recipients of health and care services in the event of a long-term lapse in payment services.		yes	Organizational	Health and Welfare	
		e	The emergency network is established in nursing homes, home-based services and residences/institutions with 24-hour staffing.	yes		Organizational, technical	Health and Welfare	
		f	The security alarms and their robustness are also continuously assessed as part of the municipality's welfare technology compared to e-communications and welfare technology.	yes		Technical	Health and Welfare	
		g	Establish an iodine project owned by the infection control supervisor in Stavanger municipality	yes		Organizational	Growing up and education and Health and welfare (community medicine)	
		h	HV: Risk analysis for electric car fleet in home care	yes		Organizational	Health and Welfare	
		i	BMU: Emergency docks (vulnerability assessment). Cooperation with the Norwegian Public Roads Administration.	yes		Organizational	BMU	
14	Epidemic / Pandemic	a	The municipality's business-specific emergency plans must take account of epidemics / pandemics and ensure that the businesses have harmonized measures across the municipality (this also includes continuity planning and operation of municipal services)		yes	Organizational	The service areas in New Stavanger municipality	
		b	Continuity planning in all service areas		yes	Organizational	The service areas in New Stavanger municipality	
		c	Clarify emergency kindergartens/SFO (childcare up to 4th grade)		yes	Organizational	Growing up and education	
		d	Arrange cooperative exercise		yes	Organizational	Higher level: Municipal Department of Public Safety and Preparedness, the service areas/companies are themselves responsible for exercises	
15	Hospital Fire/Explosion	a	The following measures are transferred to SUS: Assess the need for a risk assessment of stored radioactive material.	yes		Organizational	SUS	
		b	Assess joint practice	yes		Organizational	Health and Welfare	
		c	Have municipal preparedness for changed treatment needs when receiving more discharged SUS patients.		yes	Technical, Organizational, Operational	Health and Welfare	
16	Hospital Sabotage/	a	Initiative to start making plans to deal with the consequences of a terrorist incident.		yes	Organizational	SUS	

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	Terrorist Attack	b	Exercises, to test whether competence, routines, skills and staffing are in place for a desired level of preparedness.	yes		Operational	SUS/ Health and Welfare	
		c	Implementing the emergency planning system at the Emergency Department must take care of the consequences of terror/sabotage in a sufficiently good manner	yes		Operational	Health and Welfare	
17	Nursing Home/Institution Fire	a	Install sprinkler systems in all departments of the nursing homes (Finnøy)	yes	yes	Technical	Health and Welfare	
		b	Nursing homes / institutions must have at least one annual preparedness drill and regular fire drills	yes		Organization, Operational	Health and Welfare	
		c	Make sure that Rogaland fire and rescue is informed about which municipal housing is in use	yes	yes	Organizational	Health and Welfare	
		d	Consider annual inspection of refugee housing	yes		Organizational	Rogaland fire and rescue - gives advice on this to Health and Welfare	
		e	When allocating housing for the disadvantaged: greater focus on the right housing for the right resident, also in accordance with fire protection.	yes		Organizational	Health and Welfare	
		f	Exercises, to test whether competence, routines, skills and staffing are in place for a desired level of preparedness.	yes		Operational	Health and Welfare	
18	Failure of Emergency Services - General	a	Coordination of planning, exchange of planning documents and implementation of joint RVA with the emergency services. This is to better understand the possibility of 'failure in emergency services' and the potential consequences of such a failure.	yes		Organizational, Operational	Municipal Department of Public Safety and Preparedness	
		b	Clarify information hubs if electricity/e-communications outage	yes		Organizational	Municipal Department of Public Safety and Preparedness	
19	Major Accident-Industry	a	Spatial planning - avoid establishing new businesses with major accident potential near densely built-up areas	yes		Organizational	City and community planning	
		b	Spatial planning – focus from the authorities on companies with major accident potential that are located near densely built-up areas and/or near critical infrastructure	yes		Organizational	City and community planning	
		c	Collaborate more closely with companies with major accident potential within RVA and emergency planning	yes		Organizational	Municipal Department of Public Safety and Preparedness	
		d	The municipality should participate in emergency preparedness exercises for major accident businesses that	yes		Operational	Municipal Department of Public Safety and Preparedness	

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			have the potential to affect the municipality directly/indirectly					
		e	The municipality should participate in a preparedness exercise with neighboring municipalities (with major accident companies that have the potential to influence the municipality directly/indirectly, e.g. Sola municipality (Risavika), Karmøy municipality (Kårstø) etc.)	yes		Operational, Organizational	Municipal Department of Public Safety and Preparedness	
		f	The county governor should involve the municipalities more actively in the follow-up/supervision of major accident businesses	yes		Organizational	Municipal Department of Public Safety and Preparedness	
		g	Establish a meeting arena where the municipality/major accident companies can meet informally to discuss relevant and current social security and preparedness topics.	yes		Organizational	Municipal Department of Public Safety and Preparedness	
20	Major Accident - Aviation	a	Coordination of plans	yes		Organizational and Operational	Municipal Department of Public Safety and Preparedness	
		b	Exercises, to test whether competence, routines, skills and staffing are in place for a desired level of preparedness.	yes	yes	Operational	Municipal Department of Public Safety and Preparedness	
21	Major Accident - Sea	a	Coordinated plans between emergency services, shipping company and municipality	yes		Organizational	Municipal Department of Public Safety and Preparedness	
		b	Notification lists that are distributed to all cooperative actors	yes		Organizational	Municipal Department of Public Safety and Preparedness	
		c	Plan for psychosocial follow-up	yes		Organizational	Municipal Department of Public Safety and Preparedness	
		d	EPS				Municipal Department of Public Safety and Preparedness	
		e	Exercises, to test whether competence, routines, skills and staffing are in place for a desired level of preparedness.	yes	yes	Operational	Municipal Department of Public Safety and Preparedness	
22	Major Accident - Road	a	The Norwegian Road Administration thinks more holistically now than before. There is a focus on increased investment in: public transport and cycling/walking, traffic safety; Get traffic out of the cities	yes		Organizational	The Norwegian Public Roads Administration and City and community planning	
		b	Routines to ensure that safety is ensured during bus transport	yes		Organizational, Operational	Rogaland County Municipality (Kolumbus) State Road Administration	
		c	Plan for the improvement of the existing road network (municipal part of Rennesøy and Finnøy)	yes		Organizational, Technical	Urban Environment and development	

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		d	Vulnerability assessment, municipal road network. Plan for diversion/rerouting of traffic if the road is blocked	yes	yes	Organizational	Urban Environment and development	
		e	Formalization of winter maintenance on the municipal road network (enter into contracts/agreements)	yes		Organizational, Technical, Operational	Urban Environment and development	
		f	Contingency plans (systematic review of which roads are to be plowed first)	yes		Organizational	Urban Environment and development	
		g	Contingency plans to ensure goods and passenger transport if the tunnels are closed	yes	yes	Organizational, Operational	Urban environment and development and the Norwegian Road Administration	
		h	Continuity planning to ensure municipal services (life and health)	yes	yes	Organizational	Mentioned in the service areas' risk and vulnerability analyses	
		i	Alternative connection in case of power failure	yes	yes	Technical, Organizational	The Norwegian Public Roads Administration and City and community planning	
		j	Coordination of planning between emergency agencies, the Norwegian Public Roads Administration and the municipality	yes		Organizational	Municipal Department of Public Safety and Preparedness	
		k	Exercises, to test whether competence, routines, skills and staffing are in place for a desired level of preparedness.	yes	yes	Operational	Municipal Department of Public Safety and Preparedness	
		l	Systematic learning and evaluation of incidents/exercises will give us better and more robust preparedness in relation to all types of events.	yes	yes	Organizational	Municipal Department of Public Safety and Preparedness	
		m	The municipality otherwise has a strong commitment in relation to RVA analyzes and preparedness conditions related to the tunnels and wants measures that further increase safety.	yes		Organizational	Municipal Department of Public Safety and Preparedness	
23	Major Accident - Railway	a	Invite participation from the railway undertakings in gatherings of a public safety nature	yes		Organizational	Municipal Department of Public Safety and Preparedness	
		b	Good planning processes in accordance with the applicable laws and regulations	yes		Organizational	Municipal Department of Public Safety and Preparedness	
		c	Coordination between municipality(s) and emergency services	yes		Operational, Organizational	Municipal Department of Public Safety and Preparedness	
		d	Emergency inspections (Tunnels)	yes		Technical	BaneNor, Municipal Department of Public Safety and Preparedness	
		e	Exercises, to test whether competence, routines, skills and staffing are in place for a desired level of preparedness.	yes	yes	Operational	Municipal Department of Public Safety and Preparedness	

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		f	Systematic learning and evaluation of exercises will give us better and more robust preparedness in relation to all types of events.	yes	yes	Organizational	Municipal Department of Public Safety and Preparedness	
24	Dam break	a	Dam break mapping Vanassen and Hinndalsdammen in progress. A dam break wave calculation/flood zone mapping will probably also be carried out in connection with the ongoing condition assessment.		yes	Technical, Organizational	Urban Environment and development w/Park and road	
		b	Overview of residents near the dam		yes	Organizational	Urban Environment and development w/Park and road BSP w/Map and digital services	
		c	Population alert		yes	Technical	Urban Environment and development	
		d	Coordinate plans between emergency services and the municipality		yes	Organizational	Urban Environment and development w/Park and road	
		e	Coordinate plans between the municipality and IVAR	yes		Organizational	Urban Environment and development IVAR	
		f	Exercises, to test whether competence, routines, skills and staffing are in place for a desired level of preparedness.	yes	yes	Operational	Urban Environment and development w/Park and road	
		g	Systematic learning and evaluation of incidents/exercises will give us better and more robust preparedness in relation to all types of events.	yes	yes	Organizational	Urban Environment and development w/Park and road	
25	Offshore Accident	a	Knowledge of the offshore industry's emergency plans with an expectation of support from municipalities.	yes		Organizational, Technical, Operational	Municipal Department of Public Safety and Preparedness	
		b	Coordination between operators and the authorities	yes		Organizational	Municipal Department of Public Safety and Preparedness	
		c	Exercises, to test whether competence, routines, skills and staffing are in place for a desired level of preparedness.	yes	yes	Operational	The Operator Companies	
		d	Systematic learning and evaluation of exercises will give us better and more robust preparedness in relation to all types of events.	yes	yes	Operational	Municipal Department of Public Safety and Preparedness	
26	Fire in Buildings with Many People	a	Ensure that municipal businesses' fire and evacuation plans are maintained and that drills are carried out for own buildings with an extra focus on buildings with the status of a special fire object	yes		Organizational, Technical, Operational	Municipal Department of Public Safety and Preparedness together with the building owner	
		b	Coordination of planning between emergency agencies, the municipality and other relevant actors	yes		Organizational	Municipal Department of Public Safety and Preparedness	
		c	Exercises, to test whether competence, routines, skills and staffing are in place for a desired level of preparedness.	yes	yes	Operational	Municipal Department of Public Safety and Preparedness	

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		d	Systematic learning and evaluation of exercises will give us better and more robust preparedness in relation to all types of events.	yes	yes	Operational	Municipal Department of Public Safety and Preparedness	
27	Serious Crime – including terrorism and ongoing life-threatening violence	a	Risk and vulnerability analyses, emergency plans and exercises with a focus on serious crime must be carried out/revised in all service areas and businesses in New Stavanger (including dealing with violence and threats)	yes	yes	Organizational, Technical, Operational	Applies to all service areas in New Stavanger	
		b	Strengthen joint training across agencies/levels (municipality, police)	yes		Organization, Operational	Municipal Department of Public Safety and Preparedness	
		c	Run coherent exercises from business level to top crisis management - as well as across agencies.	yes		Operational, Organizational	Municipal Department of Public Safety and Preparedness	
		d	Establish a cooperative center when handling larger events and/or when needed/handling incidents		yes	Operational, Organizational	Municipal Department of Public Safety and Preparedness	
		e	Systematic learning and evaluation of incidents/exercises will give us better and more robust preparedness in relation to all types of events.	yes	yes	Operational	Municipal Department of Public Safety and Preparedness	
28	Failure in Information Security	a	RVA, detailed for the IT department	yes		Organizational	IT	
		b	Revise security policy	yes		Organizational	IT	
		c	Systematic work with redundancy and risk spreading	yes		Organizational, Technical	IT	
		d	Develop emergency plans		yes	Organizational	IT	
		e	Prepare, revise and document routines	yes		Organizational	IT	
		f	Exercises, to test whether competence, routines, skills and staffing are in place for a desired level of preparedness.	yes	yes	Operational	IT	
		g	Systematic learning and evaluation of incidents/exercises will give us better and more robust preparedness in relation to all types of events.	yes	yes	Operational	IT	
		h	Skills development and awareness-raising at all levels in the municipality	yes		Organizational, Technical, Operational	IT	
		i	All managers must be trained in GDPR (2019)	yes		Organizational, Operational	IT	
		j	Develop and anchor routines related to GDPR at all levels in the municipality	yes		Organizational	IT	
		k	The municipality must be at the forefront and use good solutions to ensure information security	yes		Organizational	IT	
		l	Enter into necessary agreements	yes		Organizational	IT	

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		m	The controller must define the purpose of, and have legal authority for, the processing of personal data (if the processing is not illegal)	yes		Organizational, Technical, Operational	IT	
29	Damage to Cultural Heritage/ Cultural Environment	a	Ensure that cultural-historical buildings are registered as special fire objects, and ensure that they are included in the municipality's emergency map basis	yes		Organizational, Technical	BSP w/city antiquities	
		b	Prepare a safeguarding plan for cultural heritage / cultural environment where it is lacking	yes		Organizational	BSP w/city antiquities	
		c	Prepare contingency/object plan for each individual cultural monument/cultural environment.	yes		Organizational	BSP w/city antiquities	
		d	Coordination of plans	yes		Organizational, operational	BSP w/city antiquities	
		e	Communication/information	yes		Organizational, Technical, Operational	BSP w/city antiquities	
		f	Systematic learning and evaluation of incidents/exercises will give us better and more robust preparedness in relation to all types of events.	yes	yes	Organizational	BSP w/city antiquities	
30	Fire in the Wooden Town - Old Stavanger	a	Follow up on the status of measures in the Fire Protection Project, and update CRVA if necessary	yes		Organizational	BMU w/Stavanger property	
		b	Exercises, to test whether competence, routines, skills and staffing are in place for a desired level of preparedness.	yes	yes	Operational	BMU w/Stavanger property	
		c	Systematic learning and evaluation of incidents/exercises will give us better and more robust preparedness in relation to all types of events	yes	yes	Organizational	BMU w/Stavanger property	
31	Release of Hazardous Goods	a	Assess whether the municipality itself has a need for personnel to be deployed in the event of a possible pollution action - in addition to what the municipality has available via the fire service. Follow up with possible assessments of requirements for availability, capacity, mobilization time, organization etc.	yes	yes	Organizational, Technical, Operational	BMU w/Environment and waste disposal	
		b	Ensure that the release of dangerous goods on vulnerable road sections is covered by the vulnerability maps	yes		Organizational, Technical	BMU w/Environment and waste disposal	
		c	Establish a routine that ensures that the vulnerability maps are updated regularly	yes		Operational, Organizational and Technical	BMU w/Environment and waste disposal	
		d	Exercises, to test whether competence, routines, skills and staffing are in place for a desired level of preparedness.	yes	yes	Operational	BMU w/Environment and waste disposal	

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		e	Coordination of plans	yes		Organizational Operational	BMU w/Environment and waste disposal	
		f	Systematic learning and evaluation of incidents/exercises will give us better and more robust preparedness in relation to all types of events.	yes	yes	Organizational	BMU w/Environment and waste disposal	
32	Emission of Diesel etc. From Tank Facilities/ pipelines	a	Ensure that the Planning and Building Act is followed (including guidelines and provisions)	yes		Organizational	BMU w/Environment and waste disposal	
		b	Coordination of plans between relevant actors	yes		Organization, Operational	BMU w/Environment and waste disposal	
		c	Exercises, to test whether competence, routines, skills and staffing are in place for a desired level of preparedness.	yes	yes	Operational	BMU w/Environment and waste disposal	
		d	Systematic learning and evaluation of incidents/exercises will give us better and more robust preparedness in relation to all types of events.	yes	yes	Organizational	BMU w/Environment and waste disposal	
33	Acute Air-pollution	a	Coordination of the municipality and the Norwegian Road Administration (thresholds for the implementation of measures, etc.)	yes		Organizational Operational	Fire w/Environmentally managed health care, Health manager	
		b	A communication plan is implemented in the event of acute air pollution	yes	yes	Operational, Organizational and Technical	Fire w/Environmentally managed health care, Health manager	
		c	Exercises, to test whether competence, routines, skills and staffing are in place for a desired level of preparedness.	yes	yes	Operational	Fire w/Environmentally managed health care, Health manager	
		d	Systematic learning and evaluation of incidents/exercises will give us better and more robust preparedness in relation to all types of events.	yes	yes	Organizational	Fire w/Environmentally managed health care, Health manager	
34	Nuclear Accident	a	Establish routines for updating the nuclear emergency plan		yes	Organizational	National level The county governor in Rogaland	
		b	Regional coordination when preparing emergency plans/measure cards		yes	Organizational, Operational	National level The county governor in Rogaland	
		c	Prepare a joint communication plan for use in the event of serious incidents such as nuclear accidents		yes	Organizational	National level The county governor in Rogaland	
		d	Exercises, to test whether competence, routines, skills, and staffing are in place for a desired level of preparedness.	yes	yes	Operational	National level The county governor in Rogaland	
		e	Systematic learning and evaluation of incidents/exercises will give us better and more robust preparedness in relation to all types of events.	yes	yes	Organizational	National level The county governor in Rogaland	

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35	Failure of Animal Health	a	Collaborate with the Norwegian Food Safety Authority on regular participation by the municipality in exercises on "Failure in animal health"	yes	yes	Organizational Operational	Citizen service and communication w/ Industry	
		b	Assess how foot-and-mouth disease should be taken care of in municipal emergency plans. The result must be followed up in relevant plans.	yes	yes	Organizational	Citizen service and communication w/ Industry	
		c	Clarify and follow up the municipality's responsibility for preventing and handling scenarios with anthrax spores in drinking water	yes	yes	Organizational	Citizen service and communication w/ Industry	
		d	Use VOF (notice of errors) for public registration of errors in / when keeping livestock	yes		Organizational, Operational	Citizen service and communication w/ Industry	
		e	Regional coordination of plans	yes		Organizational	Citizen service and communication w/ Industry	
		f	Communication (Create a strategy for information to the population in the event of an outbreak of animal disease, and assess whether this is well enough taken care of in the municipality's communication strategy)	yes	yes	Organizational, Operational	Citizen service and communication w/ Industry	
		g	Exercises (Practice the collaborative relationship between the Norwegian Food Safety Authority and the municipality)	yes	yes	Operational	Citizen service and communication w/ Industry	
		h	Systematic learning and evaluation of incidents/exercises will give us better and more robust preparedness in relation to all types of events.	yes	yes	Organizational	Citizen service and communication w/ Industry	
36	Infectious Plant Disease	a					Urban environment and development w/Park and road	
37	Dramatic and Lasting Drop in Oil Prices / Phasing Out of Fossil Energy Sources	a	Stimulate the ability to change by investing in R&D, start up etc., to compensate for the drop in oil prices / phasing out of fossil energy sources	yes	yes	Organizational	Citizen service and communication w/ Industry	
		b	Stimulate a broader business community in order to be more robust against a dramatic and lasting fall in the price of oil / phasing out of fossil energy sources.	yes		Organizational	Citizen service and communication w/ Industry	
		c	The municipality must cooperate with business associations etc. to get more legs to stand on, and compensate for the drop in oil prices / phasing out of fossil energy sources		yes	Organizational	Citizen service and communication w/ Industry	
38	Failure of Banking and	a	Coordination of the municipality's planning work with SR Bank, including notification routines	yes		Organizational	Municipal Department of Public Safety and Preparedness	
		b	Stavanger 72, Self-preparedness campaign		yes	Operational and Citizen action	Municipal Department of Public Safety and Preparedness	

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	Payment Solutions	c	Should be addressed by DSB towards the Ministry of Finance	yes		Organizational	Municipal Department of Public Safety and Preparedness	
		d	Make sure that RVA Health and Welfare mentions this incident in its analysis	yes		Organizational	Health and welfare	
39	Incident that Requires the Evacuation of the Forus Area	a	All businesses must carry out a RVA analysis	yes	yes	Organizational	Current service areas, Municipal Department of Public Safety and Preparedness	
		b	Follow up on identified measures in the inter-municipal sub-plan for Forus	yes		Organizational	Current service areas, Municipal Department of Public Safety and Preparedness	
		c	Coordination of plans with relevant actors	yes	yes	Organizational Operational	Current service areas, Municipal Department of Public Safety and Preparedness	
		d	Communication and information to the public must be coordinated		yes	Organizational Operational	Citizen service and communication	
		e	Exercises, to test whether competence, routines, skills and staffing are in place for a desired level of preparedness.	yes	yes	Operational	Current service areas, Municipal Department of Public Safety and Preparedness	
		f	Systematic learning and evaluation of incidents/exercises will give us better and more robust preparedness in relation to all types of events.	yes	yes	Organizational	Current service areas, Municipal Department of Public Safety and Preparedness	
40	Failure of Ecom (e-communications)	a	Make own RVA for Stavanger municipality's failure of e-communications together with relevant actors	yes	yes	Organizational	Municipal Department of Public Safety and Preparedness	
		b	Consider alternative services and service providers in the event of a failure in e-communications		yes	Organizational Technical Operational	Municipal Department of Public Safety and Preparedness	
		c	Consider access to a satellite phone that does not depend on the national access network, if the emergency network is not considered robust enough.		yes	Technical and Operational	Municipal Department of Public Safety and Preparedness	
		d	Set requirements for uptime / redundancy in the Delivery Agreement SLA (Service Level Agreement) with ICT suppliers		yes	Organizational	Municipal Department of Public Safety and Preparedness	
		e	Create redundant connections to the access network through e.g. connection to both mobile, fiber or copper networks: Telephone: make sure you have both a landline and a mobile phone Mobile data communication: mobile broadband can act as a back-up if fixed broadband fails Broadband: consider having different broadband (for example fiber and DSL subscriptions reserve). Make sure that fiber and copper cable do not go in the same trench	yes	yes	Technical and Operational Organizational	Municipal Department of Public Safety and Preparedness Service, IT Areas with a societal critical function	

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			Fixed connection: Backup solutions for point-to-point connection (for example, dark fiber)					
		f	Emergency network for everyone who will have emergency tasks		yes	Technical and Operational	Municipal Department of Public Safety and Preparedness	
		g	Prepare notification lists/telephone lists for everyone who has emergency network terminals		yes	Operational, Organizational	Municipal Department of Public Safety and Preparedness	
		h	Update and distribute notification lists/telephone lists, which include numbers for alternative communication solutions, to cooperative actors		yes	Operational, Organizational	Municipal Department of Public Safety and Preparedness	
		i	Ensure backup power for important equipment (mobile phones, modems, routers, computers, etc.). Examples of backup sources for electricity are batteries, fuel cells, uninterruptible power supply and aggregates.	yes	yes	Technical and Operational	IT service areas with a critical social function, Municipal Department of Public Safety and Preparedness	
		j	Subscription with several providers with independent core networks (for example, subscription with Telia and Telenor, where both access network and core network are separate). It is important to use the extra subscription occasionally, so that it does not become inactive.	yes	yes	Operational, Organizational and Technical	Municipal Department of Public Safety and Preparedness	
		k	Receive and familiarize yourself with advice and recommendations from the National Communications Authority.	yes	yes	Organizational	IT, Municipal Department of Public Safety and Preparedness	
		l	Ensure that the municipality has good information security and security related to the data services offered	yes		Organizational	IT	
		m	Arrange exercises to test whether competence, routines and skills are in place for a desired level of preparedness.	yes	yes	Operational	Municipal Department of Public Safety and Preparedness	
41	Failure of Sewage/Sewage services/ Ability to	a	Ensure that the municipality and IVAR jointly have sufficient contingency measures if a critical sewer line is out of order		yes	Organizational Technical Operational	Urban environment and development w/WA	
		b	Coordination of plans between relevant actors	yes	yes	Organizational	Urban environment and development w/WA	

Appendix 1. A table presenting the proposed Stavanger CRVA (2019b) measures as classified by the authors. In the pink shade, the measures are classified by type (preventive & consequence-reducing), and in the yellow shade by function (operational, organizational, technical, and citizen action)

	Handle Sewage	c	Communication	yes	yes	Organizational	Urban environment and development w/WA	
		d	Exercises, to test whether competence, routines, skills and staffing are in place for a desired level of preparedness.	yes	yes	Operational	Urban environment and development w/WA	
		e	Systematic learning and evaluation of incidents/exercises will give us better and more robust preparedness in relation to all types of events.	yes	yes	Organizational	Urban environment and development w/WA	
		f	Consider getting an overview and managing overflows to the least vulnerable areas.	yes	yes	Organizational, Technical	Urban environment and development w/WA	
42	Failure in Renovation	a	Sprinkler system in the garage at Forus (there are only alarms now)		yes	Technical	Urban environment and development w/Environment and renovation	
		b	Coordination of plans	yes	yes	Organizational	Urban environment and development w/Environment and renovation	
		c	Communication	yes	yes	Organizational	Urban environment and development w/Environment and renovation	
43	Failure in Goods/Passenger Transport	a	Gain insight into, or influence, a holistic RVA analysis for the airport, and follow up the municipality's responsibilities afterwards	yes	yes	Organizational	Municipal Department of Public Safety and Preparedness	
		b	Gain insight into, or influence, comprehensive RVA analysis for undersea tunnels, and follow up the municipality's responsibilities afterwards	yes	yes	Organizational	Rogaland County Municipality, Municipal Department of Public Safety and Preparedness	
		c	Gain insight into, or influence, plans for detours (especially dangerous goods) and diversion of ferry traffic across the Boknafjorden via Mekjarvik, and follow up the municipality's responsibilities afterwards	yes	yes	Organizational	Rogaland County Municipality, Municipal Department of Public Safety and Preparedness	
		d	Coordination/establishment of a cooperative center if needed		yes	Organizational	Municipal Department of Public Safety and Preparedness	
		e	Communication	yes	yes	Organizational	Citizen service and communication	
		f	Exercises, to test whether competence, routines, skills and staffing are in place for a desired level of preparedness.	yes	yes	Operational	Rogaland County Municipality, Municipal Department of Public Safety and Preparedness	
		g	Systematic learning and evaluation of incidents/exercises will give us better and more robust preparedness in relation to all types of events.	yes	yes	Organizational	Rogaland County Municipality, Municipal Department of Public Safety and Preparedness	
44	Extreme Weather /	a	Climate-RVA (to identify how climate change will affect locally)		yes	Organizational	Municipal Department of Public Safety and Preparedness	

Appendix 1. A table presenting the proposed Stavanger CRVA (2019b) measures as classified by the authors. In the pink shade, the measures are classified by type (preventive & consequence-reducing), and in the yellow shade by function (operational, organizational, technical, and citizen action)

	Natural Event	b	The municipality must take future climate change into account in municipal planning		yes	Organizational	BSP v/Overall plan, Municipal Department of Public Safety and Preparedness	
		c	Self-preparedness campaign, Stavanger72		yes	Operational and Citizen Action	Municipal Department of Public Safety and Preparedness	
		d	Coordination and cooperation across the region in order to meet the future climate challenges together		yes	Organization, Operational	Municipal Department of Public Safety and Preparedness	
		e	The various service areas must carry out a RVA, as well as continuity planning to be able to ensure service delivery in the event of extreme weather (emergency plan)		yes	Organizational	Municipal Department of Public Safety and Preparedness	
		f	Communication		yes	Organizational	Citizen Services and Communication	
		g	Exercises, to test whether competence, routines, skills and staffing are in place for a desired level of preparedness.		yes	Operational	Municipal Department of Public Safety and Preparedness	
		h	Systematic learning and evaluation of incidents/exercises will give us better and more robust preparedness in relation to all types of events.	yes	yes	Organizational	Municipal Department of Public Safety and Preparedness	
45	Natural and Forest Fire	a	Consider arranging suitable places for barbecues in hiking areas on Finnøy/Rennesøy (safe areas)	yes	yes*	Technical and Operational	Urban environment and development w/Park and road	
		b	Assess consideration zones in relation to buildings and forest fire risk	yes		Technical and Operational	Urban environment and development w/Park and road	
		c	Assess traffic restrictions in certain given situations (e.g. in the event of extreme drought. Prohibition of edge mowers summer 2018) Prohibit felling and the use of chains in exposed areas (during dry periods)	yes		Technical and Operational	Urban environment and development w/Park and road	
		d	Prohibit the use of disposable grills in exposed areas	yes		Technical, Operational, Organizational	Urban environment and development w/Park and road	
		e	Assess the need to set out bins in exit areas to reduce littering of glass etc.	yes		Technical, Operational, Organizational	Urban environment and development w/Park and road	
		f	Coordination of plans between municipalities, Rogaland fire and rescue, police, health and SF	yes	yes	Organizational	Urban environment and development w/Park and road	
		g	Exercises, to test whether competence, routines, skills and staffing are in place for a desired level of preparedness.	yes	yes	Operational	Urban environment and development w/Park and road	
		h	Systematic learning and evaluation of incidents/exercises will give us better and more robust preparedness in relation to all types of events.	yes	yes	Organizational	Urban environment and development w/Park and road	

Appendix 1. A table presenting the proposed Stavanger CRVA (2019b) measures as classified by the authors. In the pink shade, the measures are classified by type (preventive & consequence-reducing), and in the yellow shade by function (operational, organizational, technical, and citizen action)

		i	Enter into agreements with emergency resources (fire boats, ambulances, Rødne, Helgøy)		yes	Organizational	Municipal Department of Public Safety and Preparedness, The County Municipality of Rogaland	
		j	Reception (and further notification internally) in the event of an extreme weather warning from the County Governor		yes	Organizational	Municipal Department of Public Safety and Preparedness	
		k	Improved weather forecasting (EU project Anywhere) for more specific and accurate weather forecasting in relation to forest fires. Can predict drought ½ -1 year into the future. This can lead to a more proactive approach	yes	yes*	Technical	Municipal Department of Public Safety and Preparedness	
		l	Drone (standby)		yes	Technical	BSP w/Map and digital services	
		m	Maps (better maps, especially in 3D) and plotters also for Finnøy and Rennesøy		yes	Technical	BSP w/Map and digital services	
		n	Crew management (have methodology/data tools)		yes	Operational, technical	BSP w/Map and digital services	
		o	Obtain information from IVAR about the consequences for water supply if high-altitude basins become unavailable		yes	Technical, operational	Urban environment and development w/WA	
		p	Emergency network for the municipalities		yes	Organizational, Operational	Municipal Department of Public Safety and Preparedness	
		q	Notification lists must be developed (emergency network)	yes	yes	Organizational	Municipal Department of Public Safety and Preparedness	
		r	Communication plan in the event of e-communications failure (Finnøy has price in the network, Rennesøy ok)		yes	Organizational	Municipal Department of Public Safety and Preparedness	
46	Social Security Challenges Related to Immigration **	a	Increased focus on negative social control in some groups, as well as radicalization.	yes		Operational, Organizational	Municipal Department of Public Safety and Preparedness	
47	Hybrid Events**						Municipal Department of Public Safety and Preparedness	

** Events not analyzed

Appendix 2. Table showing tally of measures and barrier types as classified by the authors used to create figures: 14 and 15 (Pie charts)

Event		Preventive Measures	Preventive and Consequence Reducing Measures	Consequence-Reducing Measures	Operational	Technical	Organizational	Citizen Action
1	Failure of Food Supply	0	0	2	1	0	1	1
2	Distribution of Hazardous Food	1	0	0	0	0	1	0
3	Failure/ Interruption of Drinking Water Supply (long-term)	0	4	5	6	3	8	1
4	Distribution of Contaminated Drinking Water	0	4	3	3	3	7	1
5	Contaminated Drinking Water, Air, Food etc. Due to Radioactive Fallout	0	0	6	2	1	6	1
6	Power Supply Failure (long-term)	3	1	8	3	5	12	2
7	Failure of Gas Distribution (long-term)	0	3	0	0	0	5	0
8	Failure of District Heating (long-term)	0	3	0	1	1	3	0
9	Failure to Provide the Necessary Shelter and Population Notification/ Evacuation	4	0	0	0	0	5	1
10	Failure of Regional Coordination and Crisis Management	11	0	2	1	0	12	0
11	Failure of Local Crisis Management	13	0	1	2	0	13	0
12	Failure of Population Information Regarding Prevailing Risks, Crises, and Crisis Management	8	0	1	2	2	9	0
13	Failure in Health and Care Services	8	0	1	0	2	3	0
14	Epidemic / Pandemic	0	0	3	0	0	4	0
15	Hospital Fire/Explosion	2	0	1	1	1	3	0
16	Hospital Sabotage/Terrorist Attack	2	0	1	2	0	1	0
17	Nursing Home/Institution Fire	4	2	0	2	1	4	0
18	Failure of Emergency Services - General	2	0	0	1	0	2	0
19	Major Accident- Industry	7	0	0	2	0	6	0
20	Major Accident - Aviation	1	1	0	2	0	1	0
21	Major Accident - Sea	3	1	0	0	0	4	0
22	Major Accident - Road	7	6	0	4	3	13	0
23	Major Accident - Railway	4	2	0	2	1	4	0
24	Dam break	1	2	4	1	2	5	0
25	Offshore Accident	2	2	0	3	1	2	0

Appendix 2. Table showing tally of measures and barrier types as classified by the authors used to create figures: 14 and 15 (Pie charts)

26	Fire in Buildings With Many People	2	2	0	3	1	2	0
27	Serious Crime – including terrorism and ongoing life-threatening violence	2	2	1	5	1	4	0
28	Failure in Information Security	10	2	1	5	3	11	0
29	Damage to Cultural Heritage/Cultural Environment	5	1	0	2	2	6	0
30	Fire in the Wooden Town - Old Stavanger	1	2	0	1	0	2	0
31	Release of Hazardous Goods	3	3	0	4	3	5	0
32	Emission of Diesel etc. From Tank Facilities/pipelines	2	2	0	2	0	3	0
33	Acute Air-pollution	1	3	0	3	1	3	0
34	Nuclear Accident	0	2	3	2	0	4	0
35	Failure of Animal Health	2	6	0	4	0	8	0
36	Infectious Plant Disease	0	0	0	0	0	0	0
37	Dramatic and Lasting Drop in Oil Prices / Phasing Out of Fossil Energy Sources	1	1	1	0	0	3	0
38	Failure of Banking and Payment Solutions	3	0	1	1	0	3	1
39	Incident that Requires the Evacuation of the Forus Area	1	4	1	2	0	5	0
40	Failure of Ecom (e-communications)	1	6	6	6	5	7	0
41	Failure of Sewage/Sewage services/Ability to Handle Sewage	0	5	1	2	2	5	0
42	Failure in Renovation	0	2	1	0	1	2	0
43	Failure in Goods/Passenger Transport	0	6	1	1	0	6	0
44	Extreme Weather / Natural Event	0	0	8	3	0	6	1
45	Natural and Forest Fire	4	5	8	9	10	9	0
46	Social Security Challenges Related to Immigration **	1	0	0	1	0	1	0
	Total	122	85	71	96	55	229	8

Appendix 3. Tables showing the departments and the distribution of the measures they are responsible for are presented in Appendix C of the Stavanger Municipal CRVA (2019b). A note is attached at the bottom of the two tables explaining their content.

	Preventive	Consequence-reducing	Both	Total
MDPSP	48	27	22	97
MDPSP w/ IVAR and WA		1		1
MDPSP w/ New Agriculture office		1		1
MDPSP w/ Communications Department	1	1		2
MDPSP and All Service areas in Stavanger	3	1	6	10
Urban Environment and Development w/ WA and MDPSP		1		1
Urban Environment and Development	3	1	2	6
Urban Environment and Development w/ WA		6	10	16
Urban Environment and Development w/ Parks and Roads	3	3	6	12
Urban Environment and Development w/ Environment and Renovation		1	2	3
Health and Welfare	13	5	2	20
SUS and Health and Welfare	1			1
SUS		1		1
Fire with Environment managed healthcare, Health Manager	1		3	4
IVAR			1	1
IVAR and Stavanger Municipality w/ WA		2		2

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Urban Environment and Development w/ IVAR	1			1
Citizen and Public Relations	1			1
Citizen Service	1			1
Citizen Service and Communication with Industry	3	3	8	14
Communications Department	5			5
BSP w/ MDPSP		1		1
BSP w/ Maps		3		3
BSP w/ City Antiquities	5		1	6
IT	11	1	3	15
All Service Areas	1	4	5	10
BMU w/ Stavanger Property	1		2	3
BMU w/ Environmental Waste Disposal	5		5	10
BMU	1			1
Growing up and Education	1	1		2
City and Community Planning	2			2
Norwegian Roads and Community Planning	1		1	2
Rogaland Road Administration	1			1
Bane Nor and MDPSP	1			1
The Operator Companies			1	1
National Level, the County Governor in Rogaland		3	2	5
Rogaland County w/ MDPSP			4	4
Rogaland Fire and Rescue	1			
Stavanger Municipality and the Planning Department	1	1		2
Total	116	68	86	269

Appendix 3. Tables showing the departments and the distribution of the measures they are responsible for are presented in Appendix C of the Stavanger Municipal CRVA (2019b). A note is attached at the bottom of the two tables explaining their content.

Combined Departments	Preventive	Consequence-Reducing	Both	Total	Percent out of 269
MDPSP	52	31	28	111	41%
Urban Environment and Development	7	12	20	39	15%
Health	15	6	5	26	10%
IVAR		2	1	3	1%
Citizen Service	5	3	8	16	6%
BSP	5	4	1	10	4%
IT	11	1	3	15	6%
BMU	7		7	14	5%
Roads	2		1	3	1%
Communications Department	5			5	2%
County Governor in Rogaland		3	2	5	2%
Rogaland County w/ MDPSP		4	4	8	3%
Other	7	6	6	19	7%

Note:
Many departments share joint responsibility for the measures, which is represented by the first table of Appendix 3 and the bar chart in Figure 17.
The table above is the second table and shows the departments after they have been grouped for simplification. The colors show how the simplification of the departments was made.
In the dark grey column are those departments that did not fit clearly into the other groups. The results are shown in Figure 18. and used to create the bubble chart shown in Figure 19

Appendix 4. Tables showing the events listed for the Stavanger CRVA (2019b), (1) is showing events in connection to critical functions and measures type. (2) is showing the societal functions/basic capabilities and the measures by type and function.
The charts on the following page were used to create the bar chart shown in Figure 20.

ID	**Event**	**Societal Function/Basic Capability**	Preventive	Both	Consequence Reducing
1	Failure of Food Supply	1. Provide necessary food supply	1		2
2	Distribution of Hazardous Food				
3	Failure/ Interruption of Drinking Water Supply (long-term)	2. Provide necessary (drinking) water supply C. Water Supply		8	14
4	Distribution of Contaminated Drinking Water				
5	Contaminated Drinking Water, Air, Food etc. Due to Radioactive Fallout				
6	Power Supply Failure (long-term)	3. Provide society needs for heating B. Electricity Supply	3	7	8
7	Failure of Gas Distribution (long-term)				
8	Failure of District Heating (long-term)				
9	Failure to Provide the Necessary Shelter and Population Notification/ Evacuation**	3.2. Ability to provide temporary housing 1. Enable governance and crisis management	36	0	4
10	Failure of regional coordination and crisis management				
11	Failure of Local Crisis Management				
12	Failure of Population Information Regarding Prevailing Risks, Crises, and Crisis Management				
13	Failure in Health and Care Services	7.1. The ability to maintain necessary health and care services	18	2	6
14	Epidemic / Pandemic				
15	Hospital Fire/Explosion				
16	Hospital Sabotage/Terrorist Attack				
17	Nursing Home/Institution Fire				
18	Failure of Emergency Services - General				

Appendix 4. Tables showing the events listed for the Stavanger CRVA (2019b), (1) is showing events in connection to critical functions and measures type. (2) is showing the societal functions/basic capabilities and the measures by type and function.
The charts on the following page were used to create the bar chart shown in Figure 20.

19	Major Accident- Industry	7.3. Ability to maintain basic safety levels in businesses with the potential for major accidents	27	16	4
20	Major Accident - Aviation				
21	Major Accident - Sea				
22	Major Accident - Road				
23	Major Accident - Railway				
24	Dam break				
25	Offshore Accident				
26	Fire in Buildings With Many People				
27	Serious Crime – including terrorism and ongoing life-threatening violence	8. Maintain law and order	2	2	1
28	Failure in Information Security	10. Secure stored information	10	2	1
29	Damage to Cultural Heritage/Cultural Environment	11. Secure cultural values	6	3	0
30	Fire in the Wooden Town - Old Stavanger				
31	Release of Hazardous Goods	12. Protect the nature and the environment	6	10	3
32	Emission of Diesel etc. From Tank Facilities/pipelines				
33	Acute Air-pollution				
34	Nuclear Accident				
35	Failure of Animal Health	12.2 Take care of animal health	2	6	0
36	Infectious Plant Disease				
37	Dramatic and Lasting Drop in Oil Prices / Phasing Out of Fossil Energy Sources	13. Maintain value creation	5	3	5
38	Failure of Banking and Payment Solutions				
39	Incident that Requires the Evacuation of the Forus Area				
40	Failure of Ecom (e-communications)	A. Ecom-services	1	6	6
41	Failure of Sewage/Sewage services/Ability to Handle Sewage	D. Sewage management and waste disposal	0	7	2
42	Failure in Renovation				

Appendix 4. Tables showing the events listed for the Stavanger CRVA (2019b), (1) is showing events in connection to critical functions and measures type. (2) is showing the societal functions/basic capabilities and the measures by type and function.
The charts on the following page were used to create the bar chart shown in Figure 20.

43	Failure in Goods/Passenger Transport	F. Goods and passenger transport	0	6	1
44	Extreme Weather / Natural Event	5.1 Ability to monitor and limit the risk of accidents and natural events	4	5	16
45	Natural and Forest Fire				
46	Social Security Challenges Related to Immigration **				
47	Hybrid Events**				

Appendix 4. Tables showing the events listed for the Stavanger CRVA (2019b), (1) is showing events in connection to critical functions and measures type. (2) is showing the societal functions/basic capabilities and the measures by type and function.
The charts on the following page were used to create the bar chart shown in Figure 20.

Societal Function/Basic Capability	Preventive	Both	Consequence-reducing	Operational	Technical	Organizational	Citizen action
Food	1		2	1	0	2	1
Water		8	14	11	12	21	3
Need for heat/ electric supply	3	7	8	4	6	20	2
Temp housing/governance and crisis management	36		4	5	2	39	1
Necessary heath and care	18	2	6	6	4	16	0
Basic safety in businesses with regards to major accidents	27	16	4	17	8	37	0
Maintain Law and Order	2	2	1	5	1	4	0
Secure stored info	10	2	1	5	3	11	0
Secure cultural values	6	3		3	2	8	0
Protect nature and environment	6	10	3	11	4	15	0
Animal health	2	6		4	0	8	0
Value creation	5	3	5	4	0	11	0
Ecom services	1	6	6	6	5	7	0
Sewage management and waste disposal		7	2	2	3	7	0
Goods and passenger transport		6	1	1	0	6	0
Accidents and natural events	4	5	16	12	10	9	1