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The risk-based approach to dimensioning of Arctic emergency response – real and perceived emergency response in Greenland and Svalbard

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There are specific hazards in the Arctic that challenge everyday activities, emergency response, and rescue operations. Both Greenland and Svalbard face challenges in emergency preparedness and have adopted strategies to approach these. While the Arctic hazards they confront are similar, there are differences in the cost and effectiveness of their responses. Many countries, including those in the Arctic, are adopting a risk-based approach to emergency preparedness and response planning. Risk-based dimensioning aims to ensure consistency between available emergency response resources and the local economic reality, matching identified risks. Many factors influence decision-making on preparedness, such as context-specific hazards, available resources, experiences with previous events, overall activity, and the need to prioritise different public goods. The paper aims to examine the specific emergency preparedness structures established in Greenland and Svalbard to address local risks and the extent to which they can be characterised as risk-based. The findings in this study stem from data collected during emergency response, discussions with key stakeholders in emergency preparedness in the two contexts, and the author's own observations in Svalbard and Greenland. The paper explains the available rescue resources in Longyearbyen and Nuuk, identifies risks, and outlines the development of a local emergency response framework. It then discusses the practical applicability of a risk-based approach to dimensioning in Arctic emergency response. The findings show that in Nuuk, the risk-based approach was based on different scenarios, while in Longyearbyen, the focus was on the consequences of different identified hazards. The differences between the two can at least partly explain the significant cost difference in local emergency preparedness.

Keywords: Preparedness dimensioning, Arctic, Risk analysis, Preparedness analysis, Preparedness planning

1. General Appearance

Dimensioning emergency response in Arctic conditions has been and continues to be a complex task. Long distances, harsh conditions, limited infrastructure, and difficulty retaining qualified personnel have been among the challenges faced by municipalities and governments in the region. Efforts have been made to implement standards and principles to achieve the right balance between risk and resources, but most of this work has not led to a universally agreed-upon approach. This paper examines two Arctic contexts, Svalbard and Greenland, that have sought to strike a balance between risks, resources, and the challenging Arctic environment.

Longyearbyen, Svalbard, is situated at 78 degrees north and has a total landmass of 62.050 km^2 (Sysselmesteren, 2016). It is the home of a relatively small community of around 2.600 inhabitants, where the majority live in the city. According to the guidelines, it is the task of the Longyearbyen local council to "carry out a comprehensive risk and vulnerability analysis, during which it will map, systematise and assess the likelihood of undesirable events that may occur in the Longyearbyen and plan for how these may affect the area and the Longyearbyen local council." (DSB, 2018). The work has resulted in analyses in 2016 and 2023 that identified a series of risks that could potentially impact the settlement (Lokalstyret, 2023; Sysselmesteren, 2016). An event in 2015 resulted in two fatalities, and in 2017, several buildings were destroyed, but luckily, the incident did not claim any lives (Brattlien, 2017). There have also been several major fires, including the latest in 2024, which destroyed houses and forced the evacuation of 80 people (Skoglund, 2024).

On the other side of the Fram Strait, we find Greenland. With an area of around 2 million km², it is home to about 56,000 people, of whom approximately 20,000 live in the capital, Nuuk. Greenland has about 70 towns and settlements scattered across the 400,000 km² of ice-free area. The country is divided into five municipalities that manage emergency response capacity within

their regions. In general, emergency preparedness dimensioning is based on regular and significant incidents (Beredskabsstyrelsen, 2004). The approach does not include a separate risk analysis but rather specified events stating that the local emergency response is to "provide sound action against fire, injuries to persons, property and the environment in the event of accidents and disasters, including acts of war, as well as in the event of acute accidents involving dangerous substances on land." (Naalakkersuisut, 2018). In case of more significant events, the requirement is also that it should "assist the social authorities in being able to receive, accommodate and care for evacuees and other people in need." Following a natural disaster event in Karratfjorden in 2017, resulting in a Tsunami that cost the lives of four people and nine people were injured, the government of Greenland decided to prepare an analysis of the advantages and disadvantages of the municipality's handling of emergency preparedness in general and in particular in connection with disasters and disaster-like cases (Naalakkersuisoqarfik, 2018). It was likewise decided that the analysis should assess whether the available emergency equipment is sufficient and set out a series of principles for how practices would be followed when dimensioning the emergency response in towns and settlements.

The Arctic emergency response is, as the cases above describe, quite vulnerable, and an event can quickly escalate to a level where local emergency response will no longer be able to manage without outside interference. The risk-based approach to emergency response has been the prevailing dogma for governments and municipalities in the Nordics. While the concept is alluring, it holds a series of individual challenges that are difficult to overcome when implementing such systems. This paper focuses on the Arctic and uses a risk-based approach to dimensioning the dilemmas that decision-makers face when applying the principles to a Svalbard and Greenlandic context. The paper uses the two sites, Longyearbyen and the Sermersooq municipality (where Nuuk is located), as examples of contexts where risk-based systems have been applied but are, in practice, challenging to implement. Drawing on these experiences, the paper explores the concept and its limitations, and proposes a path forward by answering the research question: How is risk-based dimensioning of emergency response practised in Arctic Greenland and Svalbard?

The paper seeks to answer this question, discuss its pros and cons, and propose a possible way forward. Following the introductory section is an account of the methods used, including observations, interviews, and archival research. The third section describes the theory of risk-based dimensioning as it applies to the Arctic region. The fourth section reviews the current approach to emergency response in Svalbard and Nuuk. The analysis discusses the use of risk-based approaches, partially applied in Nuuk, and considers them the dominant approach on Svalbard. The final section discusses the practical implementation of a risk-based approach to dimensioning emergency response capacity in the Arctic, as well as possible theoretical paths forward.

2. Method

The research combines on-site observations and archival evidence of emergency response capacity in Svalbard and Greenland. The observation studies were conducted in Greenland in 2020, 2022 and 2024, focusing on the capital Nuuk, and from 2020 to 2025 in Longyearbyen, Svalbard. Where possible, the research also uses official reports to support individual testimonials, such as annual reports from local fire departments and Risk analyses. Other sources include maps, reporting, and the local media, which provided anecdotal evidence of specific events and planning processes.

Information on the dimensioning of emergency response was obtained from the governments of Greenland and Norway, which oversee the governance structures instrumental to the process (Beredskapsdepartementet, 2025; Forsvarsministeriet, 2019). The documents were supplemented by reports on the state of the emergency response and evaluation of responses obtained from official sources. More information was collected during on-site visits to Nuuk and from the emergency response in Longyearbyen.

3. Theory

The risk-based approach to dimensioning rests on the idea that identifying risk in the context in which a community exists enables the deployment of the right resources to manage it (Alexander, 2003; ISO, 2009; Njå et al., 2020). It does not entail that all hazards are mitigated, but rather that a conscious decision is taken to accept, reduce, or prevent a threat from having consequences. While most risks can be managed through various mitigation efforts, such as constructing physical barriers or investing in a redundancy system, some risks will remain that emergency response will need to be managed if realised. Residual risks remain unmanaged, even when effective disaster risk reduction measures are in place, and emergency response and recovery capacities must be maintained (Hurst et al., 2019). The risk-based dimensioning approach addresses the uncertainties associated with both existing and the remaining risks and enables the community to prioritise the types of threats it will work to reduce and those it will accept through a political process.

Preparedness is the knowledge and capacities developed by governments, professional response and recovery organisations, communities and individuals to effectively anticipate, respond to, and recover from the impacts of likely, imminent or current hazard events or conditions (Roud & Gausdal, 2019). There is no uniform standard for applying a risk-based approach to dimensioning. Hence, both the Greenlandic and Norwegian emergency responses use different methods, in Norway based on the Risk and Vulnerability analysis and in Denmark/Greenland a scenario and capacity-based approach (Beredskabsstyrelsen, 2004; Njå et al., 2020). A general model of a risk-based approach to dimensioning emergency response includes five themes (Figure 1).

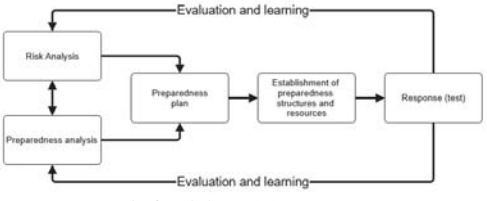

Figure 1 Model of Risk-based dimensioning

The risk analysis is the first step in the model, identifying risks impacting a given context. The investigation is followed by a preparedness analysis that encompasses official emergency response actors who would respond to the identified risks. Based on these two inputs, a preparedness plan is formulated that describes the scope of the response. Fourth, based on these, a preparedness structure can be established, and the resources needed to respond effectively to a given event can be defined through a political decision-making process. The fifth step is testing through exercises or realised risk events, and the final element is evaluation and learning from these experiences.

Risk analysis establishes the fundamental premise for the types of hazards that could potentially impact a given context. Here, a commonly used tool is the risk and vulnerability (RaV) analysis, but alternatives also exist (Njå et al., 2020). RaV involves identifying potential residual risks and creating a hierarchy of unwanted events that the emergency response can manage (Hassel & Cedergren, 2021). Identification can include natural hazard events, technical errors, accidents involving humans, and Malicious acts. The process produces a list of possible hazards that could emerge in the analysed context. The next step places these into different impact categories: Health and life, Environmental, Economic, Organising, Political, and Critical infrastructure. The categories are used to create a risk matrix that identifies all unwanted (hazardous) events, assesses the risks associated with each, and quantifies their impact. High-impact events are analysed further to establish their frequency and specific effects on vulnerable sites. The analysis shall, at a minimum, include an evaluation of the interconnectedness between infrastructures, a context-specific vulnerability assessment (e.g., barriers), and suggestions for evaluating risk-reducing and vulnerability-reducing measures.

Based on input from the RaV, an emergency preparedness analysis (EPA) can be created. The purpose is threefold. First, it establishes the basis for emergency preparedness by defining the hazardous and accident situations that fall within its jurisdiction (residual risk). The RaV identifies local threats, risks, and vulnerabilities that can be mitigated by establishing new preventive measures. However, some risks will remain, which will have to be

managed through emergency response capacities. Second, the analysis supports setting a standard for emergency preparedness that defines emergency response strategies and performance requirements, which can be agreed upon by the community. The final purpose is to identify the technical, operational, and organisational emergency response measures needed to ensure that whatever is necessary to meet performance requirements is covered, establishing an effective protective barrier.

Based on the RaV and EPA, a suggestion for a preparedness plan can be created that establishes an in situ evaluation of the mitigating response to each identified risk. The plan presents a picture of how the emergency services, as they stand, can address the different hazards identified in the RaV with the resources they have available, as described in the EPA. This enables the political level to evaluate and decide on risk acceptance and which risks to mitigate by allocating additional resources.

The preparedness structure and resources are the result of the political process; in practical terms, the resources allocated enable protective barriers within the scope of the suggested preparedness plan. The resulting preparedness structure includes infrastructures, vehicles, competencies, technical resources and communication systems. The focus here is on the realised capacity of the emergency response rather than the ones described in the preparedness plan. The organisation uses the theme to identify potential gaps between what is envisioned during the analytical phase and the emergency response's actual capacity to enact.

The response or test can occur through crisis events, but also through training specific responses to the hazards identified in the VaR, ranging from simple to complex, including walkthroughs, workshops, or orientation seminars, as well as tabletop, functional, and full-scale exercises. Depending on input from the preparedness structures and resources, different emphases can be placed on the use of equipment, coordination of resources, communication or changes made to standard operating procedures (SOPs). The response can be an exercise in which plans are rehearsed, or an actual event in which enactment arises from a realised event. In either case, it is an opportunity to test the realisation of the agreed prepardness plan, thereby demonstrating the organisation's ability to respond in accordance with its agreed standards.

Evaluation and learning are structured, systematic approaches to improve the risk-based dimensioning process. An effective emergency response is based on the premise that the right resources are available and utilised when a risk is realised. In practice, this means that the knowledge and capacities developed by the municipal response is evaluated and enacted upon to ensure that there is a continuous alignment between the risk acceptance of the community, as envisioned by the political layer, and the capacity of the preparedness organisation. After receiving a response, either through exercise or realised hazard events, the organisation debriefs its members to identify key learning points and gaps in the plan, preparedness structure, and the resources applied. These key learning points are subsequently used in the risk analysis, enabling the emergency response organisation to enter into a virtuous circle of continuous improvement.

4. Analysis

4.1. *State of Emergency response in Greenland*

Responsibility for Greenlandic emergency response rests with the municipalities that manage the available resources, while dimensioning falls under the jurisdiction of the Government of Greenland (Naalakkersuisut, 2018). The municipalities consist of both towns and settlements (bygd) and coordinate the available resources between these different cities. Hence, a city will usually look out for nearby settlements in the event of an emergency.

It has proven challenging to meet the minimum requirements for both the number of staff and their training. Especially in the settlements, there is a lack of qualified volunteers and leadership experience. Given the minimum requirement, there should be just under 900 employed in emergency response across the approximately 50 settlements and towns with employed firefighters. However, about 110 employees are missing from the roster, representing 10-15% of the total required by the government.

Staff shortages are more pronounced in some places, as some cities and bygds have decided to recruit more staff than the minimum required.

4.2. *Sermeersoq Municipality*

The municipality of Sermeersoq is the largest in Greenland, covering 531.900 km2, and is the home of around 24.000 inhabitants. It is the administrative centre of Greenland and the home of the Greenlandic government, Naalakkersuisut, and parliament, Inatsisartut. Most of the area is covered by the inland ice, which also creates a physical divide between the west (where most people live) and the east coast, where Tasiilaq, the only city on the coast, is located.

Nuuk is the capital of Greenland and, with around 20,000 inhabitants, it is also home to the country's largest emergency response capacity. The fire station is centrally placed in town, within reach of the three main populated areas of Nuuk, Qernertunnguit, and Qinngorput. The municipal response has the responsibility not only in Nuuk but also in Paamiut, Arsuk, Qeqertarsiaatsuat and Kapisillit on the west coast and Tasiilaq, Isertoq, Kulusuk, Tiilerilaaq, Kuummiut, Sermiliqaaq and Ittoqqortoormiit on the east coast. The Sermersooq municipal fire department has 35 employees, including 13 full-time and 175 part-time (Sermersooq, 2023b).

The cost of the municipal emergency response was 2.018.128 Euro in 2023 and 2.334.619 Euro in 2024 (Sermersooq, 2023a). Which is approximately 84 Euro/capita in 2023 and 97 Euro/Capita in 2024.

Fire station Nuuk also provides the country's largest number of physical resources, with nine permanent employees and 26 part-time firefighters, divided into two shifts. During the day, the phone is staffed by the administrative consultant and outside regular working hours, the line is staffed by the duty manager.

In May 2022, Nuuk put a modern fire station into service. With a central location between Nuuk city centre and Qinngorput, quick access to the entire city is ensured. On more than 2,800 m2 spread over two floors, there are 15 gates, a laundry hall, a workshop, an office, a kitchen, changing facilities, fitness and eight rooms for overnight stays. The vehicles have been in use, dating back to 1998 (a personal vehicle) and 2022 (two fire engines). The fire station is the most modern in Greenland, both in terms of equipment and facilities.

4.3. *Longyearbyen Fire Department*

The situation in Svalbard is similar in terms of remoteness but differs mainly because the emergency response is responsible for only one town (Longyearbyen) and the region as a whole is much smaller geographically (Governor, 2022). The Longyearbyen emergency response can assist the neighbouring settlements of Barrentsburg, Ny Ålesund, Barentsburg and Horsund, but, as in Greenland, there is no infrastructure which connects these places. Hence, it will take time for resources to reach the sites. The stated area of responsibility within the emergency response area "is to conduct preventive work and efficient emergency services to secure Longyearbyen's inhabitants and material values against accidents and injuries as a result of fire, explosion, chemical accidents, accidents during transport of dangerous goods and pollution." It is further stated that the fire and rescue service must provide a competitive service within its areas of responsibility.

The area of responsibility is much the same as in Greenland, with the addition of the Ambulance service, which also rests within the emergency response domain. Longyearbyen Fire and Rescue is the town's only provider of emergency services (Sæter, 2021). The service has been tasked with protecting the people of Longyearbyen, their health, the environment and material values. The response consists of 25 staff, four of whom are full-time and 21 part-time, a minor upgrade from the previous years. However, Longyearbyen is also impacted by the availability of qualified staff in all positions. In 2024, the turnover rate among permanent employees was 100%; the current fire chief and chief fire officer were on sick leave. The undersigned, as well as the fire chief, took on new roles in the unit. A new fire chief and a new fire inspector were hired." (Lokalstyret, 2024).

The cost of the municipal emergency response was approximately 657.212 Euro in 2023 and 648.026 Euro in 2024. Which is approximately 262 Euro/capita in 2023 and 259 Euro/Capita in 2024.

The fire department is centrally located within the industrial area of town, near the energy plant, harbour, diesel storage, and other critical

infrastructures. As Longyearbyen is relatively small compared to Nuuk, it takes just a few minutes to reach every corner of the town and, if needed, the four kilometres to the airport.

4.4. *State of Emergency preparedness*

Taking the outset in our understanding of risk-based dimensioning as the ability to create a virtuous self-improving circle, we analyse the challenges associated with implementation in the Arctic using examples from Greenland and Svalbard. The following analysis will illustrate how the risk-based dimensioning model exposes the challenges faced by emergency response.

The number of incidents reported by the emergency response varies. The fire departments in Longyearbyen and Nuuk report on their incidents each year, providing insights into the types of incidents and activities they handle. The number of incidents in Nuuk has steadily increased from 137 in 2020 to 212 in 2024. Over the period, the number of alarms has increased, likely correlating with the number of false alarms. Other types of incidents include house fires, search and rescue operations, environmental spills and traffic-related incidents.

Reports from Longyearbyen Brann og redning also show a steady increase in the number and nature of incidents from 222 (2020) to 389 in 2024. Since 2020, there has been almost a doubling of false alarms, mainly triggered by cooking/frying and by incidents involving water vapour from the bathroom/shower/laundry room, which the detector has detected in relatively small homes. A large number of the fires are linked to cooking, with food left in the oven or an air fryer. At the strategic level, the primary concerns are the changes the town is undergoing, such as the transition from coal to diesel as the primary energy source, the construction of a large battery farm nearby, and the influx of mass tourism.

When comparing the two contexts, note that most of Longyearbyen is built with wood as its primary building material, whereas Nuuk is primarily concrete. Therefore, the threshold for activating automatic alarm systems is lower in Longyearbyen. This, combined with the large number of students and tourists, could account for the higher number of false alarms. The ambulance service in Longyearbyen is also handled by the fire department, which accounts for many of the hospital's responses (139 in 2024).

In both Nuuk and Longyearbyen, the risk analysis is based on previous incidents and scenarios. As stated by Sermersooq, “The risks that have been identified have been based on the latest knowledge in risk identification. It is also characterised by the expertise of the emergency response team itself, but also based on information obtained from authorities, companies and relevant actors in society, to achieve a holistic approach to planning.” (Sermersooq, 2023b). The approach applied by Sermersooq is based on scenarios and what such a trajectory of events would mean to the preparedness organisations.

In Longyearbyen, the local council uses a consequence-based approach to its risk analysis: it identifies likely consequences and, based on this, evaluates them against scenarios and five distinct dimensions (Lokalstyret, 2023). The dimensions are Life and health – Deaths or severe injury, Nature and environment – Long-term damage to the environment or cultural heritage, Economy – Direct or indirect economic loss and economic loss for Lokalstyret, Societal stability – Lack of service level for the local population, disruptions of everyday life, social unrest (psychological or social reactions) and Lokalstyrets ability to govern – Crisis management, business continuity and reputation. The RaV in Longyerbyen states that “It has nevertheless been necessary to make some methodological adjustments and we have prepared an analysis based on more general events than detailed scenarios” (Lokalstyret, 2023). This means some of the analysis is based on hypothetical arguments about the consequences of a given event. The approach in Nuuk yields a long list of scenarios with varying likelihoods and consequences. Some of these are very salient, while others are marginal in terms of the role emergency response plays or the consequences. As stated in their analysis, ”It is worth pointing out that many of the risks identified do not directly fall under the responsibility of the emergency services themselves. Instead, they involve tasks where the emergency services assist other sectors in managing risks and crises” (Sermersooq, 2023b).

The choice not to use a scenario approach in Longyearbyen is argued for by stating that the “Use of scenario can also limit the [RaV] analysis.

When using scenario analyses, the analysis of probabilities and consequences will be valid only for the current scenario under the chosen assumptions. However, because the worst-case scenario is often used, other scenarios within the same event type could be milder and easier to handle as they involve fewer and less serious consequences" (Lokalstyret 2023).

Both Longyearbyen and Nuuk utilise a risk-based dimensioning approach, but differ in the utility of the empirical evidence on which they base their preparedness structures and resources. The divergence leads to quite different outcomes when the Lokalstyre in Longyearbyen invests in preparedness to mitigate identified consequences, whereas in Nuuk, it is the scenario itself that is being allocated resources to mitigate. In both contexts, obtaining external resources is not possible, which means costs will be higher than in non-arctic regions. Isolation means that a minimum set of resources must be present, which goes beyond the risk-based dimensioning approach, as events with low likelihood and consequences would need to be prioritised higher than the analysis suggests.

5. Discussion and conclusion

This paper sought to investigate the use of risk-based dimensioning in the Arctic, discuss the results, and examine the specific emergency preparedness structures established in Greenland and Svalbard to address these risks, and the extent to which we can characterise these approaches as risk-based.

The municipal emergency response organisations in Nuuk, Greenland, and Longyearbyen, Svalbard, were used as examples of how different approaches to dimensioning translate into training, equipment, and the organisation of the local fire department.

Svalbard and Greenland apply different approaches to dimensioning their emergency response. In Svalbard, a risk-based approach was preferred, using the same systems as in mainland Norway, with some considerable adjustments for remoteness. Greenland has opted for local adaptation of standards, resulting in a mix of minimum requirements, risk-based approaches, and prioritisation of the most common scenarios.

In both Longyearbyen and Nuuk, the dimensioning is based on past events and perceived consequences of these. The citizens of Longyearbyen have experienced several significant events that have led to increased emphasis on specific incident types, such as avalanches and fires, with significant consequences for the community. While in Nuuk, focusing on scenarios leads to a more balanced approach that favours the average event over outliers. In both cases, the dimensioning may be either too large, as in Longyearbyen, or too narrow in scope, as in Nuuk, where outliers would be hard to manage.

A possible path forward for developing a theoretical framework that accounts for remoteness, limited resources, and the Arctic context could be to focus on critical societal functions rather than on scenarios or past consequences. Traditionally, the focus has been on emergency preparedness capacity to save lives, and what is considered valuable to the community. Given the limitations we find in the Arctic region, it would be better to reflect on how Arctic societies function and more valuable to focus on critical societal functions and capabilities when dimensioning emergency preparedness (Duda et al., 2020; Taarup-Esbensen, 2022). Utilising a scenario and consequences to the protection and re-establishing, when an event is realised, these functions include efficiently utilising the resources from local private companies, volunteer organisations, and public organisations not officially part of the emergency response structure, supporting the overall adaptive capacity and strengthening the resilience of the community as a whole.

Such a system is based on a tiered approach, in which dimensioning is determined by the increasing number of community resources involved, as scenarios and consequences require more resources. In such a system, volunteer organisations and private companies would, under certain conditions, play an active part in the preparedness structure. Thereby increasing resilience and focusing formal resources on the predominant forms of incidents, while outliers would call for the engagement and coordination with the wider community. This would be reflected in the EPA,

which would then depict a more nuanced preparedness system and the capacity to respond effectively to different scales of events. However, such a system will also require more coordination between formal and informal systems, increasing complexity and the risk of systemic failures. However, the potential rewards will increase in proportion, enabling the mitigation of threats with greater consequences.

Both contexts have had positive experiences with this form of collaboration. In Longyearbyen, the 2017 avalanche saw widespread community involvement on all levels in coordination and in the same year, Greenland witnessed widespread volunteering as a tsunami devastated a bygd in Karratfjorden. The insights from both incidents could be utilised to improve insights into the real and perceived emergency response in Greenland and Svalbard.

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