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An Investigation of Arctic Safety Events

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Safety, Health and Environment
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Preface

This Thesis is the result of twenty weeks of analysis, research, frustration and work. The motivation for choosing this topic is a long time interest in the Arctic region and the lack of research on the subject of Arctic safety. It started as a simple question,

> *"What is unique about accidents in the Arctic?"*

Even after a long time studying in the Arctic and being involved in a handful, I could not say what was different accidents in the Arctic. In the fall of 2016, I wrote my project assignment on the topic, trying to map the literature on the subject. The result was that there was minimal scientific work on the subject. The only thing left in order to answer the question, was to do it myself.

All persons pictured or mentioned in the Thesis have given their express permission to be mentioned or pictured. Where descriptions of incidents is vague, it is on purpose.

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Skadeforebyggende
forum

Johannes Pippidis Lorentzen
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Acknowledgements

I would like to thank Store Norske Spitsbergen Kullkompani and The University Centre on Svalbard for allowing me full access to their incident databases, without which this study could never be conducted. I would also like to thank my supervisor Eirik Albrechtsen for the guidance and help provided. Loralee Ryen and Astrid Østigård also deserves thanks for their proofreading of the script.

Lastly, I would like to thank my mother for once again proofreading my Thesis.

Abstract

The Arctic is increasingly becoming an important area in Industry, Science, Tourism, and Education. With the increased activity, the number of accidents are increasing and causing a demand for better safety management. It is found that little research into the topic is previously conducted. In this Thesis, three datasets with incidents in the Svalbard region have been investigated, using a combination of accident concentration analysis, cause analysis and preventive strategies analysis. It is found that most accidents either occur during the spring or late summer period at Svalbard due to the scooter and maritime season respectively. Five incident types that are characteristic for the Arctic region has been identified; Assistance person, fall due to ice or snow, scooter incidents, unintentional discharge of weapons, and events that can not be foreseen. It is found that the operations at Store Norske Spitsbergen Kullkompani do not show any significant differences caused by being in the Arctic. The safety operations at the University of Svalbard are shown to have multiple challenges in both safety management systems and incident concentrations, and it is a combination of chance and good emergency response at UNIS that no fatalities have occurred. The UNIS operations are also shown to be adapt to ensure safe field activity despise of this.

Sammendrag

Arktis blir stadig et viktigere område innenfor industri, forskning, turisme og utdanning. Med den økende aktiviteten øker også antall ulykker, noe som fører til et behov for bedre sikkerhetsledelse i Arktis. I denne studien er det funnet at det er gjort lite forskning på dette området tidligere. Tre dataset fra organisasjoner i Svalbardområdet er undersøkt ved bruk av ulykkeskonsentrasjon, medvirkende faktorer, og årsaksanalyse. Det er funnet at antall hendelser er størst om våren og sensommeren, grunnet scooter sesongen og den maritime aktiviteten. Fem hendelsestyper karakteristisk for Arktisk er identifisert; Assistanse person, fall grunnet snø og is, scooter ulykker, vådeskudd, og hendelser som ikke kan forutsees. Aktiviteten ved Store Norske Spitsbergen Kullkompani viser ikke tegn på at den Arktiske lokasjonen påvirker sikkerhetssituasjonen. Det har også vist seg at Universitetssenteret på Svalbard har utfordringer både i sikkerhetsarbeidet og innen ulykkeskonsentrasjonene. Funn viser at det er en kombinasjon av flaks og svært god hendelseshåndtering som har hindret dødsfall. Universitetssenteret på Svalbard sin operasjon er selv med dette svært god til å forebygge hendelser selv med dette.

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Glossary

D1-D18 Deviations from Kjellén and Albrechtsen (2017) Checklist of deviations. See Table 2.1. 19

ECTS European Credit Transfer and Accumulation System. 6

H1-H10 Haddon's 10 accident prevention strategies, see Table 2.3. 22

HIPO High Potential event, events that have a high damage potential.. 18

HSE Health, Safety and the Environment. 1

JRCC The Joint Rescue Coordination Centres in Norway, or "Hovedredningssentralen". 12, 25, 75

LRKH Longyearbyen Red Cross. 12

M1-M6 Human/behavioural contributing causes from the MTO method. See Table 2.2. 19

NPI The Norwegian Polar Institute. 6

O1-O13 Organisational/economic contributing causes from the MTO method. See Table 2.2. 19

SNSK Store Norske Spitsbergen Kullkompani. 9

T1-T6 Technical/physical contributing causes from the MTO method. See Table 2.2. 19

UNIS The University Centre in Svalbard. 6

CHAPTER 1

Introduction

There is an increasing amount of human activity in the remote and challenging environments of the Arctic, the previously remote frontier comes ever closer. Each year brings new record lows in Arctic sea ice extent and opens up for even more activity both on land and at sea (NSIDC, 2016). Even as the sea ice retreats and the temperature increases (Førland et al., 2011), the hazards still exist. These hazards differ both in quantity and quality from the ones that are common in lower latitudes. Arctic safety management can be divided into two main area, namely land and sea. Almost no published work has been conducted with regard to land, and close to all focus have been on the maritime system (Lorentzen, 2016). The focus of this study is to identify the optimal approach to safety management of land activity in the Arctic, and identify characteristics and concentrations of incidents.

1.1 Questions

Even as the Arctic land masses covers 2.7% of the earth surface, it has not been a focus for safety research. The archipelago of Svalbard was the main area of focus to identify differences in safety management practices between the arctic and areas of lower latitude. The University Centre in Svalbard and Store Norske Spitsbergen Kullkompani have given access to their HSE[1] databases, and this has been analysed to uncover patterns and challenges in Arctic safety management. The investigation has been divided into four main stages.

Stage 1: Literature review. The first step was to conduct a literature review of safety events in an Arctic context and identify the gaps in safety research. The literature review was the main focus in the specialisation project associated with this degree (Lorentzen, 2016).

Stage 2: Accident concentration analysis. An accident concentration analysis' main goal is to identify clusters and patterns in accidents and reported events. The HSE event databases of Store Norske Spitsbergen Kullkompani, The University Centre in Svalbard, and the Joint Rescue Coordination Centres in Norway have been analysed.

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[1] Health, Safety and Environment

Stage 3: Accident causes. Based on the accident concentration analyses, the causes and contributing factors of these concentrations were determined.

Stage 4: Preventive measures After the contributing factors and causes have been identified, the appropriate preventive measures are discussed and presented. Many of the standard solutions might not be applicable due to the special environment in the Arctic.

1.2 Scope and limitations

To limit the scope of the investigation, following limitations have been made.

Only Svalbard: The focus of this investigation is the Svalbard area.

Only Land: As found by Lorentzen (2016), multiple studies have been conducted on Arctic maritime safety management, so maritime safety was omitted from this study.

Russian settlements: The Russian settlement in Barentsburg has significant differences in both culture and management (Grydehoej et al., 2012). Due to time, access and language constraints, all Russian activity on Svalbard have been omitted from the study.

No Avalanches: While both snow avalanches and landslides poses significant threats to the activity in Svalbard (DSB, 2016), they are omitted from this study.

No Interviews: In-depth interviews have not been conducted in this study due to time and access constraints. Many of the possible interview subjects also have some connection to the author and could therefore not be interviewed by the author alone.

Taken at face value: All data received from third parties as Store Norske Spitsbergen Kullkompani (SNSK), The University Centre in Svalbard (UNIS) and The Joint Rescue Coordination Centres (JRCC) have been taken at face value and assumed to be correct.

Outdoors: Due to the large number of entries in the SNSK dataset, the investigation has been limited to only outdoor incidents.

1.3 Svalbard

Svalbard has been chosen as the main area of study, due to its accessibility and well-developed industry and society. The Svalbard archipelago is located between $75^\circ N$ and $81^\circ N$, north of Norway as shown in Figure 1.1. The archipelago consists of multiple islands, with Spitsbergen being the largest and most populated. The main settlement in Svalbard is Longyearbyen on the shore of Advent Bay[2], where most of the population and operations are based (Figure 1.2). The second largest settlement is Barentsburg, a Russian mining town with approximately 470 inhabitants (SSB, 2017). Also, there are two major research stations, located in Ny Ålesund and Hornsund, as well as scattered trapper cabins around in the archipelago. Svalbard has an area of 61 022 km^2, where $64,7\%$ is protected. Each year there are more than 139 554 hotel nights, and there are 2145 snowmobiles. (SSB, 2017)

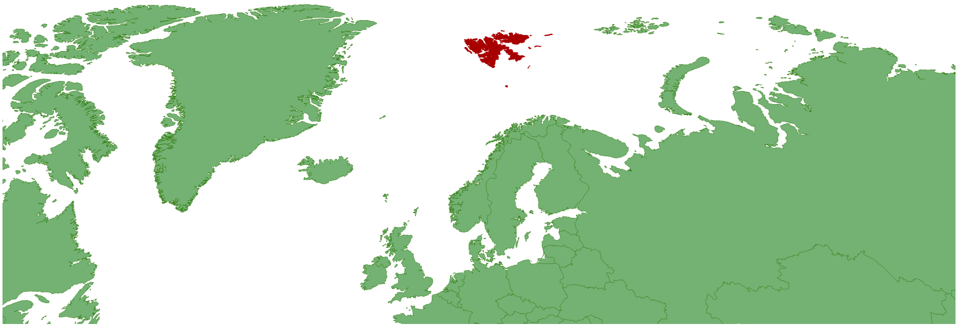

Figure 1.1: Map showing the location of the Svalbard archipelago (red), located in the Arctic ocean north of Norway. (Lorentzen, 2015)

1.3.1 Law and Order

Svalbard is by the 1920 Svalbard Treaty[3] a Norwegian territory and where Norwegian laws apply. It is however not subject to all of the laws of the Norwegian mainland, as only private law, criminal law and the procedural law apply unless otherwise specified. Other legislation and regulations only apply if separately determined (NPI, 2017). For example, "Internkontrollforskriften"[4] does not apply. There is no regular police in Svalbard, and all the functions are held by the Governor of Svalbard. The Governor is also in charge of governing, administrative tasks, end environmental management.

1.3.2 Climate and environment

The climate in Svalbard is harsh and inhospitable. There are no trees, temperatures as low as $-45°C$ in the winter, frequent high winds, and half of the year it is completely dark due to the high latitude. The other half of the year is summer, where the temperatures reach up to $13°C$, and there is the midnight sun. This

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[2] Adventfjorden, a bay at the side of Isfjorden

[3] Full name: Treaty recognising the sovereignty of Norway over the Archipelago of Spitsbergen, including Bear Island

[4] Internkontrollforskriften or "Forskrift om systematisk helse-, miljø- og sikkerhetsarbeid i virksomheter" regulates the internal control within HSE work in Norway. (Internkontrollforskriften, 2013)

Figure 1.2: Longyearbyen is the main settlement in Svalbard, with 2145 inhabitants in 2017 (SSB, 2017). The town located in on the shore of the Advent Bay. Longyearbyen consists of mostly wooden houses built on poles due to permafrost. Photo by Mateusz War / CC BY-SA 3.0.

extreme environment is both one of the largest source of risk in Svalbard, as well as, for many, the main reason for staying. Førland et al. (2011) shows that the climate in Svalbard is changing and there have been higher temperatures and an increase in precipitation in the recent years. Førland et al. (2011) also shows that this trend is likely to continue and severe weather events, such as extreme precipitation events, are likely to increase in frequency.

Most of Svalbard is covered by glaciers and crossing one is almost impossible to avoid when travelling around. The glaciers vary in type and extent, from small bottom-frozen glaciers, to calving glaciers and full-scale ice caps (Hagen et al., 1993). Crossing each type has different challenges and risks associated with them and demands different approaches. A glacier may have many dangers, such as crevasses[5] and calving events.

Svalbard is also home to many plants and animals that can pose just as much of a safety challenge as the physical environment. There are, by the last count, somewhere between 1900 and 3600 polar bears in the Svalbard archipelago (Andersen and Aars, 2016). Polar bears, or *Ursus maritimus*, are large marine bears that live in the Arctic region. They spend most of their time alone out in the ice fields, hunting for seals and anything else that can be eaten. With a body mass of up to 700 kg and a robust build, they are a formidable force to encounter. Every couple of years people are killed by polar bears, and this is the reason that everyone that leaves Longyearbyen carries a rifle.

Alongside polar bears; mice, walruses, and other animals might cause serious harm and death. Mice in parts of Spitsbergen close to Barentsburg carries a parasite called *Echinococcus multilocularis*, that can either be passed to humans by food or through other animals that eat the mice. The parasite can be lethal to humans

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[5] Cracks in the glacier that is usually up to 30 meters deep.

(Ylvisaker, 2016). Walrusess poses a threat to both man and equipment if one comes too close to a colony. They have been known to puncture boats and might kill careless swimmers that come too near. Lastly, multiple outbreaks of rabies have occurred on Svalbard, most likely introduced by polar bears coming from Siberia (Yale et al., 2014).

1.3.3 Society and population

Svalbard residents are young. Most of the population is between 20 and 40 years old, compared to the Norwegian mainland where the population is more evenly distributed (SSB, 2017). The population is also highly educated, well paid and healthy (SSB, 2014). The number of inhabitants has been stable in Svalbard for the last 20 years; however, there has been a shift towards Longyearbyen, as shown in Figure 1.3.

There are more than 40 different nationalities represented in Svalbard and Norwegian citizens constitute most of the population, followed by a significant number of Russians, Ukrainians, Swedes and Thai. (SSB, 2014)

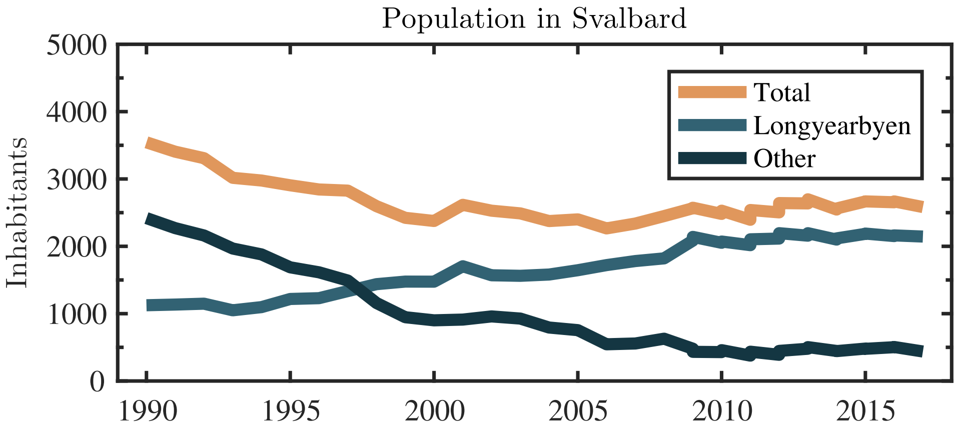

Figure 1.3: Population in Svalbard. ”Other” include Hornsund, Barentsburg, Ny Ålesund, Pyramiden and trappers. (SSB, 2017)

It is very common for the residents to be engaged in outdoor activities during their spare time, with back-country skiing, dog sledging and snowmobile driving being the most popular activities. By this effect, the average person is highly qualified in both Arctic safety and handling of incidents, and this often improves the outcomes as exemplified in the 2015 December avalanche (DSB, 2016).

1.3.4 Major actors

The major actors in Svalbard can be divided into four main groups, namely Government, Industry, Education and Research, and Tourism.

Government The Government in Svalbard is divided between the Governor of Svalbard previously named “Longyearbyen Lokalstyre (LL)”, which manages the kinder-gardens, schools, the power-plant, road maintenance, and all community servers in Longyearbyen.There is also a Russian consulate in Barentsburg.

Industry There are three principal actors in the industry in Svalbard, Store Norske Spitsbergen Kullkompani, Kongsberg Satellite Services, and Trust Arktikugo whom manages the Russian mining activities on Svalbard.

Education and research The main actor in education in Svalbard is the University Centre on Svalbard (UNIS). The Norwegian Polar Institute (NPI), has major research activity on Svalbard all year round and shares a building with UNIS. There are also multiple national polar research institutes and bases around in Svalbard, for example the Polish Station in Hornsund.

Tourism There are more than 50 different tourism companies in Longyearbyen, organised in ”Svalbard reiselivsråd”. Among the largest companies are: Hurtigruta Arctica and Radisson Blue. There is also a growing tourism industry in Barentsburg.

1.4 The University Centre in Svalbard

The University Centre in Svalbard (UNIS) is located in Longyearbyen and is the world’s northernmost higher education institution. UNIS was established in 1993 as a collaboration between the Norwegian universities to provide higher education in Arctic subjects and provide a base for Arctic research (Misund et al., 2017). Today, approximately 700 students visit UNIS each year, from more than 40 different countries. All subjects are required to have field activity, and all students have mandatory safety training.

Structure UNIS is divided into four departments, in addition to Logistics, Administration and the Library. The four are Arctic Technology, Arctic Physics, Arctic Biology and Arctic Geology. Each department is led by a “Head of department” that is responsible for all activity. Each department requires different types of field activity, which often require different approaches to safety management. Currently, another department is under development, focusing on Arctic Safety.

Safety Training All staff, students, and external guests and researchers are required to undergo mandatory safety training. For students staying the spring semester, a total of six days not including snowmobile training, are provided. The six-day course is ended with a written examination, and students are awarded three ECTS[6]. For students staying the fall semester or shorter stays, 2-3 days of safety

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[6] European Credit Transfer and Accumulation System

training is provided; it also applies to staff and visitors. This safety training is tailored to the group and includes polar bear protection, overall arctic survival, communication, avalanche training, crevasse safety, sea ice safety, first aid, and more.

The Logistics department The Logistics department is responsible for logistics and HSE at UNIS and consists of technicians, field experts and support personnel. The Logistics department is also responsible for all safety training at UNIS. Their areas of expertise cover everything from maritime logistics and cruise planning to polar bear protection and satellite communications. Through the last twenty years, the logistics department have developed to become one of the leaders Arctic field work safety. Many external research organisations request to attend the safety course.

The logistics department is also responsible for the distribution of the so-called "Welfare rifles" that students at UNIS can borrow for up to a week at a time.

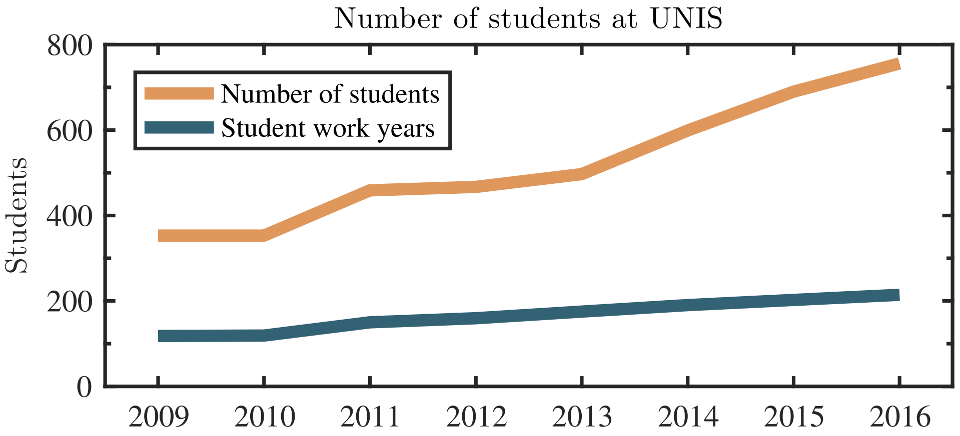

Figure 1.4: Number of students at UNIS in the period 2009-2016. Both the total number of students visiting and the total number of student work years produced is show. A student work year is defined by UNIS as 60 ECTS.

Courses UNIS offers a total of 122 different courses to students, varying in scope from 3 ECTS to 15 ECTS. The Arctic Biology department offers 37 different courses; Arctic Geology offers 34, Arctic Geophysics offers 22 and Arctic technology offers 26. In addition, there are three general courses available to the students. The courses at UNIS depend to a great extent on visiting lecturers and staff in Professor-II positions, with more than one hundred each year.

Students In 2016 there were 759 different visiting students at UNIS, producing a total of 214.4 student work years[7]. The number of students have increased over

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[7] A student work year is counted as 60 produced ECTS.

the last decade, and are set to increase even more as a strategic measure from the Norwegian government (See Figure 1.4).The students are from all over the world, with only 33% Norwegian students[8] (2016). Other student nationalities include German, British, Dutch, Canadian, and Russian. There are also some students from Australia and other more tropical locations. There is a large range in arctic experience within the student body upon arrival; from ex-military winter special forces to students from warmer climates who have never owned a jacket in their life[9]. The students live in student housing, either in Nybyen, or close to the university centre.

Figure 1.5: UNIS student Loralee Ryan conducting permafrost fieldwork in Adventdalen, close to Longyearbyen, in the summer field season of 2012. Photo by Johannes P. Lorentzen.

Field activity UNIS courses place a heavy emphasis on fieldwork, and each course is required to have a field component. In 2015 there were a total of 11 837 field days at UNIS, including teaching and excursions. Of these were 5,712 pure research days.

The field activity can be vastly different, from less demanding summer fieldwork as exemplified in Figure 1.5, to more challenging operations in winter with heavy equipment and sometimes explosives as shown in Figure 1.6. Added to this comes scientific cruises and marine operations. Each different field activity poses different

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[8] Norwegian students is here counted as those of Norwegian citizenship, not foreign students enrolled at a Norwegian university.

[9] The Student in question, Tyler Stewart, arrived from Australia at the start of January, in the middle of the dark period, in temperature of -25°C and near gale-force winds. He had never owned woollen underwear in his life and had never even needed it. However, he quickly adapted and bought a warm winter jacket.

Figure 1.6: Fieldwork with the Technology department at UNIS during the spring field season in Svea. Photo by the Johannes P. Lorentzen.

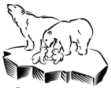
challenges and in many cases, the standard approaches enjoyed by lower latitudes cannot be used due to either regulation or accessibility.

Arctic Safety Centre In 2016 a new Arctic Safety Centre, founded at UNIS, receiving 14 Million NOK in funding from the Norwegian Ministry of Foreign Affairs. The mandate state that

> "*The purpose is to contribute to as safe and sustainable human Activity in The High Arctic as possible*"- Arctic Safety Centre Mandate

Explained in more practical terms, it shall provide a Masters program in Arctic Safety, practical safety courses for industry, academia, residents of Longyearbyen, and develop new knowledge, theory, and models. At the date of writing, the aim is to have a pilot subject running in 2018, and full-scale operation in 2019.

1.5 Store Norske Spitsbergen Kullkompani



Store Norske Spitsbergen Kullkompani (SNSK) is a shareholder company owned by the Norwegian state. It was founded in November 1916 after the American mining company American Arctic Coal Company was bought by the Norwegian state (SNSK, 1991). Today SNSK only has one mine active, Gruve 7, as both the mines in Svea and Lunckefjell are currently closed due to low coal prices and a challenging market (see Figure 1.8). Figure 1.7 shows the location of the three mines, along with Longyearbyen where the company headquarter is located.

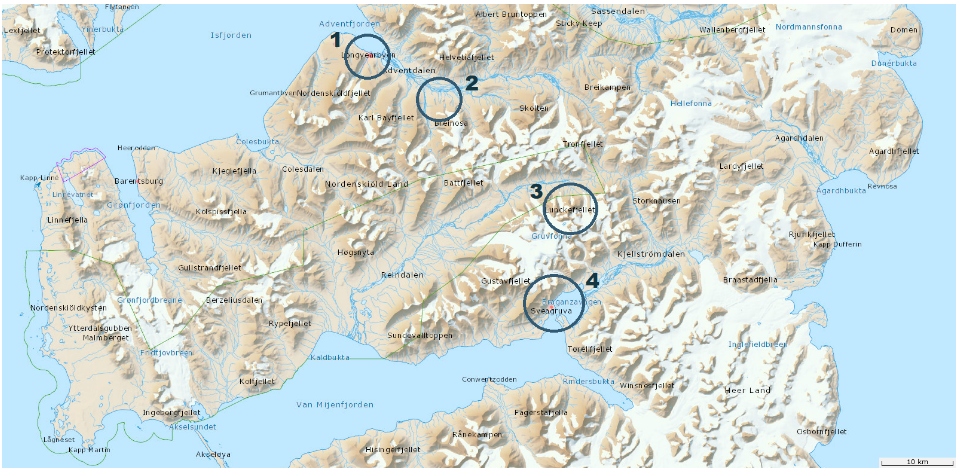


Figure 1.7: Location of SNSK mining operations in Svalbard. 1) Longyearbyen, 2) Gruve 7, 3) Lunckefjell, 4) Svea. Map by the Norwegian Polar Institute, modified by the Author.

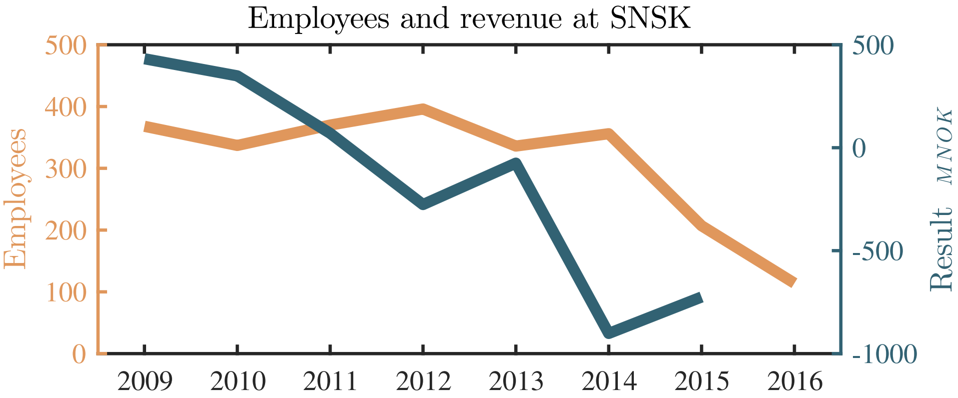


Figure 1.8: The number of employees and revenue at SNSK in the period 2009-2016. As the yearly report from 2016 is not published, the number of employees are calculated as the mean between Q4 2016 and Q1 2017.

Gruve 7 The only currently operational mine is located outside Longyearbyen, producing approximately 150 000 tonnes of coal each year. The production methods are highly advanced and done by a Continuous Miners[10] that can be remote controlled. The coal is shipped with trucks through Longyearbyen to the harbour.

Svea Svea is SNSK larger mine, located in Van Mijenfjorden approximately 2 hours by scooter from Longyearbyen. The workers had 2 weeks rotations and lived in Svea while working. Most of the workers lived in Longyearbyen when not at work. The most common transportation from Longyarbyen is by aeroplane or by scooter in the winter. The mine is currently on hiatus. Figure 1.9 and 1.10 illustrates the location and village of Svea.

Lunckefjell Lunckefjell is SNSK's newest mine and was opened in February 2014. It is located north of Svea and uses the facilities of the Svea mine. Shortly after opening, it was put on hiatus due to low coal prices.

Figure 1.9: Svea mining operations in 2013. Photo by Vetle Nilsen Malmberg / CC BY-SA 3.0.

1.6 Rescue services and emergency response

The rescue and emergency capabilities in Svalbard are based on five main organisations; The Governor, The Coast Guard, The Red Cross, The Fire Brigade and the Hospital in Longyearbyen. Each has different tasks and responsibilities. An

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[10] A machine that extracts the coal using a rotating head with tungsten carbide teeth.

Figure 1.10: The main street in the Svea mining village in 2013. The administration building is to the left, and the post office to the right. Photo by Vetle Nilsen Malmberg / CC BY-SA 3.0.

example of this is when the power-plant burned in 2012, all available resources was mobilised, including the cost guard, the fire trucks at the airport and resources from SNSK. In total almost 120 smoke-divers was available. In case of an emergency, everyone in the town that can help will do so as well (DSB, 2016).

The Governor of Svalbard The Governor on Svalbard organises most of the rescue operations and has the main responsibility in most cases. The incidents recorded by the Governor are reported to The Joint Rescue Coordination Centres (JRCC) in Norway.

Red Cross Longyearbyen Red Cross (LRKH) is a volunteer organisation that provide rescue resources in Svalbard and has approximately 60 active members. LRKH also works with preventive measures and promotes interest in outdoor activities. (LRKH, 2017)

The Coast Guard The Coast Guard is the only military presence in the Svalbard area, with the icebreaker “KV Svalbard”. Most demanding offshore rescue operations involves the icebreaker, and in case of need, it will assist the land-borne operations as well.

Longyearbyen Fire Department Longyearbyen Lokalstyre is responsible for maintaining the Longyearbyen Fire Department which consists of 24 persons in twenty-one part-time and three full-time positions. The fire department have three firetrucks in its disposal. In Larger fires, most buildings cannot be saved due to wooden constructions and low humidity.

Hospital The hospital in Longyearbyen is organised under the University Hospital of Northern Norway, and had 22 employees in 2013. There were four doctors, eight nurses, one dentist, one midwife and Occupational Health Services, among others. The hospital has a surgery room and can perform basic surgery. When major surgery is required, the patient is flown to Tromsø for treatment. There are also medical capabilities in both Barentsburg and Ny-Ålesund. (Sysselmannen, 2013)

CHAPTER 2

Theory

The work in this Thesis has to a large degree been based on the Accident Analysis Framework by Kjellén and Albrechtsen (2017), and the procedures outlined within. Database construction and access method to ensure high quality analysis by Kjellén and Albrechtsen (2017), and Rausand (2013) are used.

2.1 Experience feedback

A crucial part of a solid safety management system is the experience feedback loop, where the information on results of activities is fed back to improve the situation (Kjellén and Albrechtsen, 2017). Many different possibilities exist in designing an experience feedback loop for an organisation, and care has to be taken to customise each feedback to the system.

The idea of feedback comes from control theory, where one aims to control a system's state. In safety management, the target is zero accidents. When implementing an experience feedback loop in a safety management system, one need to consider both the level of learning and the level of control.

2.1.1 Abby's law of requisite variety

One of the challenges when implementing safety system is the lack of imagination concerning preventive measures and methods according to Kjellén and Albrechtsen (2017). Often there are focus on a few simple measures, and often disproportionately simple in comparison to the complexity of the accident sequences and conditions. *Abby's law of requisite variety* states that

> "*For an analyst to gain control over a system, he must be able to take at least as many distinct actions, i.e. as great a variety of countermeasures, as the observed system can exhibit.*" (Van Court, 1967)

meaning that when attempting to control the system one needs to be able to utilise as many different actions as the complexity of the system. This applies to all level of the organisation. Both the workers and the top managers need to have access to at least the requisite number of actions. Workers at the lower level often face a more complex system than managers at higher level working with aggregated data. Furthermore, the countermeasures need to be generated at least at the same rate as the system. As stated by Abby's law of requisite variety:

> "*For an analyst to gain control over a system, he must be able to generate countermeasures at least at a rate corresponding to the rate of variety that the observed system can exhibit.*" (Van Court, 1967)

Kjellén and Albrechtsen (2017) summarises Abby's law of requisite variety with three abilities that the analyst must show to exercises full control of the system:

1. Ability to take at least as great a variety of actions as the observed system can.
2. Ability to take precisely the correct set of action alternatives to counter those changes generated by the system.
3. Ability to collect and process information and to decide on and implement measures at a rate at least equal to the system's rate of change.

Control theory In control theory, there is a similar demand of the system that is called *Controllability*. It states that to control a system, the controllable variables need to be at least of as many dimensions as the controlled system, as well as be able to influence the system variables (Sterman, 2000; Balchen et al., 2016).

2.1.2 Van Court Hare's hierarchy of order of feedback

Organisational learning can, according to Van Court (1967), have five different orders, from no learning to higher order goal changing. A zeroth order system will repeat the same accidents, while higher order learning help improving safety on a long term basis.

0th order An uncontrolled system without feedback is called the zeroth order system. There is no learning from previous experience, and the same type of incidents appear time and time again. A so-called *Open Loop system* within control theory.

1st order The first order feedback is the lowest order of feedback, comparable to a *simple machine* without selective memory, where a correlation of deviations is identified by accident investigation or safety inspections.

2nd order The second order feedback loop in safety management is when preplanning is introduced, with organised memory and predictive feedback. It is also called a *Tactical system*.

3rd order A third order feedback system is when the system learns from experience and has the ability to use corrective plans and develop new ones. The third order includes a change in routines, instructions, rules or design. The third order is also called a *Strategic system*.

4th order The fourth and highest level of learning according to Van Court (1967) is the *Goal changing system*, where the system learns and consciously develops, selects and implement new plans. The forth level includes a change in HSE policy and the general HSE goals of the organisation.

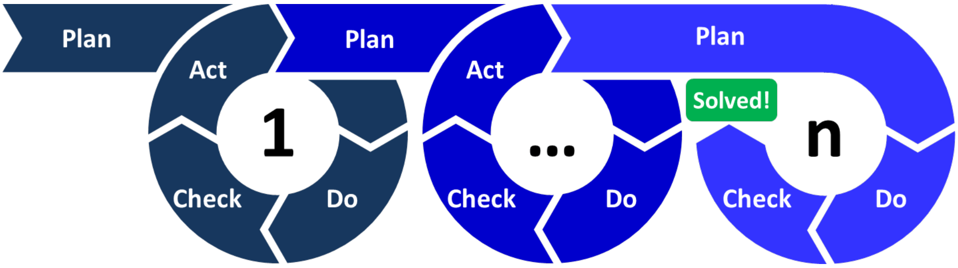

Figure 2.1: The process of using Deming's cycle in safety management. In safety management, the problem is never completely solved, and the process continues ($n \to \infty$). Figure by Christoph Roser / CC BY-SA 4.0

2.1.3 Safety Information system

To enable learning, a memory or *safety information system* needs to be implemented. Kjellén and Albrechtsen (2017) states that the safety information system is a vital part of any safety management system, providing support to the decision makers, and enabling learning. A safety information system provides four functions; *Reporting and collection of data*, *Storing* of data and retrieval, *Information processing*, and *Distribution* of information to decision makers.

The quality and efficiency of the safety information system are critical, as a failure in any one of the functions might cripple the safety management system (Kjellén and Albrechtsen, 2017).

2.1.4 Implementations

There are multiple ways of implementing an experience feedback loop, as summarised by Kjellén and Albrechtsen (2017). A simple implementation of the experience feedback loop is the Plan-Do-Check-Act method, also called *Deming's cycle* (Deming, 2000). Deming's cycle consists of four parts making up a continual loop for improvement as shown Figure 2.1. In safety management, the problem is never completely solved, and the process continues. The four main parts are

Plan In the planning phase, the situation is planned, and the information is gathered. Where are we? Where do we want to go? How do we get there?

Do The second phase is to execute the plan of the first, including securing resources, communication, training and the execution.

Check Thirdly, one need to check the results of the Do phase, checking if it followed the plan and if the goal was met.

Act The last part or the circle is to act upon the findings within the phases, summing up experience and implementing corrective actions.

Deming's cycle is implemented by many different organisations, standards and laws such as the ISO 14 001 standard.

2.2 Accident Analysis Framework

The Accident Analysis Framework use an accident sequence model dividing the accident into three main sections: Input, Process, and Output (also known as the Input-process-output model). This investigation focuses primarily on the Input portion of the system.

Input The "input" of an accident is considered the root cause of the initiation of the accident and other contributing factors. The central philosophy is that accidents rarely occur by pure chance - some deviations and irregularities precede the event. Kjellén and Albrechtsen (2017) defines *Root causes* as the most basic cause of the incident within the organisation, and *Contributing factors* as the human, technological, and organisational conditions within the organisation that contribute to the accident.

Process The second part of the accident is called the "process" by Kjellén and Albrechtsen (2017) and is divided into three parts: Deviation, Incident and Target Absorbs Energy. The first part of the accident is the deviation (also called the initial phase), is where the process deviates from the normal operation. Following is the Incident phase, which starts with a loss of control or a person in a danger zone. This loss of control eventually leads to the phase where the target absorbs the energy and takes harm.

Output After the target has absorbed the energy, comes the "output" of the system, defined as the; damage or loss. Kjellén and Albrechtsen (2017) defines four main groups of loss; Loss to people, Loss to the environment, Loss of material assets, and Loss of reputation.

2.3 Database construction, quality and retrieval

The first step in an investigation into a safety database, is to ensure that the database is of sufficient quality and that the fundamental data is in place. If the data and database are not of sufficient quality, the resulting analysis would be worthless[1].

Database construction During construction of the database, or ensuring that the database has the required information for the analysis, there are seven different types of information required for the "smallest efficient set" (Kjellén and Albrechtsen, 2017); Administrative conditions, Injured persons, Work situation, Sequence of events, Loss, High Potential (HIPO) event, and remedial actions.

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[1] Garbage in, garbage out. If what comes into the analysis is garbage, what comes out is also garbage.

Data retrieval After building the database and ensuring the quality, then the working set must be constructed. This working set is constructed based upon a search or limitation of the full database to investigate a particular type of event (Kjellén and Albrechtsen, 2017).

Errors Following the initial search, the errors must be managed. There are two main types of errors in the data retrieval that are possible: Type I & II errors. Both need to be addressed to ensure a high-quality working set (Kjellén and Albrechtsen, 2017).

Type I errors are events that are wanted but not retrieved in the dataset. Type I errors are connected to the *degree of retrial* of incidents in the database. These are most often handled after Type II errors.

Type II errors are events that are retrieved but not wanted in the dataset. Type II errors are connected to the *degree of precision* of events in the database. In this Thesis, insufficient quality is counted under Type II errors.

2.4 Accident cause analysis

There are multiple different ways of investigating causes and contributing factors of accidents, such as: Safety Management and Organisation Review Technique (SMORT), The Human Factor Analysis and Classification System (HFACS), Man-Technology-Organisation (MTO), and much more. In this investigation, it was decided to use a combination of MTO and the deviation checklist by Kjellén and Albrechtsen (2017).

Checklist of deviations Within the Accident Analysis Framework, Kjellén and Albrechtsen (2017) have developed a compatible checklist of deviations that reflect the different aspects of deviations. The checklist of deviations is recreated in Table 2.1, where the deviation codes (D1-D18) that will be used in this Thesis, are presented.

Man-Technology-Organisation The Man-Technology-Organisation method was developed for the Swedish nuclear industry, but has later become more widespread. It combines a checklist of different contributing factors with other methods, to build an image of what led to the incident. The underlying idea in the MTO method is a system perspective of events, understanding that each event is a sum of many different contributing factors (Kongsvik, 2013). Three main categories, Man, Technology and Organisation are covered as shown in Table 2.2, where also the codes used in this Thesis are presented (M1-M6, T1-T6, O1-O13).

Table 2.1: Checklist of deviations (Kjellén and Albrechtsen, 2017)

Work situation:	
D1	Human error
D2	Technical failure
D3	Disturbance in material flow
D4	Personnel deviations
D5	Inadequate information
D6	Delay in progress
Environment:	
D7	Intersecting or parallel activities
D8	Bad housekeeping
D9	Disturbances from the environment
D10	Substandard building and infrastructure
Incident:	
D11	Loss of control of energy or person relative to energy flow
D12	Failure in active safety barriers
D13	Failure in fixed barriers
D14	Failure in personal protective equipment or clothing
D15	Persons in danger zone
Development of injury/damage:	
D16	Failure in alarm and mobilisation of emergency response team
D17	Failure in limiting injury/damage
D18	Failure in management of information to internal and external stakeholders

Table 2.2: The Man-Technology-Organisation model for classification of contributing factors in incidents, adapted from Kjellén and Larsson (1981), and Kjellén and Albrechtsen (2017)

Human/behavioural:	
M1	Supervision, instructions
M2	Informal information flow
M3	Workplace norms
M4	Individual norms and attitudes
M5	Individual qualifications and experience
M6	Special circumstances
Technical/physical:	
T1	Workplace layout • Access to equipment • Walkways, transportation routes • Safe distance between moving equipment
T2	Design of equipment • Physical hazards • Reliability • Man-machine interface
T3	Physical working environment (Lighting, inner climate, noise)
T4	Protective equipment, guarding
T5	Work materials, chemicals
T6	Safety equipment and systems
Organisational/economic:	
O1	Work organisation, manning, job description
O2	Activity planning
O3	Methods of work, work pace
O4	Instructions, work procedures
O5	Maintenance routines, work permit
O6	Management of change
O7	Education, training of personnel
O8	Supervision
O9	Systems of remuneration, promotion, sanctioning
O10	Controls of other types (e.g. economic, “third party”)
O11	System of shift, work schedule
O12	Routines in safety work
O13	Organisation of on-scene emergency management

Table 2.3: Haddon's 10 accident prevention strategies. Adapted from Haddon (1980), and Kjellén and Albrechtsen (2017).

Related to energy source:	
H1	Prevent the build up of energy
H2	Modify the quality of the energy
H3	Limit the amount of energy
H4	Prevent uncontrolled release of energy
H5	Modify the rate and distribution of energy
Related to the separation of the energy source from the target:	
H6	Separate, in time or space, the energy source from the vulnerable target
H7	Separate the energy source and the target by physical barriers
Related to the vulnerable target:	
H8	Make the target more resistant to damage from the energy flow
H9	Limit the development of loss (injury or damage)
H10	Stabilise, repair, and rehabilitate the object of damage

2.5 Preventive measures

There are numerous different methods, books, and theories on how to build and design preventive measures against accidents. One of the most versatile of these is the *Energy model* that focuses on the energy of the system (Kjellén and Albrechtsen, 2017). The Energy model is based on the idea that for harm to occur, there has to be a transfer of energy from a source to the target. It defines ten different types of energy that might cause harm; Gravitational, Kinetic (Motion), Mechanical, Electrical, Pressure, Temperature, Chemical, Biological, Radiational, and Sound Energy, each of which have different prevention strategies (Rausand, 2013).

Haddon's 10 accident prevention strategies Haddon's 10 accident prevention strategies are built upon the Energy model (Haddon, 1980), and outlines ten different strategies to prevent accidents. The strategies are grouped into three categories: those related to the energy source, those related to the separation of energy and the target, and those related to the target. In Table 2.3, the ten strategies are presented, along with the codes used in this Thesis (H1-H10).

CHAPTER 3

Methodology

The investigation is based on the outline presented by Kjellén and Albrechtsen (2017), and adapted to this particular situation. The investigation consists of six main steps: Gaining access to the datasets, constructing databases, selecting working sets, investigation of accident concentrations, investigation of accident causes, and evaluating preventive strategies. Also an evaluation of the author's connection to the organisation was done and measures to ensure a professional distance were taken.

All data processing and data plotting is conducted using the Microsoft Excel and the MATLAB programming language.

3.1 Professional distance

The author of this Thesis has been a student at UNIS for two years and knows many of the persons involved in the events, and measures have been implemented to ensure a professional distance.

The Connection The author have been studying at UNIS in both 2012 and 2014, and was the student representative to the board and the HSE committee in this period. He has been involved in some of the events that will be mentioned in this Thesis, and the events in the dataset from UNIS. He also knows many of the involved persons on a personal level and the employees in the Logistics department at UNIS on a professional one. Also, the author's twin brother studied at UNIS during the spring semester of 2013, and was involved in at least one incident.

The Context UNIS and Longyearbyen is are small places, where almost everyone knows everyone else. It is also difficult to understand the increase of fieldwork and organisation without having spent some time in Svalbard. As explained by many safety professionals in Longyearbyen, "Svalbard is not like anything else". This combination increases the difficulty investigating the system at a professional distance desired.

The Preventive measures To ensure professional distance, some measures have been taken as summarised below.

Avoidance It is actively sought to use other events than the ones the author has a connection to, when discussing and presenting accident types, when possible.

Interviews Of the few events that were potential subjects to interview, all of them had persons known by the author involved, and could therefore not interview them alone. The interview study initially intended was therefore not conducted.

Marking All incidents the author has been directly or indirectly involved in, or knows persons involved have been explained in the text when discussed.

Information sources Great care has been made to ensure that the information is sourced in the datasets and not in personal recollection or knowledge.

External assessment Where avoidance was not possible, external persons who do not know the individuals involved, were asked to assess the situation and ensure professional distance.

3.2 Data

This investigation is based on datasets from three different organisation, Store Norske Spitsbergen Kullkompani, The University Centre in Svalbard, and The Joint Rescue Coordination Centres in Norway.

3.2.1 Store Norske Spitsbergen Kullkompani

The SNSK data-set consists of an Excel sheet with a total of 4 305 reported events in the period from 30 March 2009 until 20 February 2017, of these, the majority were without major injuries. Many are near accidents and some observations. Each entry had the following information:

1. Identifier (ID)
2. Status
3. Date of creation
4. Contents type
5. Event classification
6. Medical treatment
7. Leave of absence
8. Assigned to
9. Proposed improvements
10. Description of event
11. Corrective measures
12. Potential loss
13. Immediate actions
14. Title
15. Reason of deviation
16. Reason for external participant
17. Event location
18. Event closure date
19. Element type
20. Path

Of the 86,100 data fields, 27,715 were blank, leaving 58,385 or 68% filled. Most of the empty fields were in a column that did not have any significant impact on the ability to interpret the event. The dataset is maintained by trained HSE professionals at SNSK and is actively used in their management.

Also, multiple background documents and presentations were received to be used as background material for their HSE efforts and systems. Yearly and quarterly reports publicly available have also been investigated.

3.2.2 The University Centre in Svalbard

The data-set from UNIS consists as a folder for each of the years between 2009 and 2016 where each incident is described in a variety of ways. The folder structure contains a total of 343 files, including reports, documentations and internal communications. The quality varies from short handwritten reports to more systematic investigative reports covering multiple documents.

In addition, background material, reports on field activity have been received. Yearly reports from 2009 to 2016 were investigated.

3.2.3 Emergency services

A request to the The Joint Rescue Coordination Centres in Norway for a record of all events recorded in Svalbard resulted in a database with events in Svalbard for the period 2007 to 2016. The database consisted of 677 entries and eight columns. Each entry had the following information:

1. Identifier
2. Category
3. Event category
4. Time and date of first alert
5. Position (Coordinates)
6. Location
7. Coordinator
8. One line description (Identity)

The total number of incidents for the whole of Norway is provided by the publicly available statistics at the JRCC web-page (JRCC, 2017). The statistics cover the period 2010-2016 for the total number of incidents in the different categories, while the monthly numbers are only available for the years 2012, 2014, and 2016. There are, however, graphs that preset the monthly distribution of events for the remaining years. The dataset also consists of a map with all of the events, shown in Figure A.1.

The full dataset with a more detailed account of events was not made available to the investigation by the JRCC because it contains personal information exempted from public disclosure.

3.3 Database construction

The first step in the database analysis is to construct the database, where the database is not present. The database UNIS is operating on, is a folder structure consisting of one main folder for each year, and most incidents have its folder subsequently. To analyse the HSE system at UNIS, a workable database was constructed in a similar style as the received database from SNSK, and following the proposed “Smallest efficient set” by Kjellén and Albrechtsen (2017)[1]. The database was only constructed with the fields required to do the analysis, and remedial actions were not implemented due to lack of data on remedial actions taken.

The database provided by SNSK were of sufficient quality, and no further construction was needed. The JRCC dataset did not contain enough data to construct a database.

3.4 Initial search and quality control

The second step is to identify the data subset in the database and construct the working dataset, and ensure the quality. The constructed database for UNIS was built from ground and Type I and Type II errors were processed under the construction, as well as the initial limitations. The UNIS database consisted of 107 events, of which 13 was discarded leaving 94 events. The JRCC dataset was selected to include only land-based events, leaving 414 events. The number of events in each working sets is shown in Table 3.1

Table 3.1: Number of events in each of the three workingsets. All disregarded entries in the UNIS database have been recorded as Type II errors. The JRCC database did not have enough information to evaluate Type I & II errors. Entries with insufficient quality have been noted as Type II errors.

	UNIS	**SNSK**	**JRCC**
All events	107	4 305	677
Initial search	107	68	414
Type I errors	-	19	-
Type II errors	13	14	-
Total	94	73	414

3.4.1 SNSK

The 4 305 reported events in the SNSK database demanded more limitations in the working dataset. It was decided to limit the dataset only to outdoor events with some form of injury, as inside operations were assumed to be closer to mainland operations and less relevant for the study.

Initial search The SNSK database has specific options for each location, and for all outdoor areas, it is in a category with ”Outside” in location name. The initial

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[1] Table 14.1 in “Prevention of accidents and unwanted occurrences” by Kjellén and Albrechtsen (2017)

search resulted in 1,064 events, and further narrowing by selecting only events with personnel injury yielded 68 incidents.

Type II errors The initial working set was then worked through removing Type II errors. These events were mostly in workshops and other semi-outdoor locations that is classified as outdoors but are not as meant in this investigation. A total of 14 Type 2 errors were located, resulting in a working set of 54 events.

Type I errors After Type II errors had been removed, a further search in the full database for Type I errors was conducted. First, fieldwork was added when on Svalbard, then multiple free-text searches for ”outside” and other related terms resulted in a total of 19 Type 1 errors. Resulting in a working set of 73 incidents.

3.5 Accident concentration analysis

When the three working sets had been constructed, some grouping became evident, and categories were developed. The categories were decided upon to reflect the particular nature of each dataset, and to a large as possible extent, to be comparable with each other. When the classification was complete, a large Pivot table[2] spanning all of the different categories was created[3]. It is chosen not to use the standard definitions of loss, as summarised in Table 5.3 in Kjellén and Albrechtsen (2017), due to the special nature of the systems investigated. It was needed to include the differentiation between medical attention injuries and those that needed evacuation. There have been no fatalities at neither SNSK nor UNIS in the period.

SNSK The SNSK working set was categorised into nine different categories, as shown in Table 3.2. The potential and real loss were reevaluated to ensure comparability with the UNIS data. The category “Slip and fall” reflects the many ice and snow related fall injuries.

UNIS The UNIS working set reflected the complex nature of the activity present at UNIS. Thirteen different categories, as shown in Table 3.3. The two categories “Activity” and “Involved” reflects the different activities and personnel groupings at UNIS. “Involved” can include multiple options, such as both PhD students and Academic staff. As most personnel operation at UNIS does not have regular working hours, standard rates of injury will to a large extent be misleading, and therefore not included.

JRCC The JRCC has developed their own classification of events, used in all of their statistics, and these categories are used in this investigation for the JRCC data.

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[2] A Pivot table is a table that counts the number of times two options occur in the same event.

[3] Due to the large size of this Pivot table, it is not possible to add a readable version in this Thesis. However, all Pivot tables presented are sub-tables of this table.

Table 3.2: Classification and categories for the SNSK dataset. The table includes categories for the accident concentration analysis, accident cause analysis (Deviation, MTO), and preventive measures analysis (Haddon)

Category	Type	Options
Deviation	Nominal	D1-D18
Energy type	Categorical	Gravity, Motion, Mechanical, Electrical, Pressure, Temperature, Chemical, Biological, Radiation, Sound
Haddon's	Nominal	H1-H10
HIPO	Binary	Yes, No
MTO	Nominal	M1-M6, T1-T6, O1-O13
Potential Loss	Ordinal	None, Material, First aid, Medical attention, Evacuation (medical), Permanent disability, Death
Real Loss	Ordinal	None, Material, First aid, Medical attention, Evacuation (medical), Permanent disability, Death
Scooter	Binary	Yes, No
Slip and fall	Binary	Yes, No

Table 3.3: Classification and categories for the UNIS dataset. The table includes categories for the accident concentration analysis, accident cause analysis (Deviation, MTO), and preventive measures analysis (Haddon)

Category	Type	Options
Activity	Categorical	Research, Teaching, Training, Transport / Maintenance, Other
Department	Categorical	HSE / Logistics, Physics, Geology, Biology, Technology, Other
Deviation	Nominal	D1-D18
Energy type	Categorical	Gravity, Motion, Mechanical, Electrical, Pressure, Temperature, Chemical, Biological, Radiation, Sound
External	Binary	Yes, No
Haddon's	Nominal	H1-H10
HIPO	Binary	Yes, No
Involved	Nominal	Students, Academic staff, PhD, Other
Location	Categorical	Indoors, Outdoors, Fieldwork, Sea, Other
MTO	Nominal	M1-M6, T1-T6, O1-O13
Potential Loss	Ordinal	None, Material, First aid, Medical attention, Evacuation (medical), Permanent disability, Death
Real Loss	Ordinal	None, Material, First aid, Medical attention, Evacuation (medical), Permanent disability, Death
Scooter	Binary	Yes, No

3.6 Accident cause analysis

Based on the identified categories and concentrations, each event was further analysed to determine the deviations and contributing elements. The analysis was done using the Deviation checklist in combination with the Man-Technology-Organisation method Kjellén and Albrechtsen (2017), Table 5.10 and Table 5.13. The results were then added to the large Pivot table and analysed for correlation.

3.7 Preventive measures

Similarly to the Accident cause analysis, events have been categorised by Haddon's 10 accident prevention strategies (Haddon, 1980; Kjellén and Albrechtsen, 2017). The evaluation was done by looking at what strategies that best could help reduce the risk that this should happen again, without being unrealistic. Due to the large number of events in the working sets and similarity, not all events have been assessed with Haddon's 10, all incidents involving scooters and slip and fall are excluded, as well as events with no potential for injury.

CHAPTER 4

Literature review

As part of the specialisation project[1] during the fall of 2016, a literature study regarding arctic safety was conducted with the aim of mapping the work and research on arctic safety. The main findings and highlights are presented in this chapter. Since December, no new publications directly relevant to this topic have been published, based on the same structured searches used in the literature study.

The literature study was conducted with two main methods, a quantitative analysis and a traditional literature study. A total of 72 articles have been identified to be relevant to arctic safety management.

4.1 The quantitative study

To map the publications regarding arctic safety management, a series of structured searches on Google Scholar, Scopus, Oria, and Google web search was conducted. The research resulted in 72 publications within a multitude of disciplines and subjects.

4.1.1 Classification of publications

Each of the publications has been evaluated according to nine different topics, to build an image of the field. The topics were Industry, Location, Sea or Land, Publication type, Discipline, Method, Characteristics, Challenges and Other. Table 4.1 show the topics and the number of publications in each publication within each category of topic specified. All topics, except "Publication type", are non-exclusive.

There are 19 publications in the review that is relevant for the study of terrestrial safety management in the arctic, and 64 relevant to the marine arctic. If one further narrows into publications that directly concerns the Arctic, and not only is relevant to the arctic, the number is reduced to twelve publications. Of these, there are only two publication (Crain et al., 2015; Bergan and Naseri, 2015), that discuss arctic safety management as in the context used in this Thesis.

Correlation of topics Based upon the categorisation of the 72 publications a Pivot table was created to investigate the correlation and patterns. In Table 4.2 a reduced size of this Pivot table is shown, omitting the topics "Location",

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[1] A part of the master's program at NTNU

Table 4.1: Overview of topics and categorisation of the 72 publications included in the literature review. (Lorentzen, 2016)

Category	#	Category	#
Industry		Method	
Oil and gas	32	Quantitative	38
Shipping and navigation	38	Qualitative	23
Tourism	5	Case	9
Research	6	Simulation	1
Other industry	5	Review	19
Other	10	Expert	16
Location		Other	33
Norwegian Arctic	9	Characteristics	
Russian Arctic	10	Large distances	22
American Arctic	4	Cold	22
Canadian Arctic	4	Ice	33
Greenlandic Arctic	1	Lack of experience	10
General Arctic	38	Lack of infrastructure	20
Not Arctic	15	Vulnerable	12
Sea / Land		Seasonal variations	11
Sea	64	Other	23
Land	19	Challenges	
Publication type		SAR / EER	19
Article	34	Infrastructure	16
Conference	24	Communication	11
Report	9	Regulation and standards	24
Other	5	Maps and survey	6
Discipline		Ice information and maps	13
Medical and work hygiene	6	Risk understanding	12
Insurance, law and policy	11	Other	35
Navigation and marine	22	Other	
Risk and safety	34	Peer-review	34
General engineering	13	Quality and relevance	-
Environmental and oil spill	10	Lacking data	17
Other	6	Comments	-

"Characteristics" and "Other", due to readability. Some correlations can be found in the table, indicating the focus of the available literature. Underneath is listed four correlations that became apparent.

- Navigation and Marine — Risk and safety
- Oil and gas — Sea
- Shipping and Navigation — Sea
- Insurance, law and policy — Regulation and standardisation

Table 4.2: Pivot table showing the correlation between different topics in the quantitative literature study. The topics "Location", "Characteristics" and "Other" is left out. The table is based on the work in the specialisation project. (Lorentzen, 2016)

	Literature topics																										
	Industry (I)						**S**		**Pub. (P)**				**Discipline (D)**							**Challenge (F)**							
Literature topics	Oil and gas	Shipping and navigation	Tourism	Research	Other industry	Other	Sea	Land	Article	Conference	Report	Other	Medical and work hygiene	Insurance, law and policy	Navigation and marine	Risk and safety	General engineering	Envi. and oil spill	Other	SAR / EER	Infrastructure	Communication	Regulation and standards	Maps and survey	Ice information and maps	Risk understanding	Other
I1	32	11	4	3	4	2	31	7	11	12	7	2	0	3	4	18	11	6	4	9	7	6	12	2	3	8	18
I2	11	38	4	3	3	1	37	2	17	16	2	3	0	8	21	19	2	1	2	14	9	7	13	3	9	5	18
I3	4	4	5	2	2	1	5	1	2	3	0	0	0	1	1	4	0	0	1	4	2	2	2	0	1	0	4
I4	3	3	2	6	3	0	4	4	1	4	1	0	1	0	0	4	0	1	1	2	1	1	2	1	1	0	3
I5	4	3	2	3	5	2	3	3	0	5	0	0	0	0	0	4	2	1	1	2	2	2	2	0	0	1	3
I6	2	1	1	0	2	10	4	9	6	4	0	0	4	0	1	2	2	3	1	1	2	2	1	0	0	1	5
S1	31	37	5	4	3	4	64	12	28	22	9	5	0	11	22	32	11	9	6	19	15	10	22	6	13	12	33
S2	7	2	1	4	3	9	12	19	10	7	2	0	5	0	1	5	6	6	2	2	5	2	4	2	2	1	10
P1	11	17	2	1	0	6	28	10	34	0	0	0	5	5	9	11	4	3	2	8	5	3	7	2	7	6	16
P2	12	16	3	4	5	4	22	7	0	24	0	0	0	0	10	14	7	3	3	8	7	6	6	2	5	2	13
P3	7	2	0	1	0	0	9	2	0	0	9	0	0	3	2	6	1	3	1	2	2	1	7	1	0	3	4
P4	2	3	0	0	0	0	5	0	0	0	0	5	0	3	1	3	0	1	0	1	2	1	4	1	1	1	2
D1	0	0	0	1	0	4	0	5	5	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	2
D2	3	8	1	0	0	0	11	0	5	0	3	3	0	11	1	2	0	1	1	2	2	0	10	0	3	1	4
D3	4	21	1	0	0	1	22	1	9	10	2	1	0	1	22	13	1	1	0	8	5	5	5	3	6	5	9
D4	18	19	4	4	4	2	32	5	11	14	6	3	0	2	13	34	4	4	2	13	11	7	13	3	3	7	18
D5	11	2	0	0	2	2	11	6	4	7	1	0	0	0	1	4	12	2	2	3	3	3	4	2	1	2	8
D6	6	1	0	1	1	3	9	6	3	3	3	1	0	1	1	4	2	10	1	1	2	1	3	2	1	2	5
D7	4	2	1	1	1	1	6	2	2	3	1	0	0	1	0	2	2	1	6	2	1	1	3	0	1	1	5
F1	9	14	4	2	2	1	19	2	8	8	2	1	0	2	8	13	3	1	2	19	10	5	7	5	7	2	12
F2	7	9	2	1	2	2	15	5	5	7	2	2	0	2	5	11	3	2	1	10	16	4	7	2	3	0	10
F3	6	7	2	1	2	2	10	2	3	6	1	1	0	0	5	7	3	1	1	5	4	11	3	2	3	2	7
F4	12	13	2	2	2	1	22	4	7	6	7	4	0	10	5	13	4	3	3	7	7	3	24	2	6	4	11
F5	2	3	0	1	0	0	6	2	2	2	1	1	0	0	3	3	2	2	0	5	2	2	2	6	4	1	2
F6	3	9	1	1	0	0	13	2	7	5	0	1	0	3	6	3	1	1	1	7	3	3	6	4	13	3	6
F7	8	5	0	0	1	1	12	1	6	2	3	1	0	1	5	7	2	2	1	2	0	2	4	1	3	12	5
F8	18	18	4	3	3	5	33	10	16	13	4	2	2	4	9	18	8	5	5	12	10	7	11	2	6	5	35

4.1.2 Frequent words

In addition to the categorisation of the publications, a frequent word analysis was conducted in order to gain an overview of which terms used. The analysis is based on the abstracts of the 72 publications. Words of the same stem (e.g. risk and risks) have been counted together, and common and binding words (e.g. "it", "and", "main") have been removed. The twelve most used words are as follows:

arctic:	212	sea:	71	data:	50
ice:	117	operations:	58	analysis:	49
conditions:	90	accidents:	55	safety:	48
risk:	88	navigation:	52	cold:	47

The most common term is not surprisingly "arctic", followed by "ice" and "conditions". It might be worth noting that "risk" is mentioned 40 times more the "safety", something that might indicate that the focus is on the risks involved and less on the safety of the system.

4.2 Literature on Arctic safety management

Based on the findings in the quantitative literature review, it is clear that there are not many publications of the topic of arctic safety management, outside of the maritime, and oil and gas industry. It has not been any literature review on the topic published, and most of the publications do not have peer-review (Reports, Conference Papers, and Other). None of the publications found directly focused on the challenges of Arctic terrestrial industry.

4.2.1 Fieldwork and academic activities

Only one publication concentrates on the fieldwork and academic activities in the Arctic region. This was in the workshop paper by Crain et al. (2015), a result from a workshop held in February 2014. The workshop was attended by 53 American professionals within the field and lasted two days. One of the sessions involved a hypothetical risk assessment and management process for an arctic fieldwork operation, and it resulted in a table of important points in each phase of the operation and planning. One of the major challenges is to share information and knowledge between organisations operating in arctic conditions.

Training The workshop recommends that all arctic field researchers must have at least a general training on satellite communication, VHF radio, other relevant communication channels, CPR, first aid and navigation. Further recommendations involve the pairing of fresh scientists with a more senior scientist, an involvement of students in field activity, and development of programs that have focus on fieldwork- and risk management skills.

Conclusions and recommendations Crain et al. (2015) concludes on three main points. Firstly that there is a need to “expand the current risk management policies and procedures in ways that are both flexible and valuable; avoid implementing additional forms or paperwork that do not serve a distinct constructive purpose”. Secondly to establish a *Community of Practice*[2] within the field of Arctic field safety risk management. Thirdly, to “instil a culture of risk management ownership in the arctic community”, with a focus on open communication.

4.2.2 General Arctic safety management

No publication directly discussing the general problem of Arctic safety management was found. However, there are some that discuss the problem within the oil and gas industry that can be generalised to cover other areas.

Kampf and Haley (2011) addresses the *Wicked Problems*[3] occurring in Arctic oil and gas, and proposes a framework for handling these problems. While the framework is meant for the Arctic offshore industry, many of the approaches can be applied to other Arctic areas. The approach focus on the involvement of stakeholders and *systems thinking*.

Khan et al. (2015) looks at the lessons learned from operations in harsh environments and summarises a workshop on the topic held at the Memorial University of Newfoundland in 2013 where approximately 120 researchers and practitioners attended. It is argued that activity in the Arctic faces huge challenges and that further work should include a roadmap development to identify barriers, comparative studies of standards, development of guidelines, and the establishment of a joint centre of excellence for safety and integrity analysis of operations in harsh environments.

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[2] Community of Practice (CoP): a group of people who share a craft or profession that work together on common approaches and strategies. (Wenger, 1998)

[3] Wicked Problems: “Problems that are unstructured, complex, irregular, interactive, adaptive and novel”. (Coyne, 2005)

CHAPTER 5

Results

In this chapter, the results of the analysis is presented. Section 5.1 presents the temporal distribution of events in the three datasets. In Section 5.2 the concentration of the different events is presented, while Section 5.3 presents the different causes of the events identified. Lastly Section 5.4 presents the results from the preventive strategies analysis.

5.1 Temporal distribution of events

The temporal distribution of events is often the most obvious sign that accidents are not caused by pure chance. In this section, the temporal distribution of the events from JRCC, SNSK, and UNIS is presented. The data is based directly on the datasets.

5.1.1 JRCC

In Figure 5.1 the monthly distribution of events in Svalbard is presented with a total number of 677 events. Two peaks, Mar-Apr and Jun-Aug is evident. The land based events have one significant peak in Mar-Apr.

In Figure 5.2 a normalised distribution monthly distribution of events in Svalbard and the whole of Norway. The Svalbard data is based on the events between 2007 and 2016 ($n = 677$), while the curve for the whole of Norway is based on the years 2012, 2014, and 2016 ($n = 10\ 535$). The data from the missing years is not publicly available. The most dominant feature is the large proportional deviation in Mar-Apr compared to the mainland.

5.1.2 SNSK

Figure 5.3 shows the yearly number of events in the SNSK database, where the orange field is the total number of reported events and the blue is the number of events outdoors. Two peaks in the total number of reported events are in 2009 and 2014. There is a gradual increase in the number of outdoor events until a peak in 2014, where it decreases in 2015 and 2016.

The monthly distribution is shown in Figure 5.4 shows a significant peak in reported events in May, a decrease in Jul-Aug and a smaller peak in Oct. The

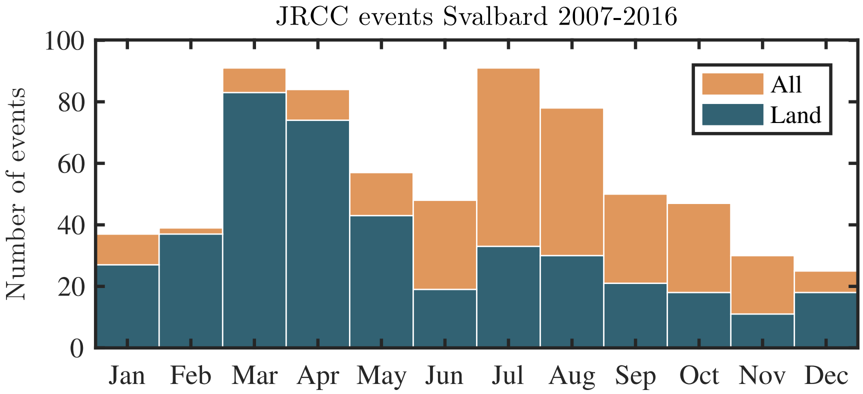

Figure 5.1: All registered events in Svalbard in the period 2007-2016 by The Joint Rescue Coordination Centres in Norway.

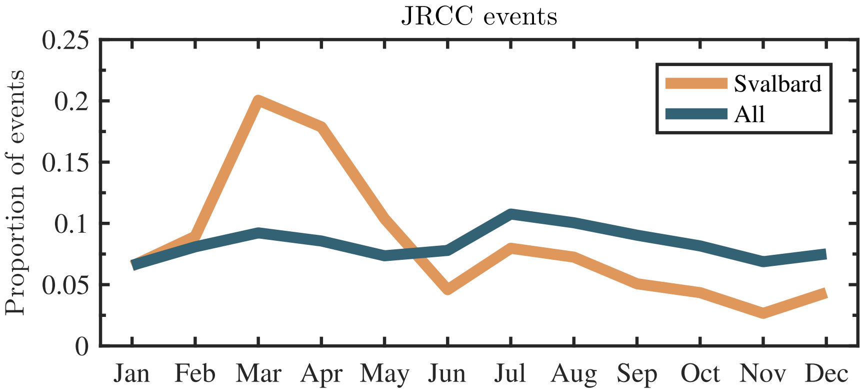

Figure 5.2: Normalised distribution of land based JRCC events in Svalbard compared to the total number of recorded land based events in Norway. The data for all events is based on the numbers from 2012, 2014, and 2016.

outdoor events is relatively stable with maxima in Apr and Oct. Most outdoor events occur in Oct.

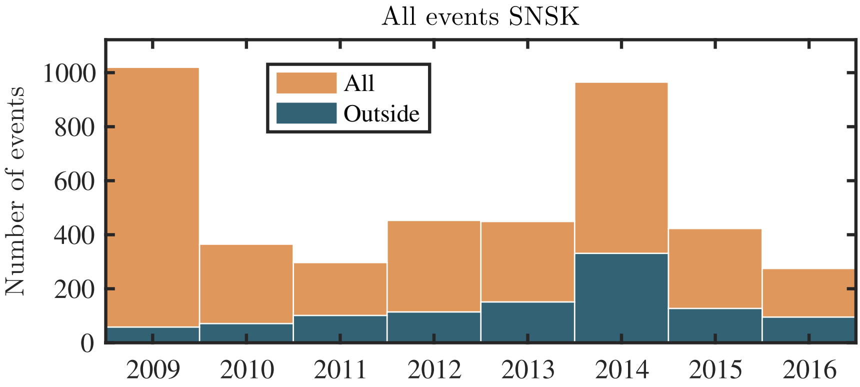

Figure 5.3: All registered events by SNSK in the period 2009-2016 by year.

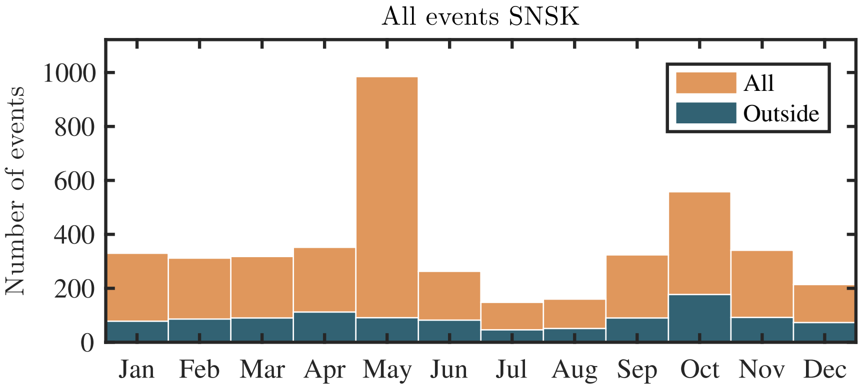

Figure 5.4: All registered events by SNSK in the period 2009-2016 by month.

5.1.3 UNIS

Figure 5.5 shows the monthly distribution of events at UNIS for the years 2009-2016. There is a clear peak in Mar, and most events are recorded in the period Feb-Apr. Another peak appears in Jul-Aug. The events with injuries appear to follow the same pattern as the total number of reported events.

If one calculates the number of recorded events per student year at UNIS, using the numbers from Figure 1.4 and 5.7, the situation is different, as shown in 5.6. There is a relatively stable number of events per student work year, and a small increase can be seen in events that result in injury. The yearly distribution of events, presented in Figure 5.7 show a slight increase in total recorded events in the period, while the number of injuries is more clearly increased over the period.

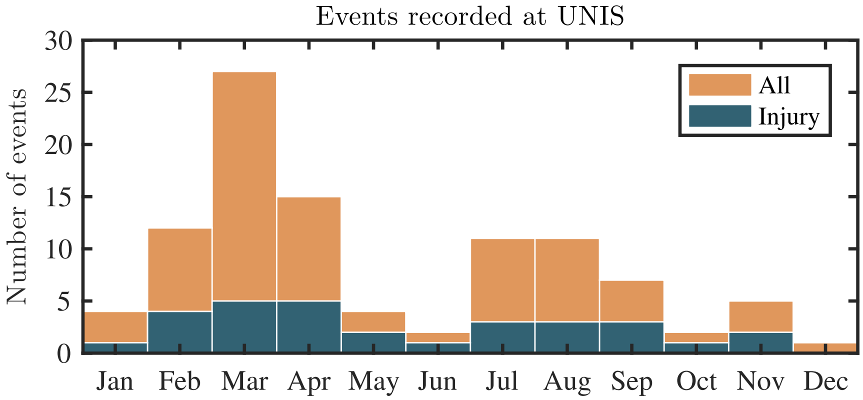

Figure 5.5: All registered events by UNIS by month for the period 2009-2016.

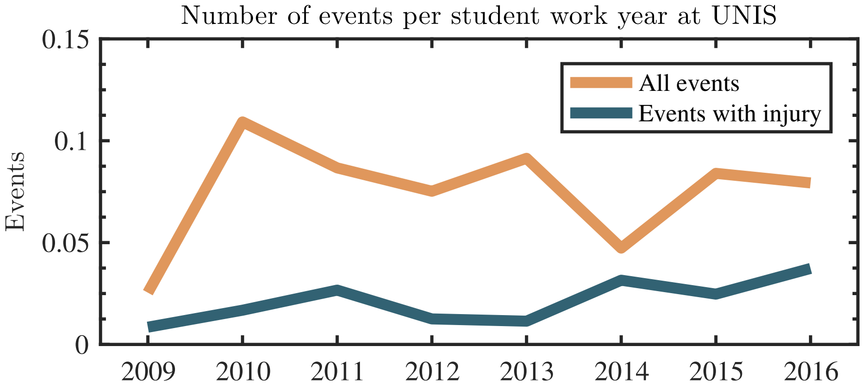

Figure 5.6: Number of events per student work year at UNIS in the period 2009-2016.

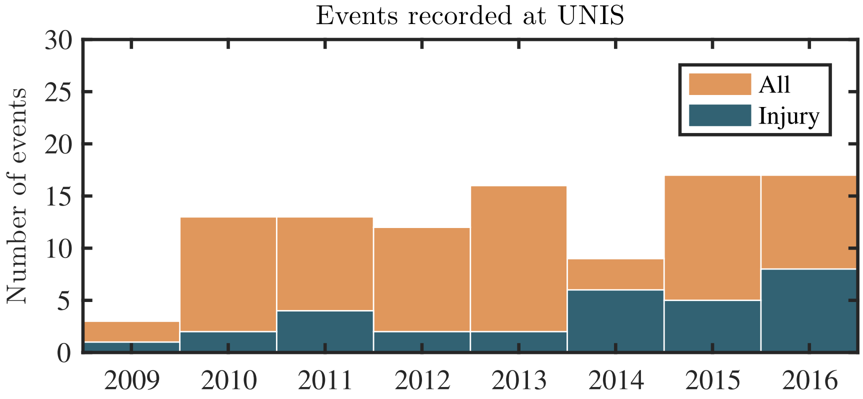

Figure 5.7: All registered events by UNIS by year for the period 2009-2016.

5.2 Event concentration analysis

The event concentration analysis was conducted for all three datasets, JRCC, SNSK, and UNIS.

5.2.1 JRCC

The JRCC operates with 18 different categories for land-based events and provided national statistics within these categories. In Table 5.1 the percentage distribution and difference in each category is presented. The percentages are both calculated as compared with the total number of events each year, including air, sea, and undefined, and compared with the total number of land-based events. The percentages are calculated using the statistics by the JRCC (JRCC, 2017), and the given dataset of events in Svalbard. The number of events are given in Appendix A, Table A.1.

Deviation The deviation for each category is then calculated in percentage points, shown to the right in Table 5.1. The most notable deviations are the number of assisted persons (Assistanse person), air ambulance (Luftambulanse), missing person (Savnet person), and avalanches and landslides (Skred - Ras).

Relevant categories Some of the categories used by the JRCC are less relevant for the activity in Svalbard, such as “Skogbrann” (forest fire)[1] or “Transportulykke - jernbane” (Railroad), and the deviation here is easily explained.

5.2.2 SNSK

The concentration analysis based upon the SNSK dataset did only result in one significant concentration, that of falling because of a slippery surface (e.g. ice or snow). As shown in Table 5.2, most of the injuries are caused by Gravity, followed by Mechanical and Motion.

Loss The events most commonly result in First aid or medical attention as shown in Table 5.3. The low number of material no-loss events is due to the working set only containing events marked with personal injury. The resulting loss is generally less than the potential, and there have been no deaths[2] or disabilities by outdoor activities in SNSK during this period.

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[1] As mentioned in the Section 1.3.2, there are no trees in Svalbard, making a forest fire highly unlikely.

[2] The last case of a fatality in SNSK was in 2005.

Table 5.1: Percentage of recorded events on land by The Joint Rescue Coordination Centres in Norway in the period 2010 to 2016 compared to the events in Svalbard for the period 2007 to 2016. The difference is given in percentage points.

	Alle events		**Svalbard**		**Difference**	
Categories land:	**Tot.**	**Land**	**Tot.**	**Land**	**Tot.**	**Land**
Alpinulykke - fjell - bre - grotte	0.5%	1.1%	0.6%	1.0%	0.1	-0.2
Assistanse person	7.4%	17.7%	19.6%	32.0%	12.2	14.4
Atomulykke	0.0%	0.0%	0.0%	0.0%	0.0	0.0
Bombe/terror	0.0%	0.1%	0.0%	0.0%	0.0	-0.1
Drukning - Kantring	0.9%	2.2%	0.1%	0.2%	-0.8	-2.0
Farlig gods	0.0%	0.0%	0.0%	0.0%	0.0	0.0
Industriulykke	0.1%	0.2%	0.1%	0.2%	0.1	0.1
Luftambulanse	13.8%	33.0%	29.2%	47.7%	15.5	14.7
Naturkatastrofe	0.1%	0.2%	0.0%	0.0%	-0.1	-0.2
Nødpeilesender - PLB	1.2%	2.9%	2.1%	3.4%	0.9	0.5
Nødsignaler - pyro - lys - andre	0.6%	1.5%	1.5%	2.4%	0.9	0.9
Savnet person	15.5%	37.0%	4.6%	7.5%	-10.9	-29.5
Skogbrann	0.3%	0.7%	0.0%	0.0%	-0.3	-0.7
Skred - Ras	0.7%	1.8%	2.4%	3.9%	1.6	2.1
Transportulykke - jernbane	0.0%	0.1%	0.0%	0.0%	0.0	-0.1
Transportulykke - vei	0.4%	0.8%	0.3%	0.5%	-0.1	-0.4
Andre	0.0%	0.0%	0.1%	0.2%	0.1	0.2
Udefinert - LAND	0.3%	0.7%	0.6%	1.0%	0.3	0.2
Sum:	**41.8%**	**100%**	**61.3%**	**100%**	**19.4**	**0.0**

Table 5.2: Pivot table showing the correlation between the identified observed real loss and the main energy in outdoor events at SNSK in the period 2009-2016.

		Energy									
		Gravity	**Motion**	**Mechanical**	**Electrical**	**Pressure**	**Temperature**	**Chemical**	**Biological**	**Radiation**	**Sound**
Real loss	**None**	4	1	1	0	0	0	1	0	0	0
	Material	0	1	0	0	0	0	0	0	0	0
	First aid	10	4	4	0	0	1	0	1	0	0
	Medical attention	11	5	6	0	0	1	2	0	0	0
	Evacuation	1	1	1	0	0	0	0	0	0	0
	Disability	0	0	0	0	0	0	0	0	0	0
	Death	0	0	0	0	0	0	0	0	0	0

Table 5.3: Pivot table showing the correlation between the identified real and potential loss in from outdoor events at SNSK in the period 2009-2016.

		Potential loss						
		None	**Material**	**First aid**	**Medical attention**	**Evacuation**	**Disability**	**Death**
Real loss	**None**	0	0	0	6	0	2	0
	Material	0	0	0	0	1	0	0
	First aid	0	0	1	16	0	3	1
	Medical attention	0	0	0	13	1	9	3
	Evacuation	0	0	0	0	1	1	1
	Disability	0	0	0	0	0	0	0
	Death	0	0	0	0	0	0	0

5.2.3 UNIS

The event concentration analysis of the UNIS working set involved more categories than the SNSK analysis, as shown in Table 5.4. Based on the 94 events in the UNIS working set, the event concentration analysis yielded various results. Table 5.4 shows the correlation between the different categories at UNIS. The orange diagonal line is the self-correlation, counting the total sum within each category. A full table of sums within each category can be found in Appendix B, Table B.1.

Scooter Most of the HIPO events at UNIS occur in combination with scooters, and the highest potential for loss is concentrated accordingly. A total of 13 scooter events were classified as HIPO, while the total number of scooter events were 39.

Fieldwork With a total number of 53 events, Fieldwork has the highest number of events. Of the 53 events, 18 is categorised as HIPO.

Students The students of UNIS outnumber the staff by almost two to one if one counts student and staff work years, explaining the high number of students involved in events (58). Students are mostly involved in events during fieldwork (42), and while the activity is “Teaching”. Students are also most likely to be involved in events if studying at the Arctic Geology (17) or Arctic Biology (17) departments. Also, students are involved in many scooter- (30) and HIPO (20) events.

Geology and Biology Of the departments at UNIS, Arctic Biology has the largest number of events (28), followed by Arctic Geology (25). Arctic Geology only has events during fieldwork, while the events at Arctic Biology is more spread out. Arctic Biology has the largest number of indoor events.

HSE / Logistics and Training The events in the HSE / Logistics department occur mostly under Training and Logistics.

Involved parties There is no clear correlation between what group of personnel involved in the events, as seen in the top left part of Table 5.4. There are not two personnel groups that significantly is involved more with one group rather than another.

5.2.4 Loss

In Table 5.5 the correlation between real and potential loss is presented. The table is mostly concentrated towards high potential, but low real loss. There have been 12 incidents where one or more fatalities were potential, and no fatalities are registered.

Loss and Energy Table 5.6 presents the correlation between the real loss and the main energy involved. Most of the events are correlated with Motion. The most severe loss in the dataset is due to the temperature.

Table 5.4: Pivot table showing the correlation between different categorisation in events at UNIS in the period 2009-2016. The categories Location, Activity and Department are exclusive and therefore are the self correlation matrices diagonal.

Incident categorisation

Incident categorisation	Involved				Location					Activity					Department						Other		
	Students	Acamemic	Phd	Other	Indoors	Outdoors	Fieldwork	Sea	Other	Research	Teaching	Training	Logistics	Other	HSE / Log.	Physics	Geology	Biology	Technology	Other	Scooter	External	HIPO
Students	58	14	11	7	5	2	42	2	6	7	30	8	1	11	8	2	17	17	4	9	30	4	20
Academic	14	26	13	8	6	0	20	0	0	13	9	0	0	4	0	1	13	10	1	1	6	7	10
Phd	11	13	20	6	5	0	13	1	1	10	7	0	1	2	0	2	7	8	2	1	3	4	6
Other	7	8	6	26	2	5	11	7	1	12	3	2	5	4	6	1	6	3	1	8	3	16	8
Indoors	5	6	5	2	12	0	0	0	0	4	0	1	2	5	3	0	0	7	1	1	0	0	1
Outdoors	2	0	0	5	0	7	0	0	0	0	0	2	2	3	3	0	0	1	0	3	2	4	2
Fieldwork	42	20	13	11	0	0	59	0	0	16	33	6	0	3	6	2	25	16	4	6	36	9	18
Sea	2	0	1	7	0	0	0	9	0	4	2	1	2	0	2	0	0	4	0	2	0	3	1
Other	6	0	1	1	0	0	0	0	7	0	0	0	1	6	0	0	0	0	1	6	0	1	3
Research	7	13	10	12	4	0	16	4	0	24	0	0	0	0	0	0	10	6	3	4	3	10	6
Teaching	30	9	7	3	0	0	33	2	0	0	35	0	0	0	0	2	15	15	2	1	25	1	11
Training	8	0	0	2	1	2	6	1	0	0	0	10	0	0	10	0	0	0	0	0	8	1	3
Logistics	1	0	1	5	2	2	0	2	1	0	0	0	7	0	4	0	0	1	1	1	0	1	0
Other	11	4	2	4	5	3	3	0	6	0	0	0	0	17	0	0	0	6	0	11	2	4	5
HSE / Log.	8	0	0	6	3	3	6	2	0	0	0	10	4	0	14	0	0	0	0	0	8	1	3
Physics	2	1	2	1	0	0	2	0	0	0	2	0	0	0	0	2	0	0	0	0	1	0	2
Geology	17	13	7	6	0	0	25	0	0	10	15	0	0	0	0	0	25	0	0	0	12	6	10
Biology	17	10	8	3	7	1	16	4	0	6	15	0	1	6	0	0	0	28	0	0	14	2	6
Technology	4	1	2	1	1	0	4	0	1	3	2	0	1	0	0	0	0	0	6	0	3	1	1
Other	9	1	1	8	1	3	6	2	6	4	1	0	1	11	0	0	0	0	0	18	0	7	3
Scooter	30	6	3	3	0	2	36	0	0	3	25	8	0	2	8	1	12	14	3	0	39	3	13
External	4	7	4	16	0	4	9	3	1	10	1	1	1	4	1	0	6	2	1	7	3	17	6
HIPO	20	10	6	8	1	2	18	1	3	6	11	3	0	5	3	2	10	6	1	3	13	6	25

Table 5.5: Pivot table showing the correlation between the identified real and potential loss in from outdoor events at UNIS in the period 2009-2016.

Potential loss

Real loss	None	Material	First aid	Medical attention	Evacuation	Disability	Death
None	1	2	2	1	2	7	12
Material	0	11	2	2	4	10	7
First aid	0	0	2	2	0	5	1
Medical attention	0	0	0	4	0	9	5
Evacuation	0	0	0	0	0	0	1
Disability	0	0	0	0	0	0	1
Death	0	0	0	0	0	0	0

Table 5.6: Pivot table showing the correlation between the identified observed real loss and the main energy in outdoor events at UNIS in the period 2009-2016.

	Energy									
Real loss	**Gravity**	**Motion**	**Mechanical**	**Electrical**	**Pressure**	**Temperature**	**Chemical**	**Biological**	**Radiation**	**Sound**
None	0	15	2	1	0	3	3	1	1	0
Material	0	21	2	0	0	7	0	5	0	0
First aid	2	5	1	0	1	1	0	0	0	0
Medical attention	2	7	6	0	0	2	0	0	0	1
Evacuation	0	1	0	0	0	0	0	0	0	0
Disability	0	0	0	0	0	1	0	0	0	0
Death	0	0	0	0	0	0	0	0	0	0

5.3 Accident causes analysis

The event causes analysis has been conducted for SNSK and UNIS. The analysis was performed by categorising all incidents with the Deviation checklist[3] and MTO[4]. The dataset from JRCC did not contain enough information to perform the analysis. The total number of events in each of the contributing factors and deviations are presented in Appendix B, Table B.2.

5.3.1 SNSK

The analysis of SNSK Accident causes was conducted for all 73 events in the working set. The Pivot table for the Deviation and Contributing factors is shown in Table 5.7. Three patterns are evident from the table.

D11 — T1: There are many events classified as "D11 - Loss of control of energy or person relative to energy", and most of these are in combination with "T1 - Workplace layout".

D11 — O5: The second large correlation is between D11 and "O5 - Maintenance routines, work permit".

D1: There are in total 29 events identified with "D1 - Human error" in the SNSK working set. Most of them are correlated with M3-M6 and O2-O4. These apply to the workplace norm, norms and qualifications, and planning, work pace and work procedures.

5.3.2 UNIS

The 94 events in the UNIS working set was evaluated according to the Deviation checklist and Man-Technology-Organisation method. A Pivot table showing the correlation between the deviations and the contributing factors. A total of ten patterns is evident. The results are presented in three tables. Table 5.8 shows the correlation between the Deviations and the MTO contributing factors. In Table 5.9 and 5.10, the self-correlation between respectively the MTO contributing factors and deviations.

D1: Of the 94 events in the UNIS working set, 51 were determined to have "D1 - Human error" as one of the deviations.

D1 — M5: There are 29 occurrences of events where both D1 and M5 are present.

D1 — O7: There are 24 occurrences of events where both D1 and "O7 - Education, training of personnel" are present.

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[3] D: Deviations as defined in Table 2.1.

[4] M,T,O: as defined in Table 2.2.

Table 5.7: Pivot table showing the correlation between the identified deviations and the contributing factors in outdoor events at SNSK in the period 2009-2016.

Deviations

MTO - Contributing factors	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14	D15	D16	D17	D18
M1	1	1	0	0	1	0	0	0	0	0	1	1	0	0	0	0	0	0
M2	3	2	0	0	2	0	0	1	0	0	2	2	0	1	1	0	0	0
M3	9	2	0	1	4	0	0	2	1	0	8	2	0	1	0	0	0	0
M4	9	4	0	0	3	0	0	0	0	0	6	3	1	2	0	0	0	0
M5	5	1	0	0	0	1	1	1	0	3	6	0	1	0	1	0	0	0
M6	6	0	0	0	1	0	1	1	0	1	5	1	1	0	1	0	0	0
T1	4	3	0	0	0	1	1	4	0	5	18	0	2	0	0	0	0	0
T2	8	6	0	0	2	0	0	1	2	0	2	6	2	1	1	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T4	7	2	0	0	4	0	0	1	1	1	5	1	2	2	2	0	0	0
T5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T6	4	3	0	0	2	0	0	1	1	0	1	2	0	2	1	0	0	0
O1	2	1	0	1	1	0	0	0	0	0	3	0	0	0	0	0	0	0
O2	9	4	0	1	6	0	0	1	0	1	7	2	1	1	1	0	0	0
O3	8	1	0	1	3	0	1	2	1	0	8	0	1	0	0	0	0	0
O4	7	4	0	0	4	0	0	2	0	0	5	2	0	1	1	0	0	0
O5	1	3	0	0	0	1	0	4	1	3	12	1	1	0	0	0	0	0
O6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
O7	3	1	0	0	2	0	1	0	1	0	2	1	0	1	1	0	0	0
O8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
O9	2	0	0	0	0	0	0	1	0	0	1	1	0	0	0	0	0	0
O10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
O11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
O12	1	1	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0
O13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D1 — D11: There is a total of 28 events where both D1 and D11 are present, as shown in Table 5.10, and is the most dominant correlation within the deviations.

T2 — D1: The correlation between "T2 - Design of equipment" and D1 occur 13 times.

T2 — D2: There is a total of 18 times where both T2 and "D2 - Technical failure" occur in the same event. These are mostly quite clear technical failures or where the design of the equipment has been significant for the development of loss.

D11 — M5: There are 20 events where both D11 and M5 was present.

D11 — T2: There are 12 occurrences of both D11 and T2.

D11 — O7: There are 15 events where both O7 and D11 was present.

M5 — O7: The largest and most significant feature of the self-correlation Pivot table of MTO in Table 5.9 is M5-O7 that occurs 20 times.

Higher order Pivot If one were to make higher order Pivot tables ("Pivot cubes")[5], another correlation would be apparent. There is a total of 12 events that all have D1, O7 and D11 in common. Also, of these twelve, eleven were scooter accidents, and ten had M5 as a contributing factor. This might indicate a cause connection between D1, O7, M5 and Scooter events.

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[5] They have been made on an experimental basis, but does not easily give itself to two-dimensional representation, and printing on paper.

Table 5.8: Pivot table showing the correlation between the identified deviations and the contributing factors in outdoor events at UNIS in the period 2009-2016.

Deviations

MTO - Contributing factors	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14	D15	D16	D17	D18
M1	7	1	0	0	6	0	1	2	1	0	2	1	0	0	2	0	0	0
M2	5	1	1	0	2	0	2	1	1	0	1	0	0	0	1	0	0	0
M3	6	1	0	1	6	1	0	2	1	1	3	0	0	1	1	0	0	0
M4	15	2	0	1	4	1	2	3	0	0	4	1	0	1	1	0	0	0
M5	29	4	0	1	6	1	2	1	6	0	20	4	0	0	4	0	0	0
M6	7	3	0	0	1	0	0	0	5	0	8	3	1	0	2	0	0	0
T1	0	2	0	0	2	0	1	1	0	0	0	0	0	1	2	0	0	0
T2	13	18	0	0	4	0	3	1	3	0	12	5	1	2	4	0	0	0
T3	5	3	0	0	1	0	0	0	7	2	7	2	1	0	1	0	0	0
T4	0	2	0	0	1	0	0	0	2	0	1	1	1	2	0	0	0	0
T5	0	1	1	0	1	0	0	1	0	0	0	0	0	1	0	0	0	0
T6	3	2	0	0	1	0	1	0	1	0	2	2	0	0	1	0	0	0
O1	2	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0
O2	10	1	1	1	7	1	2	1	6	2	5	2	0	0	3	0	0	0
O3	3	1	0	0	0	0	1	1	0	0	2	0	0	1	0	0	0	0
O4	8	4	1	0	8	0	2	3	1	1	1	1	0	1	4	0	0	0
O5	4	5	0	1	1	1	1	1	1	0	3	2	0	1	1	0	0	0
O6	1	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
O7	24	3	0	1	6	1	1	2	4	0	15	6	0	0	3	0	0	0
O8	3	0	0	1	5	1	0	2	0	0	3	0	0	0	1	0	0	0
O9	3	0	0	0	2	0	0	2	0	0	0	0	0	0	0	0	0	0
O10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
O11	1	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0
O12	6	1	1	1	4	1	0	1	1	0	3	1	0	0	2	0	0	0
O13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 5.9: Pivot table showing the correlation between different contributing factors in events at UNIS in the period 2009-2016.

MTO - Contributing factors

MTO - Contributing factors

	M1	M2	M3	M4	M5	M6	T1	T2	T3	T4	T5	T6	O1	O2	O3	O4	O5	O6	O7	O8	O9	O10	O11	O12	O13
M1	12	2	4	4	6	1	2	5	0	2	1	1	2	1	0	8	0	0	6	4	2	0	0	2	0
M2	2	7	1	2	0	0	0	0	0	0	0	0	1	1	0	3	0	0	2	0	0	0	0	2	0
M3	4	1	9	6	3	0	2	2	1	0	1	0	1	3	1	4	2	0	5	5	3	0	1	2	0
M4	4	2	6	17	10	0	1	3	1	0	1	0	2	3	3	3	5	1	11	4	4	0	1	3	0
M5	6	0	3	10	37	6	0	10	5	1	0	2	2	6	2	3	3	1	20	3	2	0	1	5	0
M6	1	0	0	0	6	14	0	5	5	1	0	1	1	1	0	0	0	0	4	2	0	0	0	1	0
T1	2	0	2	1	0	0	4	3	0	1	1	0	0	0	0	3	0	0	1	2	1	0	0	0	0
T2	5	0	2	3	10	5	3	28	3	2	0	3	0	3	2	6	6	1	6	1	0	0	0	2	0
T3	0	0	1	1	5	5	0	3	13	1	0	0	0	3	0	0	0	0	2	0	0	0	0	1	0
T4	2	0	0	0	1	1	1	2	1	5	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
T5	1	0	1	1	0	0	1	0	0	0	2	0	0	0	0	2	0	0	1	1	1	0	0	0	0
T6	1	0	0	0	2	1	0	3	0	0	0	3	0	1	0	1	0	0	3	0	0	0	0	0	0
O1	2	1	1	2	2	1	0	0	0	0	0	0	3	1	0	1	0	0	1	2	0	0	1	2	0
O2	1	1	3	3	6	1	0	3	3	0	0	1	1	17	1	3	3	1	3	2	0	0	1	2	0
O3	0	0	1	3	2	0	0	2	0	0	0	0	0	1	3	0	2	1	1	0	0	0	0	0	0
O4	8	3	4	3	3	0	3	6	0	1	2	1	1	3	0	14	0	0	5	3	2	0	0	2	0
O5	0	0	2	5	3	0	0	6	0	0	0	0	0	3	2	0	9	1	2	1	0	0	0	1	0
O6	0	0	0	1	1	0	0	1	0	0	0	0	0	1	1	0	1	1	0	0	0	0	0	0	0
O7	6	2	5	11	20	4	1	6	2	0	1	3	1	3	1	5	2	0	31	3	3	0	0	2	0
O8	4	0	5	4	3	2	2	1	0	0	1	0	2	2	0	3	1	0	3	7	2	0	1	2	0
O9	2	0	3	4	2	0	1	0	0	0	1	0	0	0	0	2	0	0	3	2	4	0	0	0	0
O10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
O11	0	0	1	1	1	0	0	0	0	0	0	0	1	1	0	0	0	0	0	1	0	0	1	1	0
O12	2	2	2	3	5	1	0	2	1	0	0	0	2	2	0	2	1	0	2	2	0	0	1	9	0
O13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 5.10: Pivot table showing the correlation between different deviation in events at UNIS in the period 2009-2016.

Deviations

Deviations

	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14	D15	D16	D17	D18
D1	51	6	2	1	6	1	3	4	8	2	28	5	0	1	2	0	0	0
D2	6	21	1	0	0	0	1	1	5	0	6	4	1	3	2	0	0	0
D3	2	1	3	0	0	0	0	1	0	0	0	1	0	1	0	0	0	0
D4	1	0	0	1	1	1	0	0	0	0	1	0	0	0	0	0	0	0
D5	6	0	0	1	16	1	2	2	3	2	4	3	0	0	6	0	0	0
D6	1	0	0	1	1	1	0	0	0	0	1	0	0	0	0	0	0	0
D7	3	1	0	0	2	0	5	1	0	0	1	1	0	0	3	0	0	0
D8	4	1	1	0	2	0	1	5	1	0	0	1	0	0	0	0	0	0
D9	8	5	0	0	3	0	0	1	19	1	8	3	1	0	4	0	0	0
D10	2	0	0	0	2	0	0	0	1	3	1	0	0	0	0	0	0	0
D11	28	6	0	1	4	1	1	0	8	1	39	2	0	1	0	0	0	0
D12	5	4	1	0	3	0	1	1	3	0	2	10	1	0	3	0	0	0
D13	0	1	0	0	0	0	0	0	1	0	0	1	2	0	0	0	0	0
D14	1	3	1	0	0	0	0	0	0	0	1	0	0	4	0	0	0	0
D15	2	2	0	0	6	0	3	0	4	0	0	3	0	0	11	0	0	0
D16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

5.4 Preventive methods

After the accident cause analysis, an investigation into possible preventive strategies using Haddon's 10 preventive strategies, classification[6] was conducted for a subset of the events. The events categorised as Scooter injuries or Fall because of a slippery surface were omitted, as well as events with a damage potential of material or no loss. The results are summarised in Table 5.11.

Table 5.11: Summation of the number of events for Haddon's 10 strategies at SNSK and UNIS.

	H1	**H2**	**H3**	**H4**	**H5**	**H6**	**H7**	**H8**	**H9**	**H10**
SNSK	7	5	14	20	6	20	3	8	14	11
UNIS	5	2	6	18	6	18	10	11	9	1

SNSK The results from Haddon's 10 strategies on the SNSK dataset is concentrated around H4, H6 and H9, and some H10. There is a split between events that one can prevent (H1-H7), and those strategies that focus on treatment and emergency response after the incident, which are reflected in the results. Many of the events in the latter group had little or none practical solution to change or separate the energy from the target.

UNIS The results from Haddon's 10 strategies on the UNIS dataset is concentrated around H4 and H6. There are few event where limiting or changing the energy is possible. Many of the H4 is concentrated on events where unwanted discarded of firearms is possible.

Strategies for concentrations In Table 5.12 the Pivot table showing the correlation between the categories and which of Haddon's strategies that are applicable. Scooter incidents are not shown as they were excluded from the analysis. Most striking are the correlation between Students and H6 - separate in time and space, indicating that students often are in harm's way.

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[6] H: Haddon's 10 strategies as defined in Table 2.3.

Table 5.12: Pivot table showing the correlation between the identified Haddon strategy and categorisation at UNIS in the period 2009-2016.

		Haddon's 10 strategies									
		H1	**H2**	**H3**	**H4**	**H5**	**H6**	**H7**	**H8**	**H9**	**H10**
Incident categorisation	**Students**	4	2	4	10	5	10	3	5	5	1
	Acamemic	2	0	1	3	1	7	2	1	3	0
	Phd	0	0	1	2	0	3	2	2	1	0
	Other	1	2	2	5	2	6	4	7	5	0
	Indors	3	0	1	2	0	5	5	3	2	0
	Outside	0	0	0	2	0	2	1	3	0	0
	Fieldwork	1	0	3	6	3	6	3	5	6	0
	Sea	0	1	1	3	3	3	2	1	1	0
	Other	1	1	2	5	0	2	0	1	1	1
	Research	0	1	2	4	2	3	6	4	4	0
	Teaching	1	0	2	3	4	4	1	2	2	0
	Training	1	0	0	1	0	2	0	1	0	0
	Logistics	0	0	0	1	0	1	2	3	1	0
	Other	3	1	3	8	0	8	2	3	3	1
	HSE / Log.	1	0	0	2	0	3	2	3	1	0
	Physics	0	0	0	0	0	1	0	0	0	0
	Geology	1	0	3	4	3	3	2	2	3	0
	Biology	2	1	1	4	3	4	4	2	3	0
	Technology	0	0	0	0	0	1	1	0	0	0
	Other	1	1	3	8	0	6	2	6	3	1
	External	1	1	2	3	1	3	1	4	2	0
	HIPO	2	2	2	5	2	8	2	1	3	1

CHAPTER 6

Discussion

Based upon the results of the database investigation and the literature review, a general understanding of the situation of Arctic safety management has been established. In this section, the results are discussed and compared to theory.

The limitations of the study are discussed and addressed in Section 6.1. Then, in Section 6.2, the time the accidents occur are addressed, followed by an general discussion about the situation and results in SNSK and UNIS (Section 6.3 and 6.4). Based on the findings, general accident types and concentrations in the Arctic are discussed in Section 6.5 along with causes and preventive measures. Lastly, in Section 6.6 application of existing theory and management strategies for Arctic safety management are discussed.

6.1 Limitations in the study

The study conducted in this Thesis is limited by multiple factors, possibly decreasing the transferability to other situations and applicability to further research. Most prominent of these are the potential cultural bias, access to data and longitudinal effects.

Cultural bias Some limitations of the validity of the study originate from the author's connection and predispositions towards the system investigated. Interpretations, sense of normality, and perspective might all differ from the norm, influencing the outcome of the analysis and event classification.

Lack of prior research studies on the topic As shown in Chapter 4, there has been little to none research on land-based Arctic safety management or general arctic safety management, increase the difficulty in anchoring the study to known facts and interpretations.

Lack of available data There is a limited group of organisations operating in the Arctic, and not all of those keep adequate records or databases of safety events. The area still has a certain degree of pioneer attitude and organisation, working against systematic safety records.

Access Gaining access to datasets involving accidents is challenging, and some of the data that exists and would have contributed to this study were not available. The unavailable data include the full database from the JRCC, reports by the travel companies in Svalbard, data for comparison with the mainland. Multiple requests to relevant parties have been made without any results.

Sample size and quality The sample size of this is limited by the small number of events in the three datasets, without the option to establish control charts[1] and statistical significance. Many of the records of events have also been found to be of inferior quality providing only limited information.

Self- and over reporting Most of the events in this study are based on self-reported data, that can contain several potential biases. Potential limitations in self-reported data might include selective memory, exaggeration, or misremembering one event as another.

There are also signs of both over- and under-reporting in the datasets. An example of this is the complete lack of fall-due-to-ice injuries reported in the UNIS dataset.

No triangulation Due to the limited time available, lack of interviews and access to the persons involved in the events, no triangulation has been conducted in this study.

Longitudinal effects The analysis in this Thesis is conducted over a period of 20 weeks, limiting the scope and depth. Gaining access to the datasets took a significant part, further limiting the time available for the analysis.

6.2 Temporal distribution

Activity in the Svalbard area is concentrated in two main periods, spring and late summer, both patterns are also reflected in the JRCC and UNIS data sets, and to a lesser degree in the SNSK dataset. This section concerns the distribution of events during the year.

6.2.1 JRCC and UNIS

Both the JRCC and UNIS datasets shows a distribution that has two main concentration, spring and late summer (Figures 5.1 and 5.5). Figure 5.1 also shows that during the spring, most events are land based, while during the late summer, they are not.

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[1] There are some possible control chart options outlined by Janicak (2009), but these are not evaluated in this Thesis.

Spring The first concentration of events in the JRCC data can be attributed to spring scooter and tourism season. The spring is the busiest time of the year in Svalbard due to increased tourism. The JRCC data also indicate that this period has a vast majority of land-based incidents. It is however not only tourists that are active during the spring, but also scientists from across the globe that come to Svalbard in this period, to do fieldwork. Many of the courses at UNIS include fieldwork, and the Logistics department is in a state of constant overwork. It is in this period that most of the scooter injuries and events occur at UNIS.

Late summer Both Figure 5.1 and 5.5 have an increase in events in the late summer (July - August), and JRCC shows that these are mostly not land-based events. The late summer in Svalbard is usually filled with more maritime activity and movement on foot[2]. The activity at UNIS in this period is also the same, and much of the activity is conducted by the Arctic biology department.

Fall and winter During the fall it gets gradually darker until there is no light at all. The first snow usually comes in November and often does not stay until late December. This combination of little or now light and no snow make the fall and winter quite quiet at Svalbard. This is reflected in both data sets. UNIS has ever had only one incident in December, and small activity during the winter. The winter activity at UNIS during the dark period is, however, increasing due to new fields of research and expanded field seasons.

6.2.2 SNSK

The activity at SNSK shows some of the same tendencies, but due to the nature of the operation, the numbers are more stable throughout the year. In Figure 5.4, the month distribution shows two main peaks, May and October, and a general trend of fewer events during summer.

Summer and winter The operations at SNSK is conducted year round and is not much dependent on the season as most are done by large machinery and inside the mountains. The decrease during summer might be contributed to two main causes, firstly that there are no snow and fewer falls. Secondly, that the management is more likely to be on vacation and that the pressure on reporting is less, as explained by the HSE responsible at SNSK.

May After a discussion with the HSE responsible at SNSK, and a search in the database, no explanation for the many occurrences in May was found. This unexplained concentration may merit additional inquiry and study. It should be noted that most of these incidents are inside, and therefore not investigated in detail.

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[2] It is not allowed to use means of transportation in Svalbard that damages the top layer due to its protected status, this prohibits the use of ATVs and other transportation.

6.3 Situation at SNSK

The situation at SNSK is comparatively normal to what is expected from other similar operations in non-Arctic environments, with few significant differences. However, compared to the international situation in the mining industry, SNSK is significantly more safe (Saleh and Cummings, 2011).

6.3.1 Accidents

As shown in Section 5.2, there was only one significant accident concentration within the outdoor operations at SNSK, namely falling due to a slippery surface, mostly due to snow and ice. This is also reflected in the cause analysis, where the three patterns (D11-T1, D11-O5, D1) indicate that the loss of control, maintenance and norms contribute to the accidents.

Many of the other accidents show indication of being more coincidental in nature, such as being bit by a visiting dog, hitting him self in the face with a shovel, or being tackled while playing bandy. Some work can be done within housekeeping, such as better handling of knives and tools after use, and ensuring safe walkways. After consulting the HSE responsible at SNSK, it is clear that they already have focus on these areas.

The preventive strategies analysis, shows that a significant amount of work should be put into limiting and preventing the uncontrolled release of energy.

6.3.2 Compared to the mainland

Both internally in SNSK and in the Norwegian industry in general, the so called H1 value is used to quantify the number of injuries resulting in leave of absence. The H1 value is defined by Norsk Industri (2017b) as

$$\text{H1-value} = \frac{\#\ \text{Injuries resulting in leave of absence} \times 1\ 000\ 000\ \text{hours}}{\#\ \text{Worked hours}} \tag{6.1}$$

In Figure 6.1, the H1 value for SNSK is compared to the nation wide average H1 value for both the Norwegian mining industry and Norwegian industry in general (Norsk Industri, 2017a). The nation wide statistics for the mining industry is based on reporting from the member companies, where one is SNSK. From the statistics it can be seen that the H1 value of SNSK does not significantly differ from that of the rest of Norway.

6.4 Situation at UNIS

The University Centre in Svalbard is special, both in its activity and safety challenges. The hazards spans from paper-cuts, through scooter accidents, to be eaten alive by polar bears. It seems that the main reasons that there have been no fatalities at UNIS is a combination of good incident handling and pure chance.

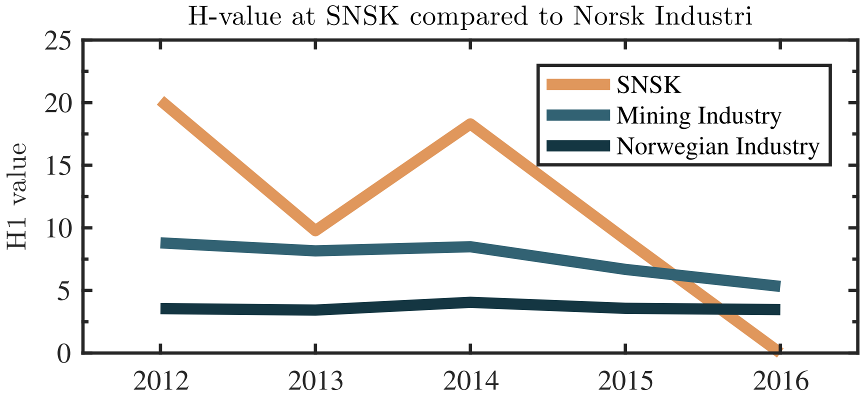

Figure 6.1: H1-value at SNSK in the period 2012 to 2016 compared to the nation wide statistics from Norsk Industri (2017a).

6.4.1 Accidents

There have been identified two types of typical events at UNIS; scooter accidents and unintentional discharge of weapons. In addition, a series of correlations was found in the accident cause analysis. Most of the accidents were at least partly due to human error.

Scooters The highest concentration of accidents was accidents where scooters were involved. The situation at UNIS is characterised by many new scooter drivers, most having only a handful of trips in their whole life. Although the students and scientist are provided with scooter training before engaged in fieldwork, this is often not enough.

Unintentional discharge of weapons As most of the students and scientists that visits UNIS have never fired a rifle in their life before coming to Svalbard, weapons handling relatively often end with unintentional discharge. It is exclusively human error with half-loading[3] that causes the worst events. General bad weapon handling is also reported.

6.4.2 Trends

In Figure 5.6, the overall number of reported events per student work year does appear to be relatively constant. However, looking at the events with injury, there are indications on of a rising number of events from 2013. This might be a statistical error, or an indication of an underlying problem.

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[3] Half-loading: Loading the rifle with bullets in the magazine, but not in the chamber.

6.4.3 General situation

Due to a relatively large amount of novel incidents, UNIS is well practised in event handling and preventative measures. The state of the database received indicates that there is a minimal system in place for systematic learning.

6.5 Event types in the Arctic

Some types of events are more prevalent in the Arctic than others. The JRCC data shows three concentrations: assistance person, air ambulance, and avalanches. Of these, air ambulance and avalanches were not considered in this study. The SNSK dataset shows one significant type of event, that of falling due to a slippery surface. The UNIS data shows two types of accidents that are common, scooter accidents and unintentional discharge of weapons. Also, many events are of a type that is impossible to predict.

6.5.1 Assistance person

A total of 12.2 % of all events reported to the JRCC is of the type assistance person. This means that in some way or another, a person was in distress and needed help. The situations differ from a scooter stuck in a ditch, to a person falling into a crevasse. The high number of these events indicate that events which require assistance of some kind occur more often on Svalbard than on mainland Norway.

6.5.2 Fall due to ice or snow

The largest concentration in outdoor events at SNSK was falling due to a slippery surface, mostly snow and ice. These events are almost exclusively reported by the SNSK, indicating differences in the reporting structure in the organisations[4]. The cause analysis indicates that the main energy is gravity, and resulting from a combination of multiple contributing causes, among those T1.

Preventive measures After asking the HSE responsible at SNSK about the concentration of fall injuries, it became clear that the preventive measures implemented by the SNSK are concentrated in ensuring safe walkways and proper footwear. It is however realised that due to the arctic climate, a completely safe set of walkways is impossible to ensure at all time.

Due to the impossibility of ensuring safe walkways at all times, an application of Haddon's strategies H8 and H9, increasing the target's resistance to the energy and limiting the development. A possible application of this would be fall-training, where workers are taught to fall correctly.

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[4] There has been similar events at UNIS, but not reported.

6.5.3 Scooter accidents

Scooters can be hard to drive and have little resemblance to driving a car. None the less, the requirement for driving a scooter at Svalbard is to have a driving license for a car or the dedicated scooter license[5]. Figure 6.2 shows the aftermath of a scooter incident on a UNIS excursion.

Scooter accidents are one of the most common events in the Svalbard, with 10 % of the events in the JRCC database, and 39 of the events in the UNIS dataset. Most of the scooter incidents at UNIS is due to either human error or loss of control. Based on the UNIS database, four main types of incidents have been identified. The variety and severity of the scooter events merit further investigation.

Crash Many of the accidents are crashes, where two scooters crash into each other, or the scooter hits an object. Most often these accidents involve the first scooter braking or stopping for one reason or another, then the second scooter read-ending the first. These accidents are mostly caused by lack of reaction of the driver behind, and some events attribute this to looking at the scenery. Based on the analysis of these events, two main strategies are apparent: changing the driving organisation, including speed and distance between scooters, and to increase the level of training.

Tipping Driving scooters can be tricky, especially in challenging terrain, causing many of the incidents to involve the scooter tipping or rolling. Better route planning and training might improve the scooter tripping rate.

Loss of control The third group of scooter accidents is when the driver loses control of the scooter. These are either due lack of skill when conducting difficult driving, or losing balance or control, then grabbing the throttle to hold on, accelerating the scooter. The strategy best suited to manage these events appeared to be more training.

Technical failure A couple of events involving scooters have been caused by a technical failure of the scooter. These often causes one of two events, fire or uncontrolled acceleration. The fires are caused by a variety of different reasons, such as to forget to turn off the parking brakes. The uncontrolled acceleration is reported in two events at UNIS, both involving the acceleration wire to freeze. There seem to be three main strategies to reduce these type of failures, training, procedures and maintenance.

6.5.4 Unintentional discharge of weapons

Due to the large amount of polar bears in the Svalbard area, everyone who leaves the main settlements carries a rifle, causing Svalbard to have high density of firearms.

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[5] On the Norwegian mainland a dedicated scooter licence is required to drive.

This high density of weapons and and frequent loading and unloading of rifles leads to a high amount of unintentional discharge.

The reason for unintentional discharge is mostly attributed to human error, especially incorrect half-loading as seen in the UNIS data. There are few potential strategies to reduce this, mainly increasing weapons training.

There are safety mechanisms on most rifles, but they are generally not in use in Svalbard. The UNIS instructions says not to use these safety mechanisms due to the likelihood of not being able to fire the rifle when needed.

6.5.5 Events that can not be foreseen

Among the many accidents and events in the investigation, there is a group that is almost impossible to predict and prepare for. In this section, two such events are presented and discussed.

Both events are complex in nature, and there has been no lack of expertise in planning the activity, and the event that occurred was deemed highly unlikely before the activity started.

Calving in Tempelfjorden

In the spring field season of 2014, a class of students were on an excursion, driving from Longyearbyen[6], through Sassendalen and down Von Postbreen, before stopping on the sea ice in Tempelfjorden, in front of Tunabreen as shown in Figure 6.3 in a line, with the front of the scooters pointing towards the glacier.

The calving Some time after the group had stopped in front of the glacier and dismounted the scooters, a loud sound was heard caused by the glacier calving[7]. The calving occurred approximately 600 meters from the group, causing two waves to propagate towards the group. The field technician from the Logistics department that was accompanying the excursion ordered everyone to get back on their scooters and keep calm, to reduce the risk of limbs being crushed within the cracks appearing.

The first wave Just after the group had mounted the scooters, the first wave hit, breaking up the ice into chunks between $2m^2$ and $10m^2$. The cracks opening was temporarily up to over 20 cm, capable of easily trapping a limb.

The second wave Moments after the first wave had passed, a second larger wave hit the row of scooters. The second wave was significantly larger than the first, and in regions closer to the glacier and the shore, throwing large chunks of ice around. As the wave was travelling through the group, one student panicked, driving at high speed right into the more violent region. After around 100 meters,

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[6] The author was a part of this group and was on the ice when the calving occurred. Most of the pictures in the report written after the incident were taken by the author, but the author was not involved in the evaluation.

[7] Calving: A calving event is when the front of a glacier breaks off.

the student was thrown off, leaving the student on the ice, and the scooter halfway through the ice.

The aftermath When the waves settled, no personal injury was sustained by any parties, and the scooter was pulled up from the ice, checked and appeared to be in drivable condition, though a bit wet. Shortly after the event, another technician from the Logistics department who was passing by, stopped and helped with the situation. The student who had driven off recovered the belongings from the scooter and walked back[8] to the rest of the group as shown in Figure 6.4.

The professional analysis Based on the event, a thorough report was written, describing the events and lessons learned. The reason for the calving is believed to be mild weather earlier in the season, that appears to have made calving events from the Tunabreen ice-front larger and more frequent than usual. The lessons learned is summarised to be

- Avoid the area of the event
- When parking in front of glaciers, avoid shallow water as it leads to higher amplitude waves.
- When parking in front of glaciers, have scooters parked in a safe direction.

The report was written by the technician and the lecturer leading the group. The lecturer is one of the leading experts on glaciers. In 2015, an article on the dynamics of the glacier system in question was published, including the period when the event occurred, showing an increase in activity in the period (Luckman et al., 2015).

Ice cave collapse

During a spring field season, a UNIS class of students were going into an ice cave at one of the glaciers around Longyearbyen, and the ice cave collapsed[9]. The group was led by the professor responsible for the course, who is also one of the leading experts on glaciers and Glacio-speleology[10]. Figure 6.5 shows the typical environment inside an ice cave.

Entering Before entering, the group leader had been informed about some cracks in the entrance of the cave by the guiding company using the cave for tourism. When entering the cave, he investigated these cracks and tested the integrity, deeming that the cave was safe. The group then entered the cave.

Collapse While the group was further inside the cave, the entrance collapsed causing 10-15 cubic meters of ice to block the entrance. The group noticed the collapse upon returning to the entrance. No one was injured during the collapse.

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[8] Even as the ice is cracked, it is still possible to walk and drive over it due to its buoyancy.

[9] The author knows multiple persons involved in this incident, both on a personal and a professional level, but was not otherwise involved.

[10] Glacio-speleology: The science of exploring and mapping ice caves.

Exiting The priority upon founding the entrance collapsed was evacuating the students. Luckily, some students had brought extra equipment, including ice climbing equipment and crampons[11], helping the evacuation.

The aftermath After exiting the cave, a brief debrief was held, and the group returned to Longyearbyen.

The professional analysis The situation could quite easily have been much more severe, and multiple fatalities were possible. Also, the evacuation could be much more difficult if a student had been injured or no one had brought their personal ice gear.

The proposed preventive measures to be implemented for further ice cave visits include having at least four students in ice gear in each visit, and a more robust testing of the ice cave before entering.

6.6 Arctic safety management strategies

Developing safety management strategies for the Arctic is a difficult process too complex to attempt in this Thesis. However, a brief outline and some demands to the system will be discussed in this section. First, the system at SNSK and UNIS is discussed and evaluated. Lastly, the general demands and potential strategies for designing such a system are outlined.

6.6.1 SNSK

The investigation shows that the safety management system implemented at SNSK to a large degree works as intended. There are few high potential events, and the H1 value is comparable to the level of mainland Norway. The system at SNSK also shows a high degree of learning, based on the internal documents provided. The main challenge lies within the evacuation of injured personnel, as the evacuation to the nearest larger hospital often can take too long time.

These situations demands a cautionary approach to safety, handling problems before they appear. Based on the study, this is also the case for the safety management at SNSK. Future work should include expanding the variations in strategies and a continued focus on potential hazards.

6.6.2 UNIS

The UNIS formal safety systems have, based on the database system and the background information, great challenges. The safety information system shows signs of weakness in most of the functions, and most evident within the storing of data. The system does show evidence of experience feedback, ambit on an elementary level.

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[11] Crampons: Large spike contraptions attached to shoes in order to gain traction on ice.

Safety information system The safety information system found at UNIS is based on reporting events when they happen, then storing these reports in a file system. The file system as it exists today makes analysis difficult, as evident by the methods implemented in this Thesis. The collection of data is also lacking, as the quality often is to low to be analysed. There is also little aggregated analysis based on the database.

Experience feedback Based on the documentations in the received database and background information, the level of experience feedback of the system is severely lacking. Using the classification of Van Court (1967), the system overall appears to be of the first level, that of a simple machine without selective memory. The proposed improvements bear sign of being directed at the direct causes, often not aiming at the contributing causes.

There is some degree of learning, but it appears mostly occasional, done on a case-by-case basis. A higher order feedback involving higher level of management and more structured feedback might improve the safety work at UNIS significantly. The first step in this will be to construct a database of incidents.

Why does it work? Even as the formal system appears to be lacking in experience feedback, it does work. There have been no fatalities, and the number of severe accidents seems low when compared to the high number of field days and fresh personnel in the field. There might be many different reasons for this, and a more in-depth analysis on the topic might yield findings that can be used in designing future safety management systems for Arctic operations.

It is worth noting that UNIS has since its start implemented most of the recommendations for safe Arctic fieldwork by Crain et al. (2015). Further investigation into the application of these measures are needed.

6.6.3 General strategies

A safety system designed for the application in the Arctic for organisations such as UNIS will have to handle a variety of different challenges, adding to the already high difficulty of designing a safety system. The system will have to both have the capabilities to ensure the day to day safety, as well as handling novel incidents as presented in Section 6.5.5. Some of the many challenges met are for example

Cultural differences There are many different cultures operating in the Arctic. Often there can, for instance, be large cultural differences between Norwegian and Russian field organisation. There is to this day little research done on the cultural differences in safety in Arctic field groups from different countries.

Macho culture Even as the society of Svalbard comes ever closer to normalisation; there exists a form of macho-culture within the field activities. Higher risks are accepted then strictly necessary, and near accidents are a bragging thing. A study of the risk perception among personnel engaged in Arctic fieldwork might be needed.

Paperwork Paperwork and scientific research will always be a problem. Based on the database of UNIS, there is already a challenge to get personnel to report medical injuries. If a larger amount of paperwork is added to this, it will probably be ignored unless considerable resources are used to enforce it.

Novel Many of the events and event types in the Arctic are novel, and hard to predict.

Lack of experience Much of the personnel, largely students, have never been in the Arctic before and does not have the experience required, as shown by the analysis.

Complexity The systems in the Arctic are often of a complex nature (Coyne, 2005).

Evacuation In the Arctic, evacuation can take days and might be impossible due to the weather conditions.

Environment The environment of Svalbard and the Arctic is fragile, and in most places, it is strictly protected by law. Many of the more technical solutions like building roads or mechanising transport are therefore impossible.

Cost One of the defining characteristics of Arctic activity, is that it is extremely expensive, and an even higher cost will be difficult to beer.

Proximity The system has to be designed and implemented by people with proximity and local knowledge and understanding of the system. There are many examples of HSE regulations within companies operating in the Arctic, especially within the oil and gas industry that hinder the operations and thereby undermine the activity that is there to protect[12]. In many cases, it also undermines the HSE work, and the rules that are seen as unnecessary are ignored.

These are just some of the many challenges the design of a safety management system for the Arctic needs to overcome. A more in-depth investigation of challenges is necessary to make a sound basis of such a development. This thesis has revealed some of the patterns in events but has not aimed to examine the general challenges for the management system as a whole.

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[12] During the 2014 International Conference on Port and Ocean Engineering under Arctic Conditions Conference held in Trondheim, many scientists expressed their frustration over HSE rules enforced on them by the larger oil and gas companies. The HSE rules said that they were not allowed onto the sea ice, making their research almost impossible to conduct. Further inquiry with the companies in question revealed that some of these regulations were created by professional in their HQ, never having set foot in the Arctic.

Design of an Arctic safety management system

A functioning Arctic safety management system should be based on experience feedback and incorporate the main elements of Deming's Cycle, as described by Kjellén and Albrechtsen (2017). It will need to be both practical and intuitive due to the nature of operations and the large change in personnel. Most importantly, it need's to be designed with an understanding of the Arctic system, tailored to fit both the environment and the people operating there.

Figure 6.2: The result of a scooter hitting an outcropping at a speed of 35-50 km/t. There were two persons on the scooter, one driver and a passenger; both were thrown off during the crash. There were no major injuries from the accident. Photo by Student / UNIS

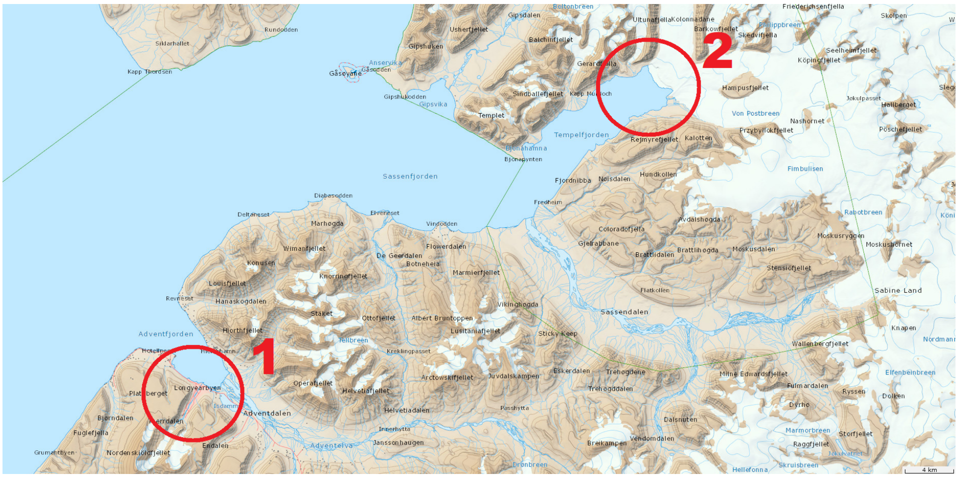


Figure 6.3: Location of the calving incident in Tempelfjorden. 1) Longyearbyen, 2) Tempelfjorden. Map by the Norwegian Polar Institute, modified by the Author.

Figure 6.4: Student recovering possessions after a calving event in Tempelfjorden during the spring season 2014. As the glacier, Tunabreen as seen in the photo, calved, waves of at least 1 meter in amplitude were formed and cracked the ice. Photo by the Johannes P. Lorentzen.

Figure 6.5: Students on their free time inside an ice cave close to Longyearbyen. Photo by Andreas Pippidis Lorentzen

CHAPTER 7

Conclusions

This Thesis has investigated three datasets with reported incidents in the Svalbard region, preforming an accident concentration, cause and preventive strategy analysis. It is found that most accidents either occur during the spring or late summer period at Svalbard due to the scooter and maritime season respectively. Five incident types characteristic of the Arctic region have been identified; Assistance person, fall due to ice or snow, scooter incidents, unintentional discharge of weapons, and events that can not be foreseen.

It is found that the operations at Store Norske Spitsbergen Kullkompani do not show any significant differences caused by the Arctic location compared to the mainland Norway.

The UNIS safety operations are shown to have multiple challenges in both safety management systems and incident concentrations, and it is a combination of chance and good emergency response at UNIS that no fatalities have occurred.

CHAPTER 8

Future work

The results of this study have shown that there are a significant amount of work still needing to be done within the field of Arctic safety management. In this chapter, some of the possible recommended future work and research will be outlined.

Future investigations

This Thesis has uncovered many opportunities for improving the understanding of the Arctic system from a safety perspective, and the subsequent future investigations are believed to yield great results.

Full access to the JRCC database Gaining access to the full JRCC database and conducting a similar analysis as carried out in this Thesis might give further background and information needed to conduct Arctic operations safely.

Comparative study with SNSK The SNSK dataset has high potential for a future study, and a comparative study with similar operations would help to identify the differences not found in this Thesis. A possible comparison would, for instance, be against Stjernøy mine, as it is the only comparable mining operation in the north part of the mainland of Norway, operating using similar techniques.

In-depth analysis of challenges A comprehensive analysis of which challenges an Arctic safety management system faces, would help provide a basis for the development of such a system. A survey should be conducting, asking different parties and actors what they perceive as their largest challenge in their safety work should also be carried out in connection to this.

Common database As the number of events in Svalbard is quite low; it can be difficult discerning patterns and learning by using only data from one organisation. Therefore a shared database with most of the actors in the Svalbard area should ideally be created. Such a database should be built using the principles from Kjellén and Albrechtsen (2017), and include among others scientific, industrial and tourism organisation.

Development of an Arctic safety management system A comprehensive framework for an Arctic safety management system will need to be developed and tested. It should be based on the principles of experience feedback and with the special conditions in the Arctic in mind.

Future work at Store Norske Spitsbergen Kullkompani

The situation at SNSK needs little improvement other than continuing the work already underway. The main room for improvement is to diversify their use of countermeasures.

Future work at the University Centre in Svalbard

The University Centre in Svalbard has faced many challenges within their safety system. Investigating the management and organisation structure at UNIS using a combination of inspections and a Safety Management and Organisation Review Technique (SMORT) tier three or four investigation should be done. Further, UNIS will need to implement a formal experience feedback system and strengthen the safety information system.

APPENDIX A

Recorded events by JRCC

A request to The Joint Rescue Coordination Centres in Norway for a record of all events recorded in Svalbard resulted in a database of all recorded events in Svalbard in the period 2007 to 2016. The database consisted of 677 entries and eight columns. In this appendix, the background statistics and spatial distribution are presented.

Number of events Table A.1 shows the yearly number of land-based events in the whole of Norway between 2010 and 2016. The sum of events in overlapping periods for Svalbard is also given.

Spatial distribution of events Figure A.1 shows the location of each of the 677 registered events in Svalbard registered by the JRCC. The largest distribution is around the Longyearbyen and Isfjorden area, as well as the Hornsund area. The last high frequent area is around Ny Ålesund.

Public statistics Figure A.2, A.3, and A.4 shows the the official yearly statistics provided by the JRCC for the years 2012, 2014, 2016 respectively. Yearly statistics are published on their website. (JRCC, 2017)

Table A.1: Number of recorded events on land by The Joint Rescue Coordination Centres in Norway in the period 2010 to 2016 compared to the events in Svalbard for the period 2007 to 2016.

	All events								**Svalbard**	
Categories land:	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**Total**	**10-16**	**07-16**
Alpinulykke - fjell - bre - grotte	30	45	34	34	57	37	25	**262**	3	4
Assistanse person	507	517	567	529	629	690	733	**4172**	99	133
Atomulykke	0	0	0	0	0	0	0	**0**	0	0
Bombe/terror	1	2	5	1	4	0	0	**13**	0	0
Drukning - Kantring	82	64	100	80	61	75	62	**524**	1	1
Farlig gods	2	0	1	0	0	0	2	**5**	0	0
Industriulykke	12	4	6	6	3	6	5	**42**	1	1
Luftambulanse	924	942	1001	1089	1281	1210	1308	**7755**	136	198
Naturkatastrofe	8	10	2	8	8	5	0	**41**	0	0
Nødpeilesender - PLB	101	108	101	95	75	100	101	**681**	7	14
Nødsignaler - pyro - lys - andre	52	66	53	52	37	48	44	**352**	9	10
Savnet person	1159	1232	1284	1251	1212	1253	1306	**8697**	23	31
Skogbrann	10	9	8	19	75	15	20	**156**	0	0
Skred - Ras	65	51	64	79	49	53	54	**415**	11	16
Transportulykke - jernbane	5	3	2	2	2	2	0	**16**	0	0
Transportulykke - vei	31	28	29	35	27	30	19	**199**	2	2
Andre	1	1	2	5	1	0	1	**11**	1	1
Udefinert - LAND	35	19	24	23	28	22	23	**174**	1	4
Total land:	**3025**	**3101**	**3283**	**3308**	**3549**	**3546**	**3703**	**23515**	**294**	**415**
Total:	**7309**	**7369**	**7364**	**8036**	**8605**	**8655**	**8881**	**56219**	**495**	**677**

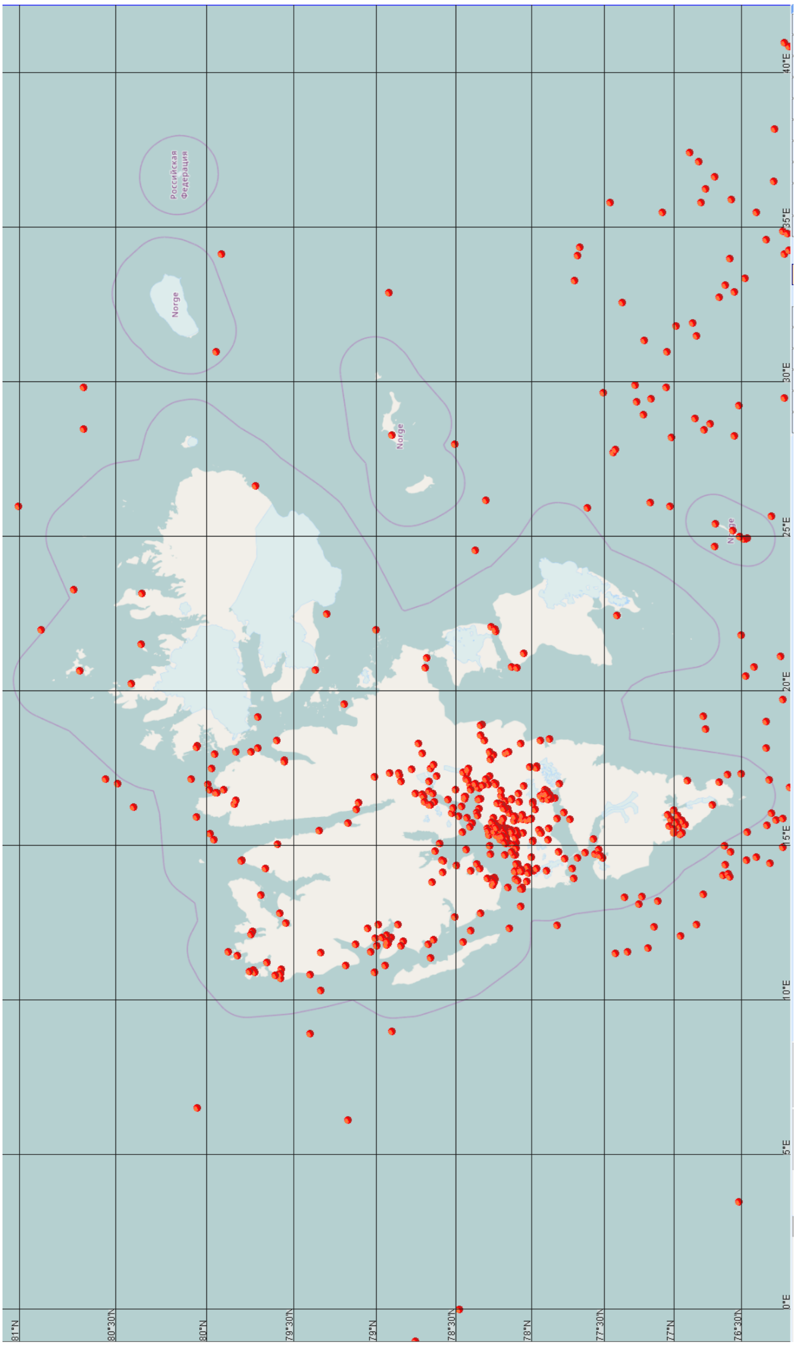
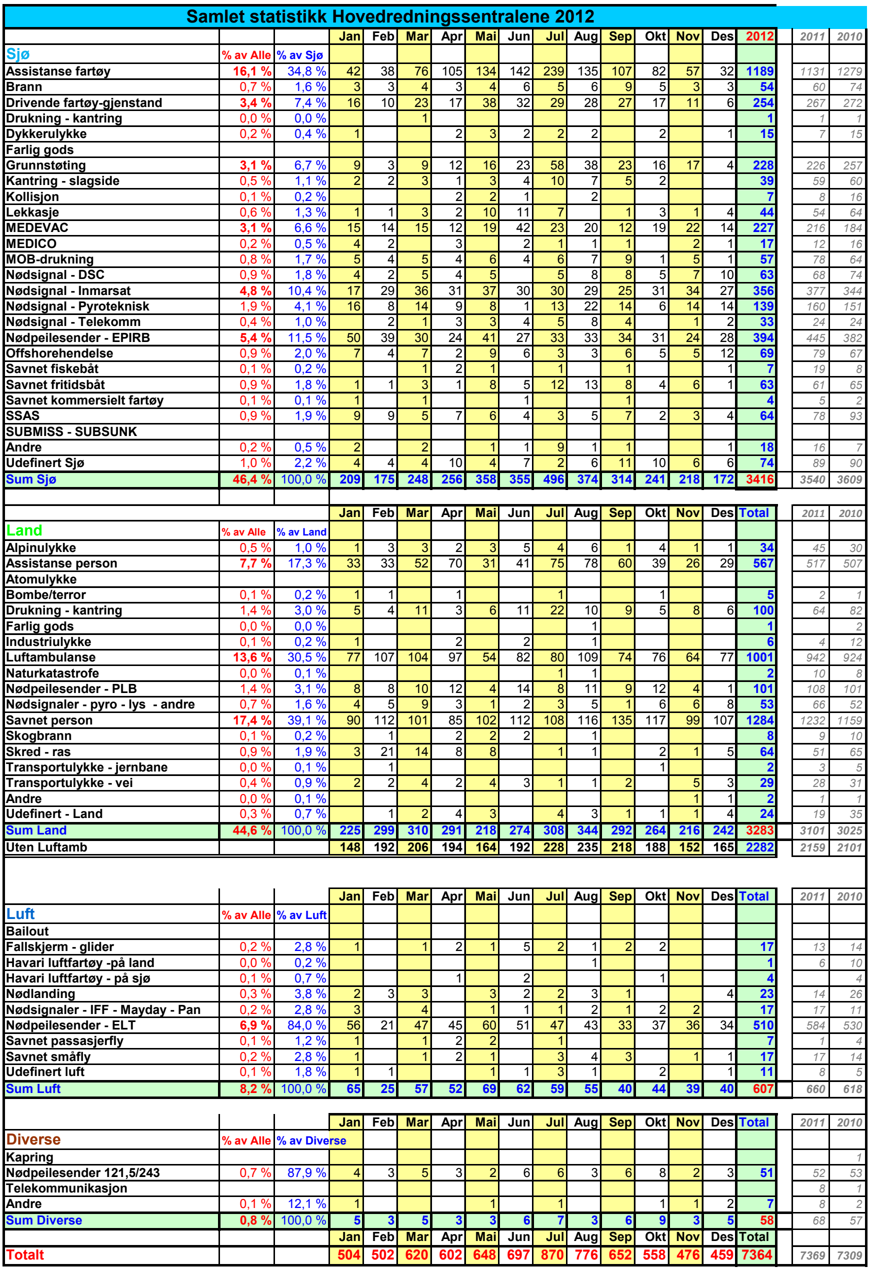


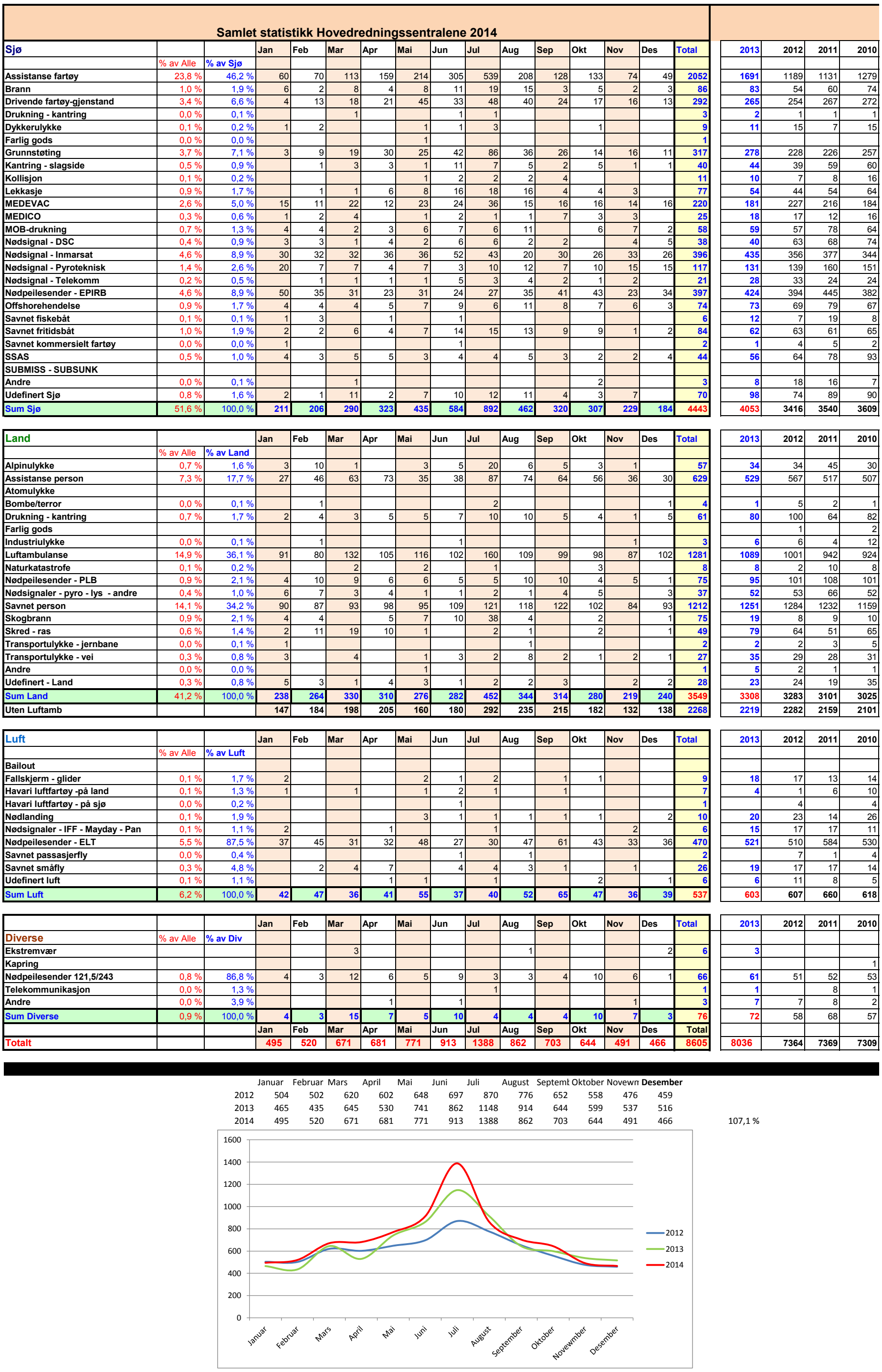
Figure A.1: Map of all registered events in Svalbard in the period 2007-2016 by The Joint Rescue Coordination Centres in Norway, courtesy of the JRCC.



Samlet statistikk Hovedredningssentralene 2012

			Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Okt	Nov	Des	2012	2011	2010
Sjø	% av Alle	% av Sjø															
Assistanse fartøy	16,1 %	34,8 %	42	38	76	105	134	142	239	135	107	82	57	32	1189	1131	1279
Brann	0,7 %	1,6 %	3	3	4	3	4	6	5	6	9	5	3	3	54	60	74
Drivende fartøy-gjenstand	3,4 %	7,4 %	16	10	23	17	38	32	29	28	27	17	11	6	254	267	272
Drukning - kantring	0,0 %	0,0 %			1										1	1	1
Dykkerulykke	0,2 %	0,4 %	1			2	3	2	2	2		2		1	15	7	15
Farlig gods																	
Grunnstøting	3,1 %	6,7 %	9	3	9	12	16	23	58	38	23	16	17	4	228	226	257
Kantring - slagside	0,5 %	1,1 %	2	2	3	1	3	4	10	7	5	2			39	59	60
Kollisjon	0,1 %	0,2 %				2	2	1		2					7	8	16
Lekkasje	0,6 %	1,3 %	1	1	3	2	10	11	7		1	3	1	4	44	54	64
MEDEVAC	3,1 %	6,6 %	15	14	15	12	19	42	23	20	12	19	22	14	227	216	184
MEDICO	0,2 %	0,5 %	4	2		3		2	1	1	1		2	1	17	12	16
MOB-drukning	0,8 %	1,7 %	5	4	5	4	6	4	6	7	9	1	5	1	57	78	64
Nødsignal - DSC	0,9 %	1,8 %	4	2	5	4	5		5	8	8	5	7	10	63	68	74
Nødsignal - Inmarsat	4,8 %	10,4 %	17	29	36	31	37	30	30	29	25	31	34	27	356	377	344
Nødsignal - Pyroteknisk	1,9 %	4,1 %	16	8	14	9	8	1	13	22	14	6	14	14	139	160	151
Nødsignal - Telekomm	0,4 %	1,0 %		2	1	3	3	4	5	8	4		1	2	33	24	24
Nødpeilesender - EPIRB	5,4 %	11,5 %	50	39	30	24	41	27	33	33	34	31	24	28	394	445	382
Offshorehendelse	0,9 %	2,0 %	7	4	7	2	9	6	3	3	6	5	5	12	69	79	67
Savnet fiskebåt	0,1 %	0,2 %			1	2	1		1		1			1	7	19	8
Savnet fritidsbåt	0,9 %	1,8 %	1	1	3	1	8	5	12	13	8	4	6	1	63	61	65
Savnet kommersielt fartøy	0,1 %	0,1 %	1		1			1			1				4	5	2
SSAS	0,9 %	1,9 %	9	9	5	7	6	4	3	5	7	2	3	4	64	78	93
SUBMISS - SUBSUNK																	
Andre	0,2 %	0,5 %	2		2		1	1	9	1	1			1	18	16	7
Udefinert Sjø	1,0 %	2,2 %	4	4	4	10	4	7	2	6	11	10	6	6	74	89	90
Sum Sjø	46,4 %	100,0 %	209	175	248	256	358	355	496	374	314	241	218	172	3416	3540	3609
			Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Okt	Nov	Des	Total	2011	2010
Land	% av Alle	% av Land															
Alpinulykke	0,5 %	1,0 %	1	3	3	2	3	5	4	6	1	4	1	1	34	45	30
Assistanse person	7,7 %	17,3 %	33	33	52	70	31	41	75	78	60	39	26	29	567	517	507
Atomulykke																	
Bombe/terror	0,1 %	0,2 %	1	1		1			1			1			5	2	1
Drukning - kantring	1,4 %	3,0 %	5	4	11	3	6	11	22	10	9	5	8	6	100	64	82
Farlig gods	0,0 %	0,0 %								1					1		2
Industriulykke	0,1 %	0,2 %	1			2		2		1					6	4	12
Luftambulanse	13,6 %	30,5 %	77	107	104	97	54	82	80	109	74	76	64	77	1001	942	924
Naturkatastrofe	0,0 %	0,1 %							1	1					2	10	8
Nødpeilesender - PLB	1,4 %	3,1 %	8	8	10	12	4	14	8	11	9	12	4	1	101	108	101
Nødsignaler - pyro - lys - andre	0,7 %	1,6 %	4	5	9	3	1	2	3	5	1	6	6	8	53	66	52
Savnet person	17,4 %	39,1 %	90	112	101	85	102	112	108	116	135	117	99	107	1284	1232	1159
Skogbrann	0,1 %	0,2 %		1		2	2	2		1					8	9	10
Skred - ras	0,9 %	1,9 %	3	21	14	8	8		1	1		2	1	5	64	51	65
Transportulykke - jernbane	0,0 %	0,1 %		1								1			2	3	5
Transportulykke - vei	0,4 %	0,9 %	2	2	4	2	4	3	1	1	2		5	3	29	28	31
Andre	0,0 %	0,1 %											1	1	2	1	1
Udefinert - Land	0,3 %	0,7 %		1	2	4	3		4	3	1	1	1	4	24	19	35
Sum Land	44,6 %	100,0 %	225	299	310	291	218	274	308	344	292	264	216	242	3283	3101	3025
Uten Luftamb			148	192	206	194	164	192	228	235	218	188	152	165	2282	2159	2101
			Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Okt	Nov	Des	Total	2011	2010
Luft	% av Alle	% av Luft															
Bailout																	
Fallskjerm - glider	0,2 %	2,8 %	1		1	2	1	5	2	1	2	2			17	13	14
Havari luftfartøy -på land	0,0 %	0,2 %								1					1	6	10
Havari luftfartøy - på sjø	0,1 %	0,7 %				1		2				1			4		4
Nødlanding	0,3 %	3,8 %	2	3	3		3	2	2	3	1			4	23	14	26
Nødsignaler - IFF - Mayday - Pan	0,2 %	2,8 %	3		4		1	1	1	2	1	2	2		17	17	11
Nødpeilesender - ELT	6,9 %	84,0 %	56	21	47	45	60	51	47	43	33	37	36	34	510	584	530
Savnet passasjerfly	0,1 %	1,2 %	1		1	2	2		1						7	1	4
Savnet småfly	0,2 %	2,8 %	1		1	2	1		3	4	3		1	1	17	17	14
Udefinert luft	0,1 %	1,8 %	1	1			1	1	3	1		2		1	11	8	5
Sum Luft	8,2 %	100,0 %	65	25	57	52	69	62	59	55	40	44	39	40	607	660	618
			Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Okt	Nov	Des	Total	2011	2010
Diverse	% av Alle	% av Diverse															
Kapring																	1
Nødpeilesender 121,5/243	0,7 %	87,9 %	4	3	5	3	2	6	6	3	6	8	2	3	51	52	53
Telekommunikasjon																8	1
Andre	0,1 %	12,1 %	1				1		1			1	1	2	7	8	2
Sum Diverse	0,8 %	100,0 %	5	3	5	3	3	6	7	3	6	9	3	5	58	68	57
			Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Okt	Nov	Des	Total		
Totalt			504	502	620	602	648	697	870	776	652	558	476	459	7364	7369	7309

Figure A.2: The 2012 JRCC public statistics of events in Norway. (JRCC, 2017)



Samlet statistikk Hovedredningssentralene 2014

Sjø			Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Okt	Nov	Des	Total	2013	2012	2011	2010
	% av Alle	% av Sjø																	
Assistanse fartøy	23,8 %	46,2 %	60	70	113	159	214	305	539	208	128	133	74	49	2052	1691	1189	1131	1279
Brann	1,0 %	1,9 %	6	2	8	4	8	11	19	15	3	5	2	3	86	83	54	60	74
Drivende fartøy-gjenstand	3,4 %	6,6 %	4	13	18	21	45	33	48	40	24	17	16	13	292	265	254	267	272
Drukning - kantring	0,0 %	0,1 %			1			1	1						3	2	1	1	1
Dykkerulykke	0,1 %	0,2 %	1	2			1	1	3			1			9	11	15	7	15
Farlig gods	0,0 %	0,0 %					1								1				
Grunnstøting	3,7 %	7,1 %	3	9	19	30	25	42	86	36	26	14	16	11	317	278	228	226	257
Kantring - slagside	0,5 %	0,9 %		1	3	3	1	11	7	5	2	5	1	1	40	44	39	59	60
Kollisjon	0,1 %	0,2 %					1	2	2	2	4				11	10	7	8	16
Lekkasje	0,9 %	1,7 %		1	1	6	8	16	18	16	4	4	3		77	54	44	54	64
MEDEVAC	2,6 %	5,0 %	15	11	22	12	23	24	36	15	16	16	14	16	220	181	227	216	184
MEDICO	0,3 %	0,6 %	1	2	4		1	2	1	1	7	3	3		25	18	17	12	16
MOB-drukning	0,7 %	1,3 %	4	4	2	3	6	7	6	11		6	7	2	58	59	57	78	64
Nødsignal - DSC	0,4 %	0,9 %	3	3	1	4	2	6	6	2	2		4	5	38	40	63	68	74
Nødsignal - Inmarsat	4,6 %	8,9 %	30	32	32	36	36	52	43	20	30	26	33	26	396	435	356	377	344
Nødsignal - Pyroteknisk	1,4 %	2,6 %	20	7	7	4	7	3	10	12	7	10	15	15	117	131	139	160	151
Nødsignal - Telekomm	0,2 %	0,5 %		1	1	1	1	5	3	4	2	1	2		21	28	33	24	24
Nødpeilesender - EPIRB	4,6 %	8,9 %	50	35	31	23	31	24	27	35	41	43	23	34	397	424	394	445	382
Offshorehendelse	0,9 %	1,7 %	4	4	4	5	7	9	6	11	8	7	6	3	74	73	69	79	67
Savnet fiskebåt	0,1 %	0,1 %	1	3		1		1							6	12	7	19	8
Savnet fritidsbåt	1,0 %	1,9 %	2	2	6	4	7	14	15	13	9	9	1	2	84	62	63	61	65
Savnet kommersielt fartøy	0,0 %	0,0 %	1					1							2	1	4	5	2
SSAS	0,5 %	1,0 %	4	3	5	5	3	4	4	5	3	2	2	4	44	56	64	78	93
SUBMISS - SUBSUNK																			
Andre	0,0 %	0,1 %			1							2			3	8	18	16	7
Udefinert Sjø	0,8 %	1,6 %	2	1	11	2	7	10	12	11	4	3	7		70	98	74	89	90
Sum Sjø	51,6 %	100,0 %	211	206	290	323	435	584	892	462	320	307	229	184	4443	4053	3416	3540	3609

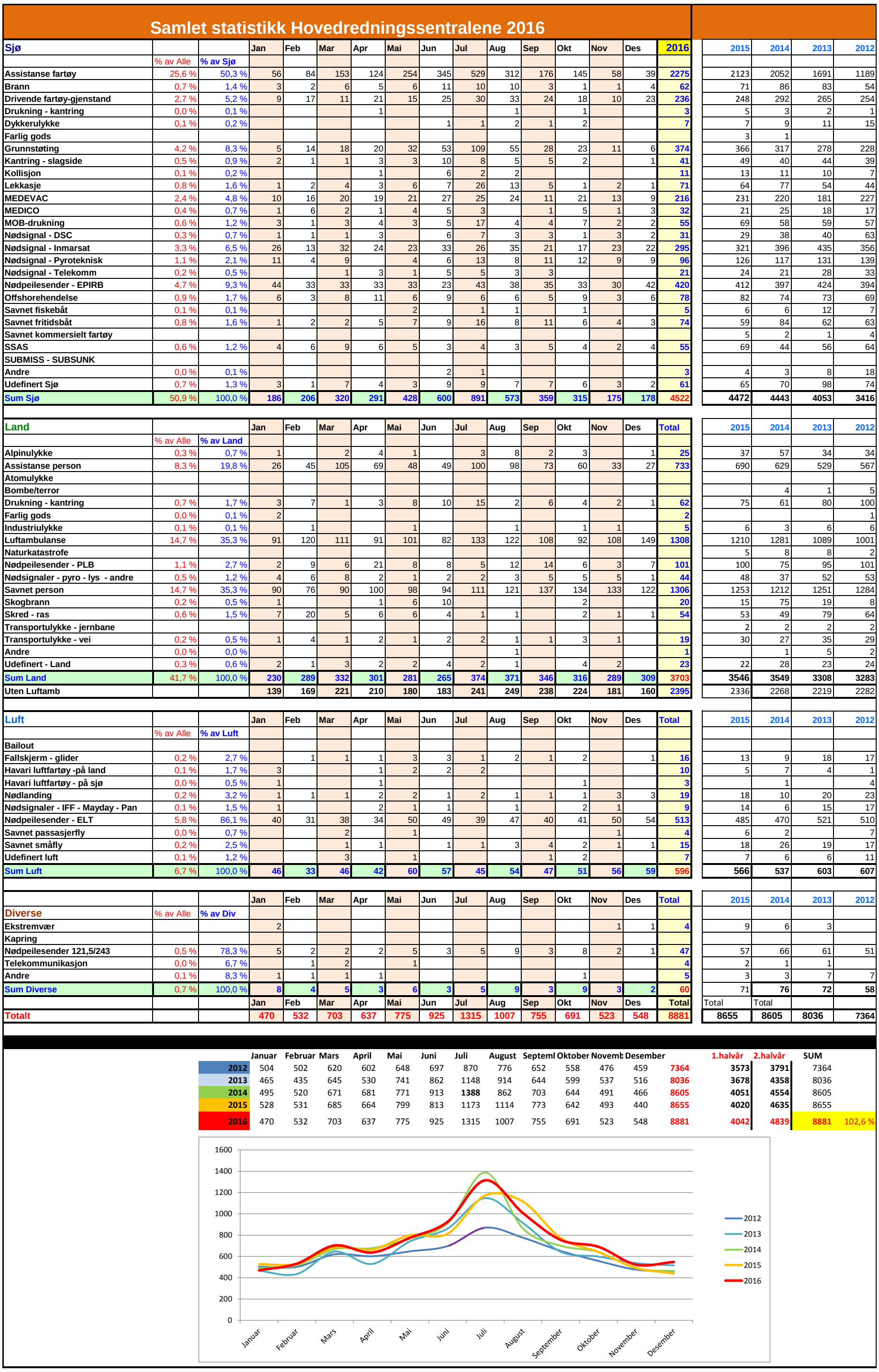
Land			Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Okt	Nov	Des	Total	2013	2012	2011	2010
	% av Alle	% av Land																	
Alpinulykke	0,7 %	1,6 %	3	10	1		3	5	20	6	5	3	1		57	34	34	45	30
Assistanse person	7,3 %	17,7 %	27	46	63	73	35	38	87	74	64	56	36	30	629	529	567	517	507
Atomulykke																			
Bombe/terror	0,0 %	0,1 %		1					2					1	4	1	5	2	1
Drukning - kantring	0,7 %	1,7 %	2	4	3	5	5	7	10	10	5	4	1	5	61	80	100	64	82
Farlig gods																	1		2
Industriulykke	0,0 %	0,1 %		1				1					1		3	6	6	4	12
Luftambulanse	14,9 %	36,1 %	91	80	132	105	116	102	160	109	99	98	87	102	1281	1089	1001	942	924
Naturkatastrofe	0,1 %	0,2 %			2		2		1			3			8	8	2	10	8
Nødpeilesender - PLB	0,9 %	2,1 %	4	10	9	6	6	5	5	10	10	4	5	1	75	95	101	108	101
Nødsignaler - pyro - lys - andre	0,4 %	1,0 %	6	7	3	4	1	1	2	1	4	5		3	37	52	53	66	52
Savnet person	14,1 %	34,2 %	90	87	93	98	95	109	121	118	122	102	84	93	1212	1251	1284	1232	1159
Skogbrann	0,9 %	2,1 %	4	4		5	7	10	38	4		2		1	75	19	8	9	10
Skred - ras	0,6 %	1,4 %	2	11	19	10	1		2	1		2		1	49	79	64	51	65
Transportulykke - jernbane	0,0 %	0,1 %	1							1					2	2	2	3	5
Transportulykke - vei	0,3 %	0,8 %	3		4		1	3	2	8	2	1	2	1	27	35	29	28	31
Andre	0,0 %	0,0 %					1								1	5	2	1	1
Udefinert - Land	0,3 %	0,8 %	5	3	1	4	3	1	2	2	3		2	2	28	23	24	19	35
Sum Land	41,2 %	100,0 %	238	264	330	310	276	282	452	344	314	280	219	240	3549	3308	3283	3101	3025
Uten Luftamb			147	184	198	205	160	180	292	235	215	182	132	138	2268	2219	2282	2159	2101

Luft			Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Okt	Nov	Des	Total	2013	2012	2011	2010
	% av Alle	% av Luft																	
Bailout																			
Fallskjerm - glider	0,1 %	1,7 %	2				2	1	2		1	1			9	18	17	13	14
Havari luftfartøy -på land	0,1 %	1,3 %	1		1		1	2	1		1				7	4	1	6	10
Havari luftfartøy - på sjø	0,0 %	0,2 %						1							1		4		4
Nødlanding	0,1 %	1,9 %					3	1	1	1	1	1		2	10	20	23	14	26
Nødsignaler - IFF - Mayday - Pan	0,1 %	1,1 %	2			1			1				2		6	15	17	17	11
Nødpeilesender - ELT	5,5 %	87,5 %	37	45	31	32	48	27	30	47	61	43	33	36	470	521	510	584	530
Savnet passasjerfly	0,0 %	0,4 %						1		1					2		7	1	4
Savnet småfly	0,3 %	4,8 %		2	4	7		4	4	3	1		1		26	19	17	17	14
Udefinert luft	0,1 %	1,1 %				1	1		1			2		1	6	6	11	8	5
Sum Luft	6,2 %	100,0 %	42	47	36	41	55	37	40	52	65	47	36	39	537	603	607	660	618

			Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Okt	Nov	Des	Total	2013	2012	2011	2010
Diverse	% av Alle	% av Div																	
Ekstremvær					3					1				2	6	3			
Kapring																			1
Nødpeilesender 121,5/243	0,8 %	86,8 %	4	3	12	6	5	9	3	3	4	10	6	1	66	61	51	52	53
Telekommunikasjon	0,0 %	1,3 %							1						1	1		8	1
Andre	0,0 %	3,9 %				1		1					1		3	7	7	8	2
Sum Diverse	0,9 %	100,0 %	4	3	15	7	5	10	4	4	4	10	7	3	76	72	58	68	57
			Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Okt	Nov	Des	Total				
Totalt			495	520	671	681	771	913	1388	862	703	644	491	466	8605	8036	7364	7369	7309

	Januar	Februar	Mars	April	Mai	Juni	Juli	August	Septemb	Oktober	Novewn	Desember	
2012	504	502	620	602	648	697	870	776	652	558	476	459	
2013	465	435	645	530	741	862	1148	914	644	599	537	516	
2014	495	520	671	681	771	913	1388	862	703	644	491	466	107,1 %

Figure A.3: The 2014 JRCC public statistics of events in Norway. (JRCC, 2017)



Samlet statistikk Hovedredningssentralene 2016

Sjø			Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Okt	Nov	Des	2016	2015	2014	2013	2012
	% av Alle	% av Sjø																	
Assistanse fartøy	25,6 %	50,3 %	56	84	153	124	254	345	529	312	176	145	58	39	2275	2123	2052	1691	1189
Brann	0,7 %	1,4 %	3	2	6	5	6	11	10	10	3	1	1	4	62	71	86	83	54
Drivende fartøy-gjenstand	2,7 %	5,2 %	9	17	11	21	15	25	30	33	24	18	10	23	236	248	292	265	254
Drukning - kantring	0,0 %	0,1 %				1				1		1			3	5	3	2	1
Dykkerulykke	0,1 %	0,2 %						1	1	2	1	2			7	7	9	11	15
Farlig gods																3	1		
Grunnstøting	4,2 %	8,3 %	5	14	18	20	32	53	109	55	28	23	11	6	374	366	317	278	228
Kantring - slagside	0,5 %	0,9 %	2	1	1	3	3	10	8	5	5	2		1	41	49	40	44	39
Kollisjon	0,1 %	0,2 %				1		6	2	2					11	13	11	10	7
Lekkasje	0,8 %	1,6 %	1	2	4	3	6	7	26	13	5	1	2	1	71	64	77	54	44
MEDEVAC	2,4 %	4,8 %	10	16	20	19	21	27	25	24	11	21	13	9	216	231	220	181	227
MEDICO	0,4 %	0,7 %	1	6	2	1	4	5	3		1	5	1	3	32	21	25	18	17
MOB-drukning	0,6 %	1,2 %	3	1	3	4	3	5	17	4	4	7	2	2	55	69	58	59	57
Nødsignal - DSC	0,3 %	0,7 %	1	1	1	3		6	7	3	3	1	3	2	31	29	38	40	63
Nødsignal - Inmarsat	3,3 %	6,5 %	26	13	32	24	23	33	26	35	21	17	23	22	295	321	396	435	356
Nødsignal - Pyroteknisk	1,1 %	2,1 %	11	4	9		4	6	13	8	11	12	9	9	96	126	117	131	139
Nødsignal - Telekomm	0,2 %	0,5 %			1	3	1	5	5	3	3				21	24	21	28	33
Nødpeilesender - EPIRB	4,7 %	9,3 %	44	33	33	33	33	23	43	38	35	33	30	42	420	412	397	424	394
Offshorehendelse	0,9 %	1,7 %	6	3	8	11	6	9	6	6	5	9	3	6	78	82	74	73	69
Savnet fiskebåt	0,1 %	0,1 %					2		1	1		1			5	6	6	12	7
Savnet fritidsbåt	0,8 %	1,6 %	1	2	2	5	7	9	16	8	11	6	4	3	74	59	84	62	63
Savnet kommersielt fartøy																5	2	1	4
SSAS	0,6 %	1,2 %	4	6	9	6	5	3	4	3	5	4	2	4	55	69	44	56	64
SUBMISS - SUBSUNK																			
Andre	0,0 %	0,1 %						2	1						3	4	3	8	18
Udefinert Sjø	0,7 %	1,3 %	3	1	7	4	3	9	9	7	7	6	3	2	61	65	70	98	74
Sum Sjø	50,9 %	100,0 %	186	206	320	291	428	600	891	573	359	315	175	178	4522	4472	4443	4053	3416

Land			Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Okt	Nov	Des	Total	2015	2014	2013	2012
	% av Alle	% av Land																	
Alpinulykke	0,3 %	0,7 %	1		2	4	1		3	8	2	3		1	25	37	57	34	34
Assistanse person	8,3 %	19,8 %	26	45	105	69	48	49	100	98	73	60	33	27	733	690	629	529	567
Atomulykke																			
Bombe/terror																	4	1	5
Drukning - kantring	0,7 %	1,7 %	3	7	1	3	8	10	15	2	6	4	2	1	62	75	61	80	100
Farlig gods	0,0 %	0,1 %	2												2				1
Industriulykke	0,1 %	0,1 %		1			1			1		1	1		5	6	3	6	6
Luftambulanse	14,7 %	35,3 %	91	120	111	91	101	82	133	122	108	92	108	149	1308	1210	1281	1089	1001
Naturkatastrofe																5	8	8	2
Nødpeilesender - PLB	1,1 %	2,7 %	2	9	6	21	8	8	5	12	14	6	3	7	101	100	75	95	101
Nødsignaler - pyro - lys - andre	0,5 %	1,2 %	4	6	8	2	1	2	2	3	5	5	5	1	44	48	37	52	53
Savnet person	14,7 %	35,3 %	90	76	90	100	98	94	111	121	137	134	133	122	1306	1253	1212	1251	1284
Skogbrann	0,2 %	0,5 %	1			1	6	10				2			20	15	75	19	8
Skred - ras	0,6 %	1,5 %	7	20	5	6	6	4	1	1		2	1	1	54	53	49	79	64
Transportulykke - jernbane																2	2	2	2
Transportulykke - vei	0,2 %	0,5 %	1	4	1	2	1	2	2	1	1	3	1		19	30	27	35	29
Andre	0,0 %	0,0 %								1					1		1	5	2
Udefinert - Land	0,3 %	0,6 %	2	1	3	2	2	4	2	1		4	2		23	22	28	23	24
Sum Land	41,7 %	100,0 %	230	289	332	301	281	265	374	371	346	316	289	309	3703	3546	3549	3308	3283
Uten Luftamb			139	169	221	210	180	183	241	249	238	224	181	160	2395	2336	2268	2219	2282

Luft			Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Okt	Nov	Des	Total	2015	2014	2013	2012
	% av Alle	% av Luft																	
Bailout																			
Fallskjerm - glider	0,2 %	2,7 %		1	1	1	3	3	1	2	1	2		1	16	13	9	18	17
Havari luftfartøy -på land	0,1 %	1,7 %	3			1	2	2	2						10	5	7	4	1
Havari luftfartøy - på sjø	0,0 %	0,5 %	1			1						1			3		1		4
Nødlanding	0,2 %	3,2 %	1	1	1	2	2	1	2	1	1	1	3	3	19	18	10	20	23
Nødsignaler - IFF - Mayday - Pan	0,1 %	1,5 %	1			2	1	1		1		2	1		9	14	6	15	17
Nødpeilesender - ELT	5,8 %	86,1 %	40	31	38	34	50	49	39	47	40	41	50	54	513	485	470	521	510
Savnet passasjerfly	0,0 %	0,7 %			2		1						1		4	6	2		7
Savnet småfly	0,2 %	2,5 %			1	1		1	1	3	4	2	1	1	15	18	26	19	17
Udefinert luft	0,1 %	1,2 %			3		1				1	2			7	7	6	6	11
Sum Luft	6,7 %	100,0 %	46	33	46	42	60	57	45	54	47	51	56	59	596	566	537	603	607

			Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Okt	Nov	Des	Total	2015	2014	2013	2012
Diverse	% av Alle	% av Div																	
Ekstremvær			2										1	1	4	9	6	3	
Kapring																			
Nødpeilesender 121,5/243	0,5 %	78,3 %	5	2	2	2	5	3	5	9	3	8	2	1	47	57	66	61	51
Telekommunikasjon	0,0 %	6,7 %		1	2		1								4	2	1	1	
Andre	0,1 %	8,3 %	1	1	1	1						1			5	3	3	7	7
Sum Diverse	0,7 %	100,0 %	8	4	5	3	6	3	5	9	3	9	3	2	60	71	76	72	58
			Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Okt	Nov	Des	Total	Total	Total		
Totalt			470	532	703	637	775	925	1315	1007	755	691	523	548	8881	8655	8605	8036	7364

	Januar	Februar	Mars	April	Mai	Juni	Juli	August	Septeml	Oktober	Novemb	Desember		1.halvår	2.halvår	SUM	
2012	504	502	620	602	648	697	870	776	652	558	476	459	7364	3573	3791	7364	
2013	465	435	645	530	741	862	1148	914	644	599	537	516	8036	3678	4358	8036	
2014	495	520	671	681	771	913	1388	862	703	644	491	466	8605	4051	4554	8605	
2015	528	531	685	664	799	813	1173	1114	773	642	493	440	8655	4020	4635	8655	
2016	470	532	703	637	775	925	1315	1007	755	691	523	548	8881	4042	4839	8881	102,6 %

Figure A.4: The 2016 JRCC public statistics of events in Norway. (JRCC, 2017)

APPENDIX B

Complementary statistics for the analysis

In this appendix, complementary statistics from the analysis of the datasets that was not included in the main Thesis are presented.

Number of events in each category at UNIS Table B.1 shows the overview of the number of events in each category from the accident concentration analysis at UNIS.

Summation of categorisation of event causes Table B.2 shows the total number of each contributing factor and deviation from the cause analysis at UNIS and SNSK.

Table B.1: Number of events in each category for the UNIS events.

Category	**#**	**Category**	**#**
Involved		Energy	
Students	58	Gravity	4
Academic Staff	26	Motion	49
PhD	20	Mechanical	11
Other	26	Electrical	1
Location		Pressure	1
Indoors	12	Temperature	14
Outside	7	Chemical	3
Fieldwork	59	Biological	6
Sea	9	Radiation	1
Other	7	Sound	1
Activity		Real loss	
Research	24	None	27
Teaching	35	Material	36
Training	10	First aid	10
Logistics	7	Medical Attention	18
Other	17	Evacuation (medical)	1
Department		Permanent disability	1
HSE / Logistics	14	Death	0
Arctic Physics	2	Potential loss	
Arctic Geology	25	None	1
Arctic Biology	28	Material	13
Arctic Technology	6	First aid	6
Other	18	Medical Attention	9
Other		Evacuation (medical)	6
Scooter	39	Permanent disability	31
External	17	Death	27
HIPO	25		

Table B.2: Summation of categorisation of event causes at SNSK and UNIS based on the cause analysis. M - Man, T - Technology, O - Organisation, D - Deviation.

MTO			**Deviations**		
	UNIS	**SNSK**		**UNIS**	**SNSK**
M1	12	2	**D1**	51	29
M2	7	4	**D2**	21	14
M3	9	12	**D3**	3	0
M4	17	10	**D4**	1	1
M5	37	10	**D5**	16	8
M6	14	11	**D6**	1	1
T1	4	18	**D7**	5	2
T2	28	12	**D8**	5	9
T3	13	0	**D9**	19	3
T4	5	10	**D10**	3	9
T5	2	0	**D11**	39	37
T6	3	4	**D12**	10	8
O1	3	3	**D13**	2	5
O2	17	13	**D14**	4	4
O3	3	9	**D15**	11	4
O4	14	9	**D16**	0	0
O5	9	13	**D17**	0	0
O6	1	0	**D18**	0	0
O7	31	4			
O8	7	0			
O9	4	2			
O10	0	0			
O11	1	0			
O12	9	1			
O13	0	0			

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