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Arctic Safety

Human Reliability in Arctic Environments

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ACKNOWLEDGMENT

The last semester of the Master of Science in Safety, Health and Environment programme consists of writing an obligatory master thesis. By choosing the theme *Arctic Safety* the thesis participants got to use their knowledge of safety theory acquired from majoring in safety combined with their interest for the Arctic.

This thesis would not have been possible to finish without my personal interest in human reliability and the Arctic and without the support from family and friends. Special tanks go to Andreas Skjerve and his supportiveness to go to Svalbard and collect data. The collective collaboration and agreement between me and Skjerve made everything possible.

Kristoffer Gjørtz

Conducting this study has been very interesting and extremely educational. The fact that this is a quite new field and only explored to a small extent it has been challenging, but the very good collaboration with Kristoffer Gjørtz made it doable. The trip we had to Svalbard was especially explanatory and fun, and we received a lot of interesting information both from our own experiences and from very competent people.

Andreas Skjerve

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ABSTRACT

This thesis presents the research on human performance in the Arctic by K. Gjørtz and A. Skjerve in connection with their master's degree during the Spring of 2018. The result is based on face-to-face interviews conducted with various people working and living on Svalbard and observations during the period from 27th of February to 13th of March 2018.

The findings from the research shows that the human reliability analysis available today lacks suitability for activity on land in the Arctic as they stand. Nevertheless, some of the content of the analyses is adaptable for an arctic context. Some of the definition and multipliers of the performance shaping factors (PSF) in this thesis is based on the PSFs from THERP, HEART, NARA, SPAR-H and Petro-HRA.

The main objective in this thesis was to find PSFs that has a significant impact on human performance in the Arctic. From the results of the interviews and the thesis participants own experiences the following PSFs were identified; Time, Experience and Training, Perception of Risk, Procedures, Equipment, Teamwork, Environmental Stressors, Fitness, Task Complexity and Attitude to Safety, Work and Management Support.

SAMMENDRAG

Denne avhandlingen presenterer forskning på menneskelig ytelse i Arktis utført av K. Gjørtz og A. Skjerve i forbindelse med deres mastergrad i løpet av våren 2018. Resultatet er basert på intervjuer gjennomført med ulike personer som jobber og bor på Svalbard og observasjoner i perioden 27. Februar til 13. mars 2018.

Funnene fra forskningen viser at de menneskelige pålitelighetsanalysene som er tilgjengelig i dag er lite velegnet for landbasert aktivitet i arktiske områder slik de er. Noe av innholdet i analysene er overførbart for arktisk kontekst. Noen av definisjonene på og multiplikatorene i ytelsespåvirkende faktorer (PSF) i denne avhandlingen er basert på PSFer fra THERP, HEART, NARA, SPAR-H og Petro-HRA.

Hovedformålet med denne avhandlingen var å finne PSFer som har en spesielt stor innvirkning på menneskelig ytelsesevne i Arktis. Ut fra resultatet fra intervjuene og egne erfaringer hos masteroppgavens forfattere, har de følgende PSFene blitt identifisert; Time, Experience and Training, Perception of Risk, Procedures, Equipment, Teamwork, Environmental Stressors, Fitness, Task Complexity og Attitude to Safety, Work and Management Support.

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Abbreviations

AEMA	Action Error Mode Analysis
EPC	Error producing conditions
GTT	Generic task types
HAZOP	Hazard and Operability Analysis
HEART	Human Error Assessment and reduction Technique
HEI	Human Error Identification
HEP	Human Error Probability
HFE	Human Failure Event
HRA	Human Reliability Analysis
ISO	International Organization for Standardization
MTO	Man-Technology-Organization
MTTF	Mean time to failure
NARA	Nuclear Action Reliability Assessment
NHEP	Nominal Human Error Probability
PSF	Performance Shaping Factors
SHERPA	The Systematic Human Error Reduction and Prediction Approach
SPAR-H	Standardized Plant Analysis Risk-Human reliability
THERP	Technique for Human Error Rate Prediction
QRA	Quantitative risk analysis
(n/k)	Not known or commented

DEFINITIONS

Activity	Can include several actions voluntarily and non-voluntary. It can also include several tasks performed during actions, movement and deeds or the condition in which things are happening or being done.
Human Error	Occasions in which a planned sequence of mental or physical activities fails to achieve its desired goal without the intervention of some chance agency. (Reason, 2017 p. 10)
Human Error Identification (HEI)	..refers to identification, description and analysis of possible erroneous action in performing a task. (Rausand, 2013 p. 427)
Human Error Probability (HEP)	The probability that an error will occur when a given task is performed. (Rausand, 2013 p. 413)
Human Failure Event (HFE)	The effect by which a human error can be observed. (Rausand, 2013 p. 414)
Human Reliability Analysis (HRA)	..is a systematic identification of the possible errors that may be made by operators, maintenance personnel, and other personnel in the system. (Rausand, 2013 p. 411)
Macrocognitive Function	..are the high-level functions through which a cognitive task is accomplished. (Whaley et al., 2016)
Macrocognitive Mechanism	..are the process of which macrocognitive functions work. (Whaley et al., 2016)
Maintainability	The ability of an item, under steady state conditions of use, to be retained, or restored to a state which it can perform its required functions, when maintenance is performed under stated conditions and using prescribed procedures and resources. (Rausand and Arnljot, 2004)
Nominal Human Error Probability (Nominal HEP)	..is the probability of a given human error when the effect of [PSFs] have not been considered. (Swain and Guttmann, 1983)
Performance Shaping Factors (PSF)	A factor that influences human performance and human error probability. (Rausand, 2013 p. 418)
Proximate Cause	Event related to the failure of a cognitive function (Kjellén and Albrechtsen, 2017)
Task	Collection of actions carried out by operators in order to achieve an objective or a goal (Rausand, 2013 p. 412)

1. INTRODUCTION

Because of the increasing activity in the remote and harsh environment of the Arctic one must also keep in mind an increased occurrence of unwanted events. The weather and environmental conditions are the main contributing factors to hazards. Every year, new weather records are set and changes in the climate opens for more activity both on land and at sea. As the sea ice retreats and the temperature increase, the hazards still exist (Førland et al., 2011). These hazards differ a great deal from areas at lower latitudes. Arctic safety management are often divided in to a specific area, for instance offshore and air traffic. However, most of the available Human reliability methods are exclusively developed for the nuclear industry and control room operators (Kirwan et al., 2004). Other methods are shown in **Appendix A** where only a few have a wider general application.

People working in the arctic must rely more on themselves than in many other contexts. Whereas people working in the petroleum and nuclear industry can rely on procedures, automated processes and support from others, people working in the arctic often cannot. The human element is therefore more important during arctic activity than in many other contexts. Safety theory focusing on human performance, such as HRAs, could therefore be used on land and sea ice in the Arctic.

The work in the petroleum and nuclear industry mainly takes place inside a control room while the work in arctic areas are mainly conducted outside. Some work in the petroleum industry requires operations outside and with that the personnel is exposed to the weather conditions, but they have the possibility to go inside if the conditions becomes too challenging. The same goes with marine activity. Since work in the arctic in many cases are conducted far away from infrastructure these “luxuries” are not presents. These factors entail requirements of a different approaches to safety management and the use of different barriers than traditionally.

According to Khan et al. (2015) there is still a need for more studies on human factors in extreme environment. There is a continuing development of standards like ISO, based on experience form countries operating in the Arctic.

Working in a demanding type of environment, like the Arctic, cannot be considered easy. Operations would be impacted by several conditions, making them harder to be accomplished. Distances, inaccessibility and harsh weather in combination with seasonal darkness, will affect the personnel’s ability to perform tasks and activities correctly within the available time. Workers who perform tasks outdoors on a daily basis during the harsh winters would experience a decreased performance and comfort. (Balindres et al., 2016)

Personal interest was the primary motivator to pick the relatively new topic Arctic safety. Within this topic, human factors in extreme conditions was particularly interesting. The increasing activity conducted in the Arctic, makes it an increasingly more relevant topic, and the need for expertise in arctic safety will increase. Due to personal interests, empirical data was gathered during a journey to Svalbard. The empirical data compiles of interviews, personal experiences gained in safety courses and field trips outside infrastructure.

Throughout this master thesis there will be an attempt to enlighten some aspects on challenges one can encounter in the Arctic and to see if there are HRA methods that can be transferred to arctic outdoor context.

1.1. Objective and Scope

The scope of this study was to examine how the arctic environment effects the safety and performance of the humans operating in the Arctic.

Due to the limitations in time it was impossible for the thesis participants to outline an entire HRA. It was therefore, in consensus with the supervisors, chosen to focus mainly on the PSF part of HRAs and secondly suggest multipliers for these.

This thesis is not human reliability analysis, but rather tries to enlighten the reader on what is important in order to identify performance shaping factors. The study can be used in further research on safety during arctic operation and in the development of an HRA or other, less comprehensive, methods intended for the use in the Arctic.

1.2. Problem Statement

This chapter outline the main purpose of the thesis. The thesis focuses on humans operating in the Arctic and how the arctic environment effects their safety and performance. The problem statement below outlines the work through the thesis:

> *Which performance shaping factors will have a significant impact on human reliability in the Arctic, and to what extent?*

Research questions:

From the problem statement the thesis participants have constructed the following research questions;

- *How relevant are today's HRA methods for onshore operations in the Arctic?*
- *How would the PSFs be defined in order to fit work outdoors in the Arctic?*
- *What would be the order of magnitude, levels and multipliers, on PSFs used outdoors in the Arctic?*
- *What needs to be done in order to fulfil the work required for an ArcticHRA?*

1.3. Limitation

Maritime activity is not included. Maritime activity is defined in this thesis as work and traveling in or over open sea water. This means that sea ice is not considered as maritime, but rather as a part of the environment. Also, as Lorentzen (2017) claim, there are a great number of studies conducted on Arctic maritime safety management.

Interviews were conducted on Svalbard and only on fulltime residents in Longyearbyen. This do not limit the thesis to Longyearbyen since major commercial companies are traveling all over Svalbard. The same applies for non-commercial institutions, for example Search and Rescue operators and educational institutes.

This thesis is limited to outdoor activities. This applies for short field trips lasting only a few hours and longer expeditions lasting several consecutive days.

1.4. Structure of the Thesis

This chapter outlines the structure of the master thesis, see **Figure 1**. **Chapter 2** provides information regarding the Arctic, Svalbard and weather conditions and hazards found in the Arctic. At the end there is an elaboration on research regarding arctic safety. **Chapter 3** outline some HRAs and elaborates the fundamental knowledge required to properly understand human reliability. The methodology, **Chapter 4,** describes the approach used to solve the addressed problems seen in **Chapter 1.2.** The methodology is based on theory to find a suitable approach and connect the results to the discussion, in **Chapter 6**.A summarisation of important findings and answers to research questions is shown in **Chapter 7** The discussion connects theory and the result from the interviews to form a conclusion, in **Chapter 8. Appendix A, B, D, E, F, G,** supplements the theory, discussion and conclusion in order to proper solve the problem statement. The semi-structured interview guide is enclosed in **Appendix C.** The transcription is excluded to preserve the identity of the interviewees and uphold anonymity.

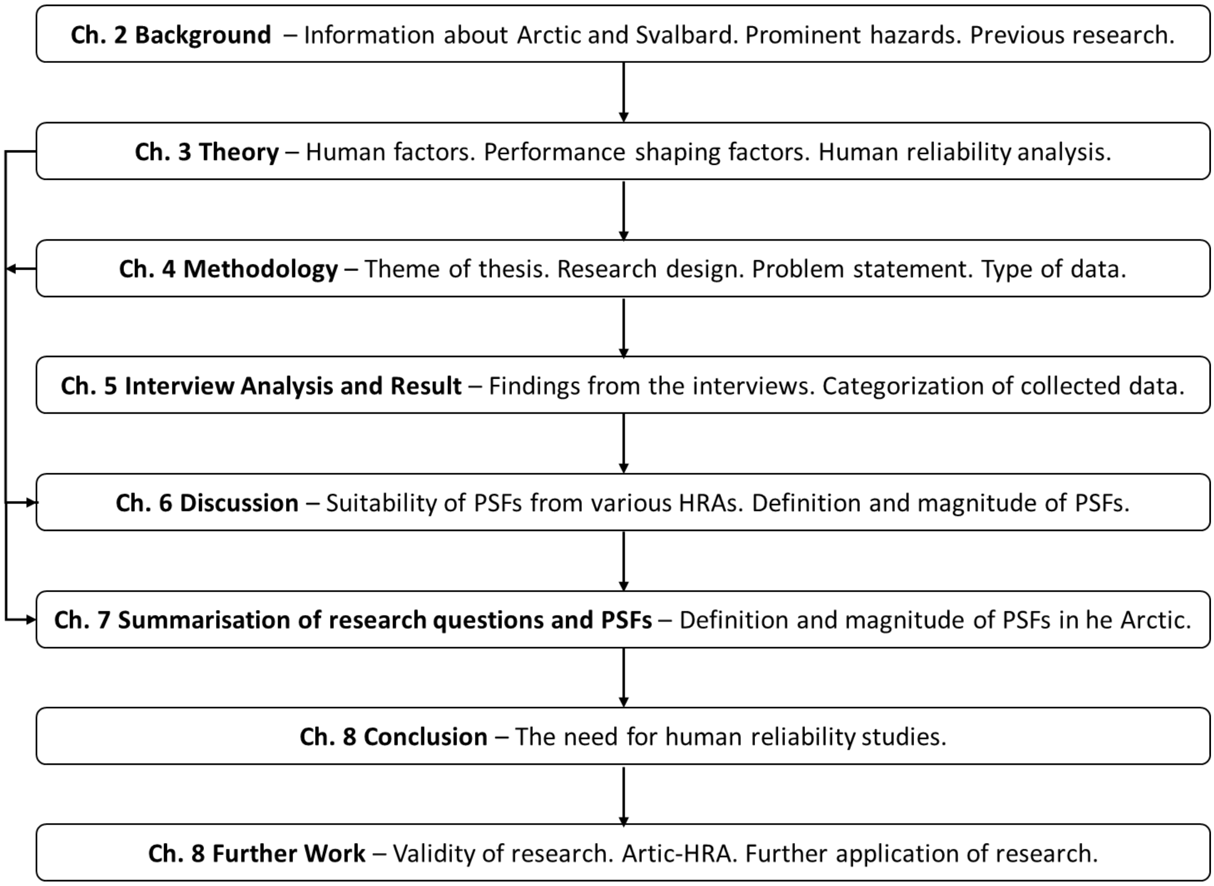

Figure 1 Structure of the thesis and the work flow shown bye directional arrows.

2. BACKGROUND

In addition to the introduction, background information on the Arctic and the archipelago of Svalbard is important for the understanding of the performance shaping factors which might have higher impact on human error probability here than other locations. For instance, how do the PSF impact human performance in the Arctic compared to the environment and areas where the petroleum, nuclear and maritime industry normally operates.

This chapter will give a brief overview on the Arctic weather conditions, topographic, geography and population in the Arctic and the archipelago of Svalbard. There is also an argument stating why human reliability is important regarding accident concentration.

2.1. THE ARCTIC

All over the earth where temperatures are below 0°C, either seasonal or permanent is called the Cryosphere. The Cryosphere makes up a huge area of the earth and includes both Antarctica and the Arctic. The Arctic is a geographical region of the northern cryosphere which is usually limited by a 10 °C isotherm for the warmest summer month. More exact, the Arctic border is commonly defined where the mean temperature of July is below 10°C. Within the Arctic, one can encounter conditions that make life rare, and for most known lifeforms it is a struggle for survival. This makes the Arctic far from an optimal environment for humans which classifies the Arctic as unhospitable and extreme. (Copland et al., 2017, Smithson et al., 2008)

The 10°C isotherm border was first designed by Alexander G. Supan in 1884. It has been improved over the decades and was last reformed by Otto Nordenskjöld in 1928. Nordenskjöl suggested that the Arctic border should cross oceans and be in favour of the coldest month. (Nordenskjöld, 1928, Przybylak, 2016)

The Arctic border passes through Iceland, south of Greenland and through Labrador City in Canada. The border continues through Alaska across the Bering Sea where it aims south. The Arctic border goes through Finnmark in Norway and along the northern edge of Russia. For a more detailed description see **Figure 2**. The map also shows the location of Svalbard, the North Pole and Norway.

Figure 2. The Arctic border (brown line) the Arctic Circle (stippled line) and Svalbard (red circle). (Adapted fromBellamy, 2010)

2.2. WEATHER

The most common way to determine climate is by the geographical latitude and the most used weather factors is wind, cloudiness and temperature. The Arctic have a relatively low air humidity and frequently high windspeeds. Most of the winds are the result of polar cells which contribute to the global circulation. In open ocean around the Arctic, especially between Iceland and Norway towards Svalbard, there are frequently arctic hurricanes (Polar lows). These hurricanes appear when warm air raises over the Atlantic Ocean and drops down over sea ice around the North Pole. (Przybylak, 2016) Lately however, the decline in sea ice could cause fewer polar lows and storms to reach the northern areas (Amundsen and Lie, 2012). More local winds will change rapidly depending to topography and temperature which make them unpredictable. Temperatures in the Arctic are mostly dependent on sunlight, the annually atmospherically circulation and changes in the snow and ice cover.

Weather stations within the Arctic are continuously reporting July as the warmest month, which oscillates and make up the 10 °C isotherm border, see **Figure 2**. For the coldest month there is higher variety, depending on location. January, February and March are usually the coldest, where the mean winter temperature is approximately -36 °C. (Przybylak, 2016) Conditions in the Arctic such as blizzards, avalanches and the continually shifting sea ice and glaciers, makes the landscape alive.

Seasonal nights and days vary with the latitude, on the North Pole polar nights and midnight sun will have a duration of 6 months. Another phenomenon in the high north is the polar refraction. This is caused by the light displacement that occurs when the sun is below the horizon, which results in a longer dusk and dawn. (Przybylak, 2016)

The Arctic cover roughly 8% of Earth's surface and is home to around 4 million people where the majority are indigenous. The Arctic is also known for its wildlife and vast resources which might be the cause for why humans have lived there for thousands of years. (Sammallahti, 1990, Przybylak, 2016)

2.3. SVALBARD

The archipelago of Svalbard is located between 74 ° and 81 ° north latitude and 10 ° and 35 ° east longitude, see **Figure 2**. Svalbard is a part of Norway but is shared with Russia through the Svalbard Treaty. The archipelago have around 2750 inhabitants where Longyearbyen has the highest population density, see **Figure 3** (SSB, 2017, Aars and Vongrave, 2017).

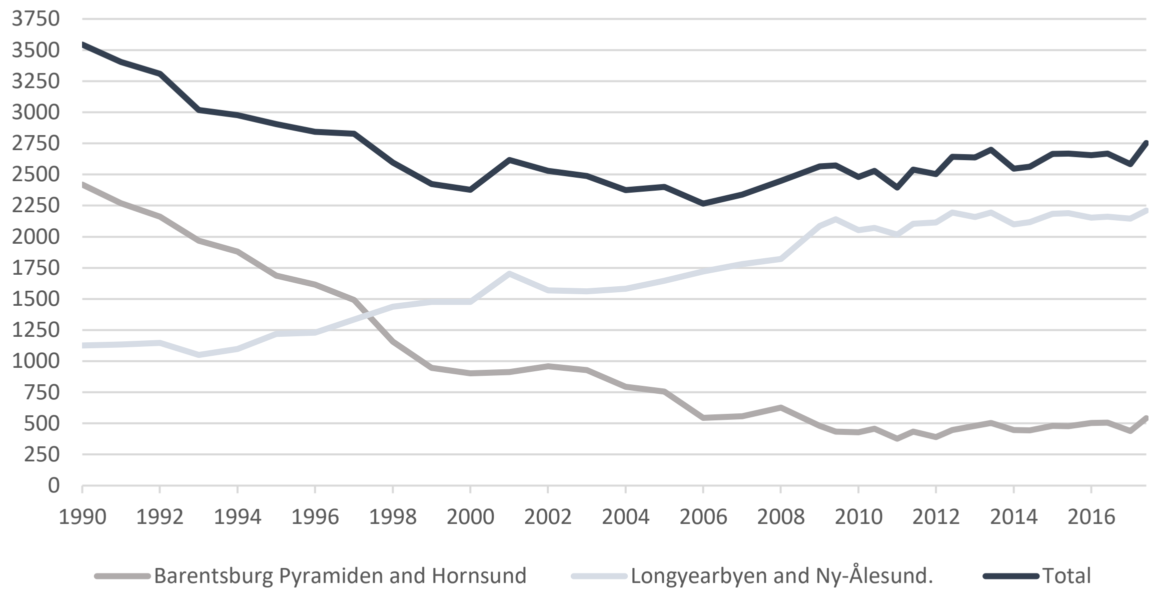

Figure 3. The decline in population for Barentsburg, Pyramiden and Hornsund and an incline in the population for Longyearbyen and Ny-Ålesund (SSB, 2017).

Svalbard is a popular traveling destination because of its relatively mild climate. Statistically, with a higher population density and more tourisms there will be an increase in unwanted occurrences. Temperature in the Atlantic sea and low air pressure from nearby Polar lows keeps Svalbards weather is mild compared to other places with the same latitude. This way tourist can experience the exotic arctic climate without participating in even more dangerous expeditions. (Polarinstitutt, 2016, Anker and MOSJ, 2014)

The archipelago of Svalbard covers an area of 61 022 km^2, where the climate differs a great deal. On the coast line west from Spitsbergen the winter temperature fluctuates between -8 and -16 °C, but it may drop to below -30 °C in just a few hours. The north and eastern coastline is covered by ice 8-9 month of the year, but the west coast may not have any ice at all through the winter. The permafrost on Svalbard reaches down 450 meters and only the first layer of one meter melts in the summer. Svalbard is constantly cover by about 60% ice, and the annual precipitation is about 300 to 500 mm but varies a lot from area to area. Like the rest of the Arctic, Svalbard has relatively low air humidity and gusty dry winds which can change rapidly. With only 10% of Svalbard covered by fauna the wind meets few obstacles. (Anker and MOSJ, 2014)

Temperatures measured at Longyearbyen Airport from August 2016 to 2017 shows July 2017 as the warmest month with an average temperature of 6.9°C. The same year the lowest temperature was -23,5°C, measured 18th of March. (NRK and Metreologisk Institutt, 2017) The lowest temperature ever measured at Longyearbyen Airport reached -46,3 °C in Mars 1986, where the all-time high was measured to 21,3 °C in July 1979. (Polarinstitutt, 2016)

From 20th of April to 23rd of August the midnight sun is visible and can be observed along the horizon. The polar nights last from 26th of October to 15th of February. (NRK and Metreologisk Institutt, 2017).

The preservation of the environment on Svalbard is important to the local inhabitants and the government of Norway. The first environmental preservation acts were introduced in 1914, today more than 65% of the total land is nature conservation area. Preservation programs like Environmental Monitoring of Svalbard and Jan Mayen (MOSJ) is monitoring the health situations of the fauna and the environment. (Sander, 2005)

2.4. HAZARDS

The Arctic is home to many hazards, typical encounters during winter season includes: snow mobile driving, avalanche terrain, sea ice, glaciers, harsh weather conditions and polar bear encounters. Typical hazards encountered during summer season include: harsh weather, rough ocean conditions, camp challenges, polar bear encounters, and hazardous slopes when travelling in steep mountainous terrain. (Indereiten et al., 2017) **Chapter 2.4.1** through **2.4.5** account for some of the most common hazards.

2.4.1. Environment

Mountain slopes can have overhanging cliffs and ice sheets which can be fatal if triggered. The wind direction and the weather conditions form overhanging snow and ice shelves which increases the risk of an avalanche. The ground on Svalbard is covered by lose rocks, making climbing mountain sides dangerous. Since there is permafrost binding the mountain together, changes in the climate and mild weather will loosen these bindings. Mountains on Svalbard have a relatively high rock tension which causes the mountain to crumble into pieces slowly.

Distances are one of the challenges on Svalbard and in general all over the Arctic. When traveling far outside infrastructure the access to proper medical facilities and rescue options decreases.

Avalanche is a fast flow of snow traveling downhill or down slopes. When mild weather meets frosty ground in combination with the other conditions, an avalanche can occur. There are naturally locations and seasons where the risk of an avalanche is higher. The seasonal risks for an avalanche are highest from December to April. (Philpott, 2006)

Glaciers or ice glaciers forms over several years. They are made by participation that becomes compressed by weather into dense ice masses. Glaciers behaves like rivers, since they flow slowly downhill due to their size and mass. They come in different size and shapes, some are small while others are hundred thousand of cubic meters. Glaciers can cause avalanches, local flooding and tsunamis (Philpott, 2006).

Crevasses are deep cracks or gaps in ice or glaciers. They are made by the natural movements in the ice or glaciers. The crevasses can be hard to detect on the surface due to snow coverage, or weather conditioning with low visibility. Falling in one can lead to fractures, and if not found, death.

Rivers in the spring and summer can be muddy and it is difficult to see how deep they are. The flowing water can make people slip and fall in crossings. Getting wet, even in the spring, can be serious if no extras clothing is are brought.

Slippery surface on ice, hard packed snow or wet ground can potentially be dangerous. No matter the means of transportation, movement over slippery surfaces can cause accidents.

Sea Ice

Sea ice has many hazards, closing cracks, thin sea ice and the risk of falling through. Changes in the sea ice can potentially make previous tracks across the sea ice deceptive. Following old tracks, might lead one into open sea water. Driving snowmobile into bumps and jumbled sea ice can cause the snowmobile to flip and crash.

Cold shock response happens when a person is immersed in cold-water. This might lead to a respiratory gasp, reduces the breath-hold time and risking the inhalation of water. The risk increases further in difficult water (high waves etc.) or if the person is forcefully immerged, for instance with heavy clothing. This will result in inefficient swim stroke mechanic, and further risking inhalation of water and swim failure. Hyperventilation may also result in spasms, cramps, disorientation and loss of consciousness which might eventually lead to drowning. (Tipton, 1989)

Wild life

The Arctic regions have a bigger diversity of animal species then Antarctica, and includes animals from North America, Europe and Asia. On Svalbard one can encounter only a few mammals for example reindeers, the Arctic fox and polar bears

Polar bears (Ursus maritimus) can be found all over the Arctic on ice-covered waters and on land. Polar bears are classified as a vulnerable species, which means they are predicted to decline in population by 30% in the next 3 generation, because of reduced area or quality of habitat. Polar bears are most common along the coastline closes to their hunting terrain but can be encountered anywhere on Svalbard. Polar bears are carnivorous and feed mostly on seals, they are also known to take down larger pray like walrus and beluga. During ice free seasons, Polar bears might also eat plants, birds and fish if available. (Wiig, 2015) Polar bears are extremely dangerous, and can easily kill a human. From 1870 to 2014, 20 people have been killed and 63 were injured from Polar bear attacks. In the later decades, there has been an increase in reported attacks. Between 2010 and 2014 there were a total of 15 reported attacks. (Wilder et al., 2017) This might be due to increased activity in the Arctic and changes in its habitat.

Tapeworm (Echinococcus multilocularis) is a parasite that is potential lethal to humans. In the Arctic, this parasite ends up in humans after contact with infected dog or fox excrements. Foxes get infected by feeding on voles, lemmings and other intermediate hosts. Small rodents ingest these eggs from plants, water, berries and on other places where foxes have defecated. This tapeworm species was first discovered on Svalbard in 1999, later there have been several reported incidents of infected humans. The tapeworm will cause permanent liver damage (alveolar hydatid disease) which will eventual kill the carrier in 7-10 years, if not treated.(Fuglei et al., 2008)

Walruses (Odobenus rosmarus) are huge sea mammals with external tusks. In large walrus males, tusks can become 1-meter long. Walruses are extremely social creatures and are normally found in large groups. The walrus males can grow to 3.6 meter in length and can weigh up to 1,5 tons. The large males are extremely territorial and will try to chase of intruders. (Lowry, 2016) Males with large tusks are dangers and can easily pierce small bouts and kayaks. Walruses can be found by the shores around Svalbard and is best avoided.

Weather in the Arctic

During the stay on Svalbard the harsh conditions were experienced first-hand. The day of arrival everything was covered in ice. Several people encountered said that these strange conditions, never before seen, were due to the changes in the climate. When combining cold temperatures and wind with other special surroundings like geography and topography, some conditions could pose a threat to human health.

Wind-chill temperature (WCT), illustrated in **Figure 4**, is a person's perceived temperature, which is not necessarily the same as measured air temperature. Through metabolism, the body produces a warm layer of air around itself to keep warm. Winds sweeps away this layer, increasing the amount of heat transferred away from the body. With an air temperature of -10°C and winds speeds of 30 km/h (8m/s), the experienced temperature will be -20°C. (Ahmad et al., 2016)

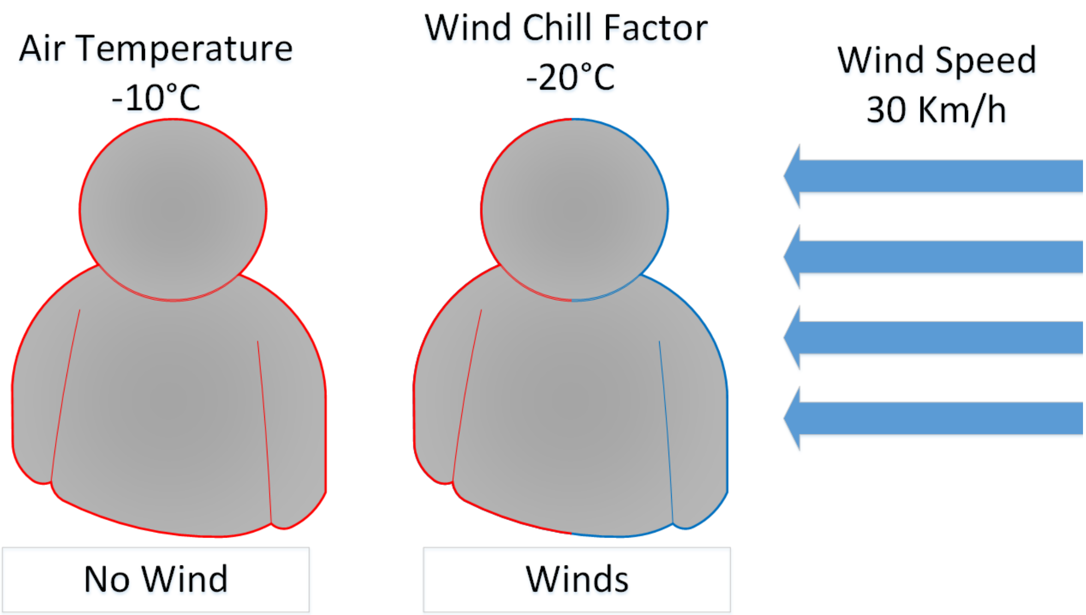

Figure 4 Experienced temperature is lower if winds are present.

Blizzards are defined as storms lasting more than 3 hours, with winds over 56km/h and that reduces visibility to less than 0.4 km. (Philpott, 2006) When cold temperatures become extreme, the dangers of a blizzard will be significant. There have been many lives lost due to the conditions followed by a blizzard. The visibility in combination with the cold is usually the cause.

Whiteout are weather conditions with zero visibility caused by flaccid snow whirled up by the wind.

2.4.2. Equipment

Incorrect rifle handling can cause misfire and unintentional discharge. An unintentional discharge happens if the rifle is loaded and there is a bullet in the chamber. Hitting the rifle into something can cause it to fire. If the bullet hits someone, it is most likely the persons will suffer sever injures. Expanding bullets used for hunting and polar bear protection is extremely lethal. The rifle should always be carried half loaded outside infrastructure.

Vehicles like cars, snowmobile, ATVs, dogsleds, belt wagon are often used for transport on Svalbard. Increase in velocity means increase in the kinetic energy. The increases in kinetic energy will cause grater harm to potential vulnerable objects. Crashing and flipping can occur even with experienced drivers.

2.4.3. Frostbite

Frostbite is tissue damage caused by cold exposure. Frostbite can range from mild superficial frost damage on skin, which can lead to a stinging or a burning sensation. It can also cause blisters and more severe injuries. The other type is deep frostbite where tissue loss is inevitably. Frostbite can be categorized in the same way as burn degrees, where 1st and 2nd are superficial and 3rd and 4th are deep frostbite. Some of the tissue damage may also be similar as with burns. (Schaider, 2015, Frostbite)

2.4.4. Hypothermia

Hypothermia is the medical term used when the body temperature gets below 35°C. There are 3 categories of hypothermia: Mild (32 – 35°C) is the initial phase to combat cold. This phase involves shivering, increased heart rate, contraction of the blood vessels and abnormal breathing. Phase two or moderate hypothermia (28 -32°C) may show signs of decreased consciousness and respiratory rate. In this phase, the victims pupils become dilated and the shivering ends. (Schaider, 2015, Hypothermia) phase two might also cause impaired judgment which can cause the victims to remove their clothing, a phenomena called *paradoxical undressing* (Ambach, 1993). The last case is severe hypothermia (below 28°C). In this case the victim of cold may be in a coma and may not breathe. In this stage, death is imminent. (Schaider, 2015, Hypothermia)

Most research on hypothermia cases, derives from World War II. Some documents describe how water temperatures from 4 to 9°C is lethal after 50 to 100 min (Turk, 2010). But this will vary a great deal depending on shape and physics on the individuals.

2.4.5. Fatigue

Glavin (2011) defines fatigue as "*the state of tiredness that is associated with long hours of work, prolonged periods without sleep or requirements to work at times that are out of synch with the body's biological or circadian rhythm*". Fatigue affects cognition, motor skills, communication and social interaction. (Glavin, 2011 p. 203)

2.5. ARCTIC SAFETY EVENTS

In 2017, J. P. Lorentzen conducted an accident concentration analysis to identify clusters and patterns in reported events for Store Norske Spitsbergen Kullkompani (SNSK), The University Centre in Svalbard (UNIS) and The Joint Rescue Coordination (JRCC). Lorentzens thesis was limited to land and outdoor events on Svalbard. (Lorentzen, 2017)

2.5.1. Accident cause analysis

Lorentzen used a combination of Man-Technology-Organization (MTO) and the Deviation Checklist by Kjellèn and Albrechtsen to identify the cause of the incidents. The total events identified as human errors were 80. The 414 events from JRCC were not included in Lorentzens thesis. In **Table 1** only the category *Work situation* and the sub-category *human errors* and its values is used to highlight events caused by humans and in what contexts. (Lorentzen, 2017)

Human errors that correlate to Human/behavior, Technical/physical and Organizational/ economic is shown in **Table 1** . There was no clear explenation as to why these events correlate to contributing factors of the MTO model. But assuming that Lorentzen had correctly defined human errors, this data can help confirm the need of an HRA or other methods for an arctic context.

Table 1 The Man-Technology-Organization model for classification of contributing factors in incidents. (Kjellén and Albrechtsen, 2017)

	Number of events identified as human errors (Adapted fromLorentzen, 2017)	
Human/behavioural:	**SNSK**	**UNIS**
- 1 Supervision, instructions	1	7
- 2 Informal information	3	5
- 3 Workplace norms	9	6
- 4 Individual norms and attitudes	9	15
- 5 Individual qualifications and experience	5	29
- 6 Special circumstances	6	7
Technical/physical:		
- 1 Workplace layout - Access to equipment - Walkways, transportation routes - Safe distance between moving equipment	4	0
- 2 Design of equipment - Physical hazards - Reliability - Man-machine interface	8	13
- 3 Physical working environments	0	5
- 4 Protective equipment, guarding	7	0
- 5 Work materials, chemicals	0	0
- 6 Safety equipment and systems	4	3
Organizational/economic:		
- 1 Work organization, manning, job description	2	2
- 2 Activity planning	9	10
- 3 Methods of work, work pace	8	3
- 4 Instructions, work procedures	7	8
- 5 Maintenance routines, work permit	1	4
- 6 Management of change	0	1
- 7 Education, training of personnel	3	24
- 8 Supervision	0	3
- 9 Systems of remuneration, promotion, sanctioning	2	3
- 10 Controls of other types (e.g. economic, third party")	0	0
- 11 System of shift, work schedule	0	1
- 12 Routines in safety work	1	6
- 13 Organization of on-scene emergency management	0	0

Lorentzen (2017) found that of the 94 events analysed from UNIS, 51 was determined to have a correlation to human error. Of the 73 events analysed from SNSK, 29 events were identified as human error. These events are shown in **Table 1**.

2.6. Previous Research on Human Performance in the Arctic

There is little research conducted within the limitations of this thesis. Some studies can still be relevant regarding the problem addressed. Noroozi et al. (2014) presents a revised method of HEART. Their paper concluded that HEP calculated in normal conditions are not compatible with scenarios in harsh and cold conditions and that cold and harsh conditions have a significant effect on human reliability due to the colds effect on cognitive performance. Mäkinen (2007) looks at the effect of cold exposure on performance and conclude that cold reduces performance on tasks of low physical activity and tasks that requires concentration and vigilance. According to Khan et al. (2015) there are significant differences on HEP in cold and normal conditions. Khan et al. (2015) also conclude that harsh environment affects complexity, uncertainty, and time available, and that fatigue occurs to a greater extent in these conditions.

3. THEORY

This chapter includes the theory required for the further work. The most important part of this thesis is the human element and how people react in an arctic context. Therefore, the first part of the chapter is about human factor and humans' cognitive functions. Following is an elaboration of performance shaping factors and how these influence cognitive functions. The last part is a presentation of different HRAs and how these make use of PSFs.

3.1. HUMAN FACTORS

When systems that are dependent on some sort of human action is designed it is important to consideration basic human capability, such as perceptual abilities, attention and memory span, and physical limitations. The foundation for the field of human factors was laid before the 20th century, but the technical advances in WW2 was the major impetus for development of the field. Human factors is defined as "*the scientific discipline concerned with the understanding of interaction among humans and other elements of a system and profession that applies theory, principles, data and other methods to optimize human well-being and overall system performance*" (Proctor and Van Zandt, 2008 p. 9).

3.1.1. Human Performance

Research on Human performance focuses on human capabilities involved in perceiving and acting on sense impression. (Proctor and Van Zandt, 2008) Human performance involves both cognitive performance and humans' ability to act on the output from the cognitive performance.

Physical Performance

Physical performance includes endurance, muscular fitness, and physical skills. Endurance is the ability to perform a task for a long continuously period of time. Muscular fitness refers to the condition of the functional properties of the muscles, such as power, force production and velocity. Physical skills are the skills required to perform a task, and to perform the task in an effective and accurate way.

According to Khan et al. (2015) "*Age should be considered for people working in extreme environments."* This was further explained by the different in the fatigue threshold individuals have by different genders, age, and general health. To not discriminate gender, age and other individual properties, he suggested a medical examination and fit-for-work analysis.

3.1.2. Human Error

Human error is understood differently by different people, and there is no standardized definition of the term. James Reason defines human error as *"occasions in which a planned sequence of mental or physical activities fails to achieve its desired goal without the* *intervention of some chance agency"*. This definition is followed by the statement that *"the definition is in no way a definition that 'blames the human.' However, it denotes a basic event that represents the failure of a component, system, or function in which human actions are involved"*. (Rasmussen, 2016 p. 11)

Actions may fail to achieve its desired goal due to the execution of an inadequate plan or wrongly executing an adequate plan. J. Reason divides human error into three main categories: slips, lapses and mistakes, illustrated in **Figure 5.** (Reason, 1997)

- ***Slips*** are actions that are carried out with the correct intention but are executed wrongly. These errors are often observable and are associated with attentional or perceptual failures.
- ***Lapses*** are similar to slips but is often not observable. These failures are associated with failure of memory, like forgetting to execute the action or forgetting the intention for the action.
- ***Mistakes*** is further divided into *rule-based mistakes* and *knowledge-based mistakes*. Rule-based mistakes involves either the misapplication of a good rule, the application of bad rule, or a *violation.* Knowledge-based mistakes happens when a person lacks knowledge of adequate solutions to a problem. Violations are deviations from safety standards, rules and regulations.

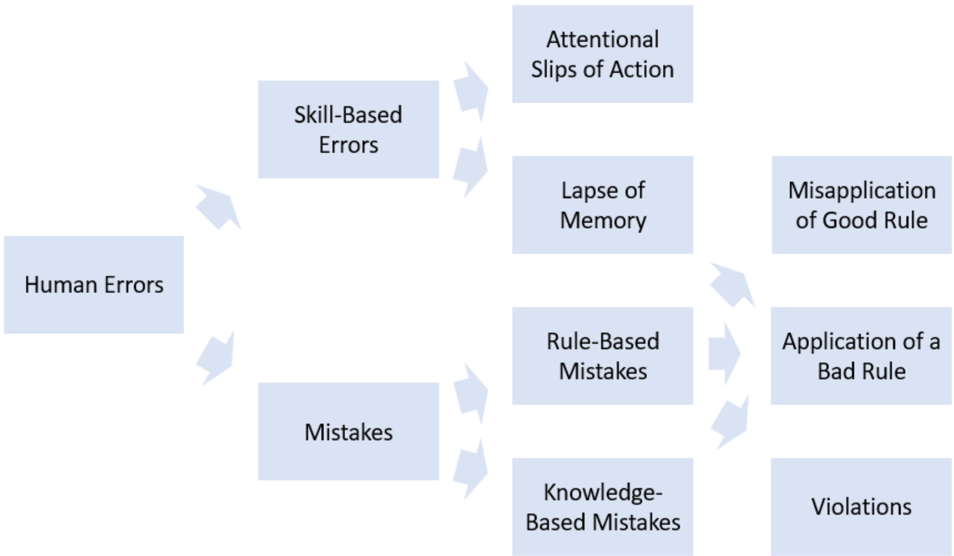

Figure 5 The different types, and "sub-types", of human error. (Adapted from Reason, 1997)

3.1.3. Macrocognition

The term macrocognition was first used by Erik Hollnagel and Pietro Cacciabue to describe cognitive functions performed in natural setting. Macrocognition focuses on the real world rather than the traditions lab-based research. In real life settings, decisions are often seen in connection with complexity, time pressure, high stakes and high risk. The conditions under which these decisions have to be made can seldom be altered. (Klein et al., 2003)

Several macrocognitive methods describing macrocognitive functions has been developed. Whaley et al. (2016) adapted a macrocognition model that consist of five macrocognitive functions:

- ***Detection and noticing*** is the process of detecting problems and perceive important information. The sensory and perceptual processes that makes it possible to perceive large amount of information and focus on the important information is central in this function. Humans can only retain sensory information for a limited amount of time and can only handle a limited amount of this information at a time.
- ***Understanding and sense-making*** is the process of understanding the perceived information and making sense of the situation. This function involves sense-making, situational awareness, interpretation of information, and combining information with knowledge to coherent the situation. The three main sources of failure in this function is perceiving wrong information, wrong understanding of the information or a combination of these.
- ***Decision-making*** is the process of selecting goals, planning, evaluating and selecting a response to achieve the goals.
- ***Actions*** is the implementation of an action on a singular manual action level or a sequence of actions. This action is implemented to achieve the selected goal. Successful execution of the previous functions is essential.
- ***Teamwork*** focuses on how people interacts with each other in the coordination process of execution of tasks. This function fails if the leadership and communication is not sufficient.

(Kjellén and Albrechtsen, 2017, Whaley et al., 2016)

Macrocognitive mechanisms are the processes which cognition takes place. A failure in a macrocognitive mechanism may manifest into a proximate cause of a failure in a macrocognitive function. Whaley et al. (2016) identified a set of proximate causes listed in **Table 2**

Table 2 Proximate causes linked to the macrocognitive functions (Adapted from Whaley et al., 2016).

Macrocognitive Function	Proximate Cause
Failure of Detection and noticing	- Cues/information not attended to - Cues/information not perceived - Cues/information misperceived
Failure of Understanding and Sense-making	- Incorrect data - Incorrect frame - Incorrect integration of data, frames, or data with a frame
Failure of Decision-making	- Incorrect goals or priorities set - Incorrect pattern matching - Incorrect psychological simulation or evaluation of options
Failure of Action	- Failure to execute desired action - Execute desired action incorrectly
Failure of Teamwork	- Failure of team communication - Failure in leadership/supervision

3.2. Performance Shaping Factors

PSFs are factors that influences human performance, either in a positive or negative way. These factors are often used in HRAs to estimate the probability for human error (HEP). Swain and Guttmann (1983) divides PSFs into three classes, external PSFs, internal PSFs and stressors. The main purpose of studying PSFs is to determent if human performance is highly reliable, highly unreliable or somewhere in between. The categorization of PSF and the definition of what they involve is dependent o which HRA is used. Some HRA methods and their PSFs is further elaborated in **Chapter 3.3.** In **Appendix B** PSFs for several other HRA methods is shown.

External PSFs defines the work situation of the people involved in the system, who keeps the system performing reliably and safe. Swain and Guttmann (1983) divides these PSFs further into three categories:

- ***Situational Characteristics*** influences the whole system, such as physical work environment, organizational structure, work hours and supervision.
- ***Task and Equipment Characteristics*** is restricted to a given task or subtask, such as perceptual and motor requirements, feedback of result and Human-Machine Interface.
- ***Job and Task Instructions*** is connected to the instructional material used for the task, such as procedures, communication and work methods.

Internal PSFs are related to the individual. Some of these factors cannot be controlled by supervision and management. Nevertheless, some can be influenced positively by policies.

- ***Individual factors*** are factors such as training and experience, state of current skills, personality and intelligence, motivation and attitudes, sex differences, physical condition and susceptible to influence both internally and externally.

Stressors is defined by Swain and Guttmann (1983) as "*any force that produces stress*" (p. 3-11), where stress is defined as "*a continuum, ranging from a minimal state of arousal to a feeling of threat to one's well-being, requiring action*" (p. 17-1). The threat may be to one's psychological and physical well-being, or often to both. In most cases it is favourable to use the term stressors instead of stress, because they are often easily measurable.

- ***Physiological stressors***, such as fatigue, discomfort or constrains by special clothing, hunger and thirst, directly effects physical stress.
- ***Psychological stressors***, such as task load and speed, monotonous work, threat stress, conflict of motion and distractions (noise, glare, light etc.) directly affects mental stress.

Figure 6 shows how performance shaping factors affects cognitive mechanisms, which can lead to a proximate cause of a failure in a macrocognitive function.

Figure 6 Relationship between the elements of macrocognition

3.2.1. PSF Quantification

As with the type of PSFs, estimated impact of the PSFs varies from one HRA to another. Usually a set of *levels* are used to describe the impact of PSFs. These levels are in turn given *multipliers*, making it possible to calculate HEP. **Appendix B** shows a full comparison between different HRA methods and their respectively levels and multipliers. The following chapters outlines the different methods to calculate HEP.

3.3. HUMAN RELIABILITY ANALYSIS

An HRA is a method for identification and evaluation of possible errors that may be caused by humans in a system. The main objectives of an HRA is to identify and analyse important human interactions, to quantify the probability of success or failure for a given situation, and to provide insight for improvements in human performance. The main steps, which can be split into sub-steps, of a HRA is: (Rausand, 2013)

- Identify critical tasks where humans can cause unwanted situations.
- Analyse these tasks and split them into subtasks.
- Identify and classify potential HFEs, the causes and respective PSFs.
- Determine HEP for each HFEs and the entire task.

Petro-HRA operates with 7 steps; Scenario description, Qualitative data collection, Task analysis, Human error identification, Human error modelling, Human error quantification and Human error reduction, illustrated in **Figure 7** (Bye et al., 2017). The 6 first steps in Petro-HRA can be seen as sub steps of the four steps from Rausand (2013). Petro-HRA includes error reduction as a step, which is an important part of HRAs.

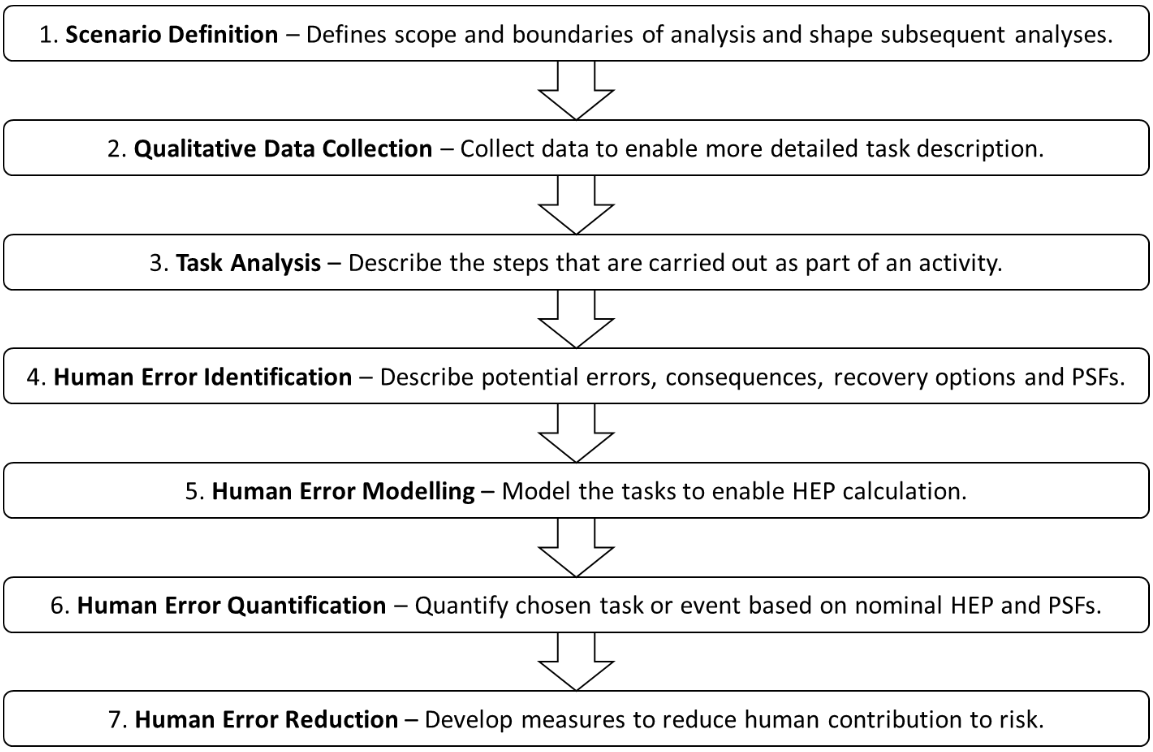

Figure 7 The seven steps in the Petro-HRA guideline (adapted from (Bye et al., 2017)).

Human Error Identification

"*Human error identification refers to identification, description and analysis of possible erroneous action in performing a task.*" (Rausand, 2013 p. 427) It is usually impossible to identify all possible HFEs but by using one of several methods, it should be possible to identify the most important HFEs. Action Error Mode Analysis (AEMA), Human Hazard and Operability (Human HAZOP) and The Systematic Human Error Reduction and Prediction Approach (SHERPA) are examples of HEI methods. (Rausand, 2013)

Human Error Probability (HEP)

HEP is the calculated probability for at least one human error occurring when a given task is performed. HEP is, as mentioned earlier, influenced positively or negatively by PSFs. To estimate HEP, the chances of failure without the interference of PSFs, called nominal HEP (NHEP), must be estimated. NHEP for a task is estimated based on large amount of data or based on expert judgement. How the NHEP is estimated and the values depends on the HRA. **Equation 1**. Is a simplified version to illustrate the calculation of HEP. A similar approach is used in SPAR-H, Petro-HRA, HEART and NARA.

$$[Tasks\ or\ conditions] * \prod [PSF\ Multipliers] = HEP \qquad \textbf{Equation 1.}$$

The total probability of failure can never exceed 1.00. In other terms the HEP must be considered to be 100% if multiplication of the factors exceeds this value.(Williams, 1988)

Chapter 3.3 elaborates five different HRA methods, THERP, HEART, NARA, SPAR-H and Petro-HRA.

3.3.1. THERP - Technique for Human Error Rate Prediction

THERP was developed for the nuclear industry by Swain and Guttmann (1983). It is based on human reliability studies at Sandia national Laboratories in the early 1950s for military systems. Swain and Guttmann (1983) defined THERP as "*a method to predict human error probabilities and to evaluate the degradation of a man-machine system likely to be caused by human errors alone or in connection with equipment functioning, operational procedures and practices, or other system and human characteristics that influence system behaviour*". (, p. 5-2)

3.3.2. THERP Quantification

Modifiers have a function similar to PSFs, but only Stress, Experience and Population Stereotypes are included. THERP is a comprehensive and complex method that requires substantial training. The method is time-consuming and can be excessive for many assessments. As Reason (1990) conclude; "*THERP remains an art form – exceedingly powerful when employed by people as experienced as Alan Swain and his immediate collaborators, but of more doubtful validity in the hands of others*" (p. 224) Due to this and time required to properly comprehend THERP was grater then time available, only a simplified version of THERPs approach is included. The basics of this method can be seen in **Equation 2**.

$$[Error\ and\ task\ Tables] \rightarrow [Nominal\ HEP] * [Modifiers] = HEP \qquad \textbf{Equation 2.}$$

3.3.3. THERP Definition of PSFs

THERP is used to generate quantitative estimates of *task reliability* and *recovery factors* based on estimates of human reliability. The *dependences level* and recovery factors in task reliability among human performance, equipment performance, other system events and outside influences, are used in the estimate. Another PSF used is called *populations stereotype.* This is used to generate quantitative approximations in populations effects on tasks or so-called *task effects.* Populations stereotypes is a potent PSF and was included in THERP to help express the estimates of HEPs in task reliability and recovery. The task effect is the probability that unrecovered errors will result in undesirable consequences to a system. Task reliability is the estimate for the probability for a task to be successful. Recovery factors is the estimated probability to detect and correct a task performed incorrectly and avoid an undesirable consequence.

It is not possible to follow a step-by-step sequence from the first to the last page in THERPs approach. Most of the applications of THERP contains estimates of the probabilities that system-required tasks will be executed correctly and, in some cases, within specified time limits. (Swain and Guttmann, 1983)

Dependence

Dependence is defined as the situations where the probability to fail in task A influence the probability to fail in task B. In short failing Task A will imitable cause failure in Task B. The dependency may exist between two tasks performed by one person, or between the tasks performed by different persons. *Coupling* was a term used similar to dependency/ independency. THERP is using dependence as a PSFs were there are 5 levels; zero dependence or independent (ZD), low dependence (LD), moderate dependence (MD), high dependence (HD), and complete dependence (CD). (Swain and Guttmann, 1983)

Experience

THERP defines *Experience Level* as the amount of involvement a person has on the job he is performing. (Swain and Guttmann, 1983) *Novice* are operators with less than 6 months of involvement at a specific plant. New operators will experience one or more transitory states and will not develop a familiarization for the specific plant with past experiences. In THERP one is considered *skilled* after 6 months which is accepted as the time required for a person to achieve full performance capability. This was usually achieved over a period of 2 years but more commonly operators had more than the minimum requirements before finishing this period of training.

THERP modifiers for novice and skilled can be found in **appendix E – "***Modifications of estimated HEPs for the effects of stress and experience level."*(Swain and Guttmann, 1983)

Stressors and stress

THERP classifies stress and stressors as psychological stressors and physiological stressors. The identifications of these factors are often subjective. And therefore, including and excluding the different types is typical done for the specific environments. Psychological stressors include task speed, distractions, monotonous work, threats from supervisors, and emergency situations. Physiological stressors include fatigue, discomfort, constriction of movement, and high temperature. This also includes positive and negative aspects of stress.(Swain and Guttmann, 1983)

"Men under stress are fools, and fool themselves."

Michel De Montaigne (1533-1592)

The stress variable is represented in 4 levels are very low (insufficient arousal to keep alert), *optimum (the facilitative level),* and the two levels of high stress: *moderately high (moderately disruptive), and extremely high (very disruptive).* The first three levels were designated as task stress, which results from a very low task load, an optimum task load, or a heavy task load. The highest level stands for threat stress and implies emotional reactions to the tasks and difficult situation. (Swain and Guttmann, 1983)

Populations stereotypes

Population stereotypes is considered a strong PSF and Swain and Guttmann (1983) describes this PSF as "*the expectancy that certain groups have for: certain modes of control activation, or modes of display presentation, outcomes, or meanings"* (p. 2-6). In THERP, this expectancy is called populational stereotypes. *"Any design that violates a strong populational stereotype means that the user must learn to inhibit his expectancies. Even with extensive training, it is difficult to change a populational stereotype completely. Under high stress levels, we tend to revert to our populational stereotypes despite training to the contrary."* (p. 2-6).

3.3.4. HEART - Human Error Assessment and reduction Technique

HEART is a first generation HRA technique developed by J. C. Williams. The method was originally designed for US nuclear power plants but it has been applied in variety of industries. The method assesses human reliability in different tasks called Generic Task Types (GTT). Under "*perfect*" conditions the human reliability for each task is, within a percental limit, consistent. When the conditions are not "*perfect*" the level of reliability is affected by factors called error producing conditions (EPC). (Williams, 1988)

3.3.5. HEART quantification

HEART includes 9 GTTs and 38 EPC and is shown in **Appendix D** with their respective multipliers. Each EPCs has an assessed proportion of affect (POA), with value from 0 to 1. **Equation 3** shows that by multiplying the nominal reliability, NHEP for the GTT with the product of the assessed effects, where ω_i is the multiplier and p_i is POA, the analyst can calculate HEP. (Rausand, 2013)

$$NHEP \cdot \prod_{i=1}^{38}([(\omega_i - 1) \cdot p_i] + 1) = HEP \qquad \textbf{Equation 3.}$$

8 of the Generic tasks types are specified and for other tasks types HEART suggest the NHEP 0,03 for "*Miscellaneous task for which no description can be found"* (Williams, 1988 p. 439)

3.3.6. NARA - Nuclear Action Reliability Assessment

NARA method is a simplified version of HEART. It uses the same approach for calculating HEP as in HEART. NARA consists of 19 EPC and 13 GTT, both NARA and HEART is empirical validated. NARA has substituted HEARTs values and incorporated them in its own HEPs. The GTTs derived form the CORE-DATA database, which contains approximately 400 Human Error Probabilities from a range of industries including; nuclear power and reprocessing, chemical industry, offshore platform drilling and evacuation, service industry, air traffic management and some military research.(Kirwan et al., 2004) This makes NARA and HEART applicable to more general domain and can therefore aid in the quantification of PSFs.

3.3.7. SPAR-H - The Standardized Plant Analysis Risk-HRA

SPAR-H is "*a simple HRA method for estimating the human error probabilities associated with operator and crew actions and decisions in response to initiating events at commercial U.S. nuclear power plants*" (Gertman et al., 2005 p. xiii). SPAR-H was developed as a simplified and generalizable alternative for the time and resource demanding THERP and Accident Sequence Evaluation Program (ASEP). ASEP is often considered more of a screening method to provide a rough estimate of HEP. (Gertman et al., 2005)

3.3.8. SPAR–H quantification

SPAR-H categorizes HFEs as either Diagnosis or Action. Diagnosis refers to the entire spectrum of cognitive process while Action refers to the execution of an action. SPAR-H includes eight PSFs: Available Time, Stress and Stressors, Experience and Training, Complexity, Ergonomics/HMI, Procedures, Fitness for Duty and Work Processes. (Gertman et al., 2005) The PSFs in SPAR-H and the levels are shown in **Appendix F.**

Calculating HEP in SPAR-H is a straight forward process. **Equation 4** shows how HEP is the product of the NHEP and the multipliers of the chosen PSFs. The NHEP set in SPAR-H is 0,01 for Diagnosis derives from the THERP table 20-1, while the NHEP of 0,001 for Action derives from varies THERP tables. (Boring et al., 2007) See **Appendix E** for more HEP values regarding actions and diagnosis. For tasks containing both Diagnosis and Action, the HEPs are calculated separately and then summed to produce the composite HEP, shown in **Equation 5**. (Gertman et al., 2005)

$$(NHEP_{action} \vee NHEP_{diagnisis}) \cdot \prod PSF\ multipliers\ = HEP$$ **Equation 4.**

If three or more PSFs with an estimated multiplier greater than 1 is included, a composite PSF score must be computed. This is done by multiplying the assigned PSF multipliers. The HEP is then calculated using **Equation 5**.

$$\frac{NHEP \cdot PSF_{composite}}{NHEP \cdot (PSF_{composite} - 1) + 1} = HEP$$ **Equation 5.**

3.3.9. SPAR-H Definition of PSFs

Since the definition of PSFs in Petro-HRA is based on the definition from SPAR-H the PSFs Available Time, Stress and Stressors, Experience and Training, Complexity, Ergonomics/HMI, Procedures and Work Processes are accounted for in the different definitions in **Chapter 3.3.12**. Fitness for Duty, which is a PSF from SPAR-H, was evaluated to be include in Petro-HRA under the name Fatigue, but according Petro-HRA the Petroleum industry has enough mechanisms to prevent factors that causes fatigue and it was therefore not included as a PSF. SPAR-Hs definition of the PSF Fitness for duty is therefore included here.

Fitness for Duty

Fitness for duty refers to whether or not the individual is physically and mentally suited to the task at hand. The levels used for the fitness for duty PSF in SPAR-H (in addition to Insufficient Information) are Unfit, Degraded Fitness and Nominal (Whaley et al., 2012). These definitions are further elaborated in **Appendix F.**

3.3.10. Petro-HRA

Petro HRA was published in 2017 and developed for use within an QRA. "*Petro-HRA is a method for qualitative and quantitative assessment of human reliability in the oil and gas industry. The method allows systematic identification, modelling and assessment of tasks that affect major accident risk*." (Bye et al., 2017 p. 2)

3.3.11. Petro-HRA quantification

The quantification in Petro-HRA are based on SPAR-H. Instead of having two different NHEP, Petro-HRA operates with only one. Petro-HRA includes nine PSFs: Time, Threat Stress, Task Complexity, Experience/Training, Procedures, Human-Machine Interface, Attitude to Safety, Work and Management Support, Teamwork and Physical Work Environment. (Bye et al., 2017)

The description of PSF levels can be found in **Appendix G** and the multipliers can be found in **Appendix B**

In Petro-HRA the NHEP is set to 0.01, the same as diagnosis for SPAR-H. HEP is calculated in the same way as in SPAR-H, by multiplying NHEP with the product of all the PSF multipliers, shown in **Equation 6** If one of the PSFs has the value HEP=1, the task is certain to fail no matter the value of the other PSF multipliers. (Bye et al., 2017)

$$NHEP \cdot \prod PSF\ multipliers \ = HEP$$

Equation 6

3.3.12. Petro-HRA Definition of PSFs

Following is the definition of the 9 PSFs included in Petro-HRA. The definitions is retrieved from Bye et al. (2017).

Time

The Time PSF considers influence on human error probability as a result of the difference (i.e., margin) between available and required time:

- ***Available time**: the time from the presentation of a cue for response to the time of adverse consequences if no action is taken (i.e. the "point of no return").*
- ***Required time**: the time it takes for operators to successfully perform and complete a task (i.e. to detect, diagnose, decide and act).*

The analyst has to evaluate if the operator has enough time to successfully carry out the task. If there is not enough time available to complete the task, failure is certain. If there is enough time to complete the task, the analyst should decide if time is limited to such an extent that it is expected to have a negative effect on performance. For example, if there is limited time available the operator(s) may complete the task in time but have failed to perform all the actions correctly due to time pressure.1 If there is considerable extra time available, this PSF is expected to improve operators' performance.

(Bye et al., 2017)

Threat Stress

Threat Stress is defined as: *"The anticipation or fear of physical or psychological harm". A threat provoking situation is one in which dangerous and novel environmental events might cause potential pain or discomfort. Examples of situations that might cause Threat Stress are situations where the operator(s) life, or other people's lives could be in danger. Another example of Threat Stress might be a threat to self-esteem or professional status if performing a wrong decision or action.*

(Bye et al., 2017)

Task Complexity

Task Complexity refers to how difficult the task is to perform in the given context. More complex tasks have a higher chance of human error. Task Complexity can be broken down into various complexity factors that alone or together increase the overall complexity of a task. Task Complexity factors include goal complexity, size complexity, step complexity, connection complexity, dynamic complexity, and structure complexity.

- ***Goal complexity** refers to the multitude of goals and/or alternative paths to one or more goals. The complexity of a task will increase with more goals/paths, especially if they are incompatible with each other (e.g., parallel or competing goals and no clear indication of the best path/goal).*
- ***Size complexity** refers to the size of the task and the number of information cues. This also includes task scope, which is the subtasks and spread of faults to other tasks. The complexity of a task will increase as the amount and intensity of information an operator has to process increases.*
- ***Step complexity** refers to the number of mental or physical acts, steps, or actions that are qualitatively different from other steps in the task. Complexity of a task will increase as the number of steps increases, even more so if the steps are continuous or sequential.*
- ***Connection complexity** refers to the relationship and dependence of elements of a task (e.g., information cues, subtasks, and other tasks). Task Complexity will increase if the elements are highly connected and it is not clearly defined how they affect each other.*
- ***Dynamic complexity** refers to the unpredictability of the environment where the task is performed. This includes the change, instability or inconsistency of task elements. Task Complexity will increase as the ambiguity or unpredictability in the environment of the task increases.*
- ***Structure complexity** refers to the order and logical structure of the task. This is determined by the number and availability of rules and whether these rules are conflicting. Task Complexity will increase when the rules are many and conflicting or if the structure of the task is illogical.*

(Bye et al., 2017)

Experience/Training

Experience is defined as how many times in the past the operator(s) has experienced the tasks or scenario in question. Training is defined as a systematic activity performed to be able to promote the acquisition of knowledge and skills to be prepared for and to do the task or scenario in question. The outcome of experience and training is knowledge and skills that is necessary to be prepared for and to perform the tasks in the scenario being analysed. Research has shown that 92 percent of training outcomes are lost after one year if the knowledge and skill is not used. Type of training might vary, and some examples are simulator training, on the *job training, classroom training, and mental training (mentally rehearsing the task steps). The analyst should evaluate if the operator(s) have the necessary knowledge and skills to do the tasks in this scenario from either experience or training. The analyst should not only check that the operators have the necessary education and certificate, he/she should specifically look at experience and training for the task(s) in the scenario that is analysed.*

(Bye et al., 2017)

Procedures

"A procedure is a written document (including both text and graphic) that represents a series of decisions and action steps to be performed by the operator(s) to accomplish a goal safely and efficiently". "The purpose of a procedure is to guide human actions when performing a task to increase the likelihood that the actions will safely achieve the task's goal".

Procedures can be used when performing a task, but they can also be used as a means to be prepared for a task, for example in scenarios with limited time to read the procedures. The operators may know the procedures so well that the procedures are not a performance driver. The analyst should evaluate whether the procedures are a performance driver or not.

It is increasingly common, especially for newer installations, for operators to use electronic procedures and documentation, rather than or in addition to paper copies. However, the following definitions of levels and multipliers should still be relevant for evaluation of electronic procedures, as well as paper procedures. If evaluating electronic procedures, the analyst should also take care to evaluate the interface that the procedures are presented on.

(Bye et al., 2017)

Human-Machine Interface

The Human-Machine Interface (HMI) PSF refers to the quality of equipment, controls, hardware, software, monitor layout, and the physical workstation layout where the operator/crew receives information and carries out tasks. Examples of HMI problems are: difficulties in obtaining relevant information or carrying out tasks through the safety and automation system, layout organization or colours that are not stereotypical, and communication difficulties due to communication technology (walkie-talkies, phones, messaging systems). In systems that use inter-page navigation it should be evaluated if it is likely that this will cause masking of relevant information or difficulties in carrying out a task due to several page shifts.

(Bye et al., 2017)

Attitude to Safety, Work and Management

The PSF Attitudes to Safety, Work and Management Support consists of two related factors that have been found to predict safety outcomes in studies of safety culture. The two factors are: 1) Attitudes to safety and work conduct; 2) Management support.

Attitudes are defined as: The individual's positive or negative evaluation of performing the behaviour. Attitudes to safety and work conduct contribute to a safety conscious work environment. An example of how Attitudes to Safety and Work Conduct could negatively affect task performance is that other concerns such as production are prioritized higher than safety when it is appropriate to prioritize safety. Another example is that the operator does not perform tasks as described in work descriptions, rules, and regulations, for example not monitoring when they should. Another example of how Attitudes to Safety and Work Conduct could negatively affect safety is that the operators are not mindful of safety. The management of the organization is responsible for developing these attitudes.

Management support means the operators experience explicit support from managers in performing the task(s) in question. An example is that the operators experience support from the management to shut down production when appropriate even if this might have large practical/economic consequences. Also, the operator does not fear any negative consequences of performing an action that they believe is a safety conscious action even if this action is later found to be wrong.

(Bye et al., 2017)

Teamwork

"Team is defined as two or more individuals with specified roles interacting adaptively, interdependently, and dynamically toward a common and valued goal". Teamwork is defined as a set of interrelated thoughts and feelings of team members that are needed for them to function as a team and that combine to facilitate coordinated, adaptive performance and task objectives resulting in value-added outcomes.

Salas et al. (2005) described teamwork as consisting of five core components (team leadership, mutual performance modelling, backup behaviour, adaptiveness, and team orientation) and three coordinating mechanisms (shared mental models, achievement of mutual trust, and closed-loop communication).

A team in this analysis should be defined as everyone who is involved in the task(s) or scenario (including management).

- ***Team leadership** is the ability to direct and coordinate the activity of other team members, assess team performance, assign tasks, develop team knowledge, skills, and ability, motivate team members, plan and organize, and establish a positive atmosphere.*

- ***Mutual performance monitoring*** *is the ability to develop common understanding of the team environment and apply appropriate task strategies to accurately monitor team-mate performance.*
- ***Backup behavior*** *is the ability to anticipate other team members' needs through accurate knowledge about their responsibilities. This included the ability to shift workload among members to achieve balance during high periods of workload and pressure.*
- ***Adaptability*** *Ability to adjust strategies based on information gathered from the environment through the use of backup behavior and reallocation of intra-team resources. Altering a course of action or team repertoire in response to changing conditions (internal or external).*
- ***Team orientation*** *is the tendency to take other's behavior into account during group interaction and the belief in the importance of the goals over individual members' goals.*
- ***Shared mental models*** *is how the team members organizing knowledge structure of the relationships among the task the team is engaged in and how the team members will interact.*
- ***Mutual trust*** *is the shared belief that team members will perform their roles and protect the interests of their team-mates.*
- ***Closed loop communication*** *is the exchange of information between a sender and a receiver irrespective of the medium*

(Bye et al., 2017)

Physical Working Environment

Physical working environment refers to the equipment used by, accessibility, and the working conditions of the person performing the task. Although ergonomic effects inside a control room such as ventilation, lighting etc. can have an impact on human performance, the effect is rarely large enough to have a significant impact on an HRA. This PSF should primarily be used for tasks outside of the control room. Examples of ergonomic issues: Extreme weather conditions, work that should be performed in an inaccessible or hard to reach place, manually operated functions in the field that are physically demanding (e.g., hard to turn valve).

(Bye et al., 2017)

Fatigue (excluded)

The fatigue PSF was evaluated for the use in Petro-HRA, but it was concluded that it has a low influence and was therefore removed. In the evaluation of the fatigue PSF performed by Rasmussen and Laumann, the causes of fatigue were divided into four categories; sleep deprivation, shift length, non-day shifts and prolong task performance. The discussion for including fatigue as a PSF stats, among others, that "*Fatigue certainly has an effect on human performance, but the effect only becomes large enough to include in very extreme situations*." (Rasmussen, 2016 p. 20)

4. METHODOLOGY

This chapter contains the methods the thesis participants has used through the research process, from development of a problem statement to presentation of a conclusion. The advantages and disadvantages with the chosen methods and the possibility of using other methods are presented.

4.1. THEME OF THE THESIS

The theme for this research was chosen in the light of previous acquired knowledge in the preliminary project leading up to this thesis. The thesis participants desire to learn more about and get further understanding of human behaviour in arctic areas, and the increased interest for the High North was the main driving forces which made the idea for an HRA adapted for the Arctic, with the working-title Arctic-HRA.

4.2. DEVELOPMENT OF THE PROBLEM STATEMENT

There are two main types of problem statements, *descriptive* and *explanatory*. A descriptive problem statement seeks to describe similarities and differences in the existing situation and an explanatory problem statement seeks to describe why there are similarities and differences. All problem statements should be formulated in such a way that it can be researched empirically and gives a clear delimitation of the study. The components in a problem statement are *what, who, where* and *when*. The problem statement will continuously develop during the study. (Jacobsen, 2015)

The thesis participants made small changes to the formulation of the problem statement throughout this thesis and the final problem statement is shown below.

> *Which performance shaping factors will have a significant impact on human reliability in the Arctic, and to what extent?*

This problem statement gives clear direction to what should be researched. The components in the problem statement are PSFs, people in general, the Arctic and present time. It is a bilateral problem statement where the first part is about defining PSFs and the second is about quantifying these PSFs.

4.3. RESEARCH DESIGN

The research design should be chosen to best fit the problem statement, and it is important for the *validity* of the research. To ensure the validity of the research it is important that the conclusion has coverage in collected data and that potential biases are controlled. It is also important that the result can be generalized. (Jacobsen, 2015)

There are several different research designs; case study, sample study and experimental study. A case study research design is a thorough study of one or few units. The units can be spilt into different levels as shown in **Figure 8.** The lowest level, *absolute unit*, is usually a single individual, while a unit on a higher level, *collective unit*, consists of several absolute units, like a group, a community or an organization. (Jacobsen, 2015)

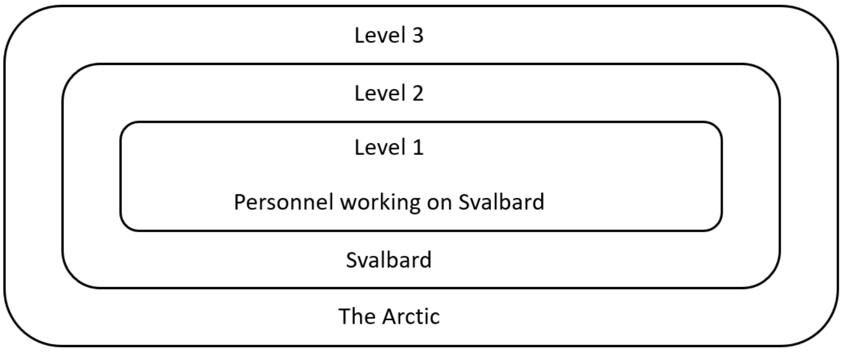

Figure 8 Different levels of a case

For this thesis it was chosen to conduct a single-case study on a collective unit, Svalbard, that included several absolute units, personnel working on Svalbard. As the desire for this study was to get a deeper understanding of the challenges that the personnel working in the Arctic faces and the causes for failure of their tasks, a case study was a suitable design. Another reason for choosing case study is because of its ability to bring about realistic and detailed descriptions of the current situation.

4.4. Collecting Empirical Data

Generally, collected empirical information is divided into *qualitative* and *quantitative* data. Qualitative data is data in the form of words, while quantitative data is data in the form of numbers. As Jacobsen (2015) states; "*qualitative and quantitative data is equally good but is suited to shed light on different questions and problems*" (p.125), what kind of data to collect should be based on the problem statement.

Qualitative study is suitable when there is little knowledge about the study subject, and it should be used when it is desirable to collect a lot of data and to understand more about the content of a subject. Some of the benefits of qualitative data is the depth and detail level of the information. It also gives a general understanding of the situation. (Jacobsen, 2015)

Besides from experiments on low temperatures impact on cognitive performance, there are little literature about arctic environments impact on human reliability. The thesis participants wanted to gain as much knowledge as possible and as rich data as possible and a qualitative approach was therefore chosen for this study.

Some downside with a qualitative approach is that the data can become complex and too rich in detail, which may result in a difficult and resource-demanding analysis phase. The thesis participants tried to avoid this by formulating questions for the interview, so it would only result in useful answers.

A quantitative approach could have been used to get more suitable data for quantification of the PSFs, but it would have been too time-consuming and to date there are little usable statistics. A qualitative approach was also considered as sufficient for the quantification of the PSFs, as it is done in several other HRAs. This approach would have included more statistical data from reported unwanted occurrences from different actors. Some data available in J. P. Lorentzen could have been used for this purpose.

There are several methods to collect qualitative data and the choice of method influences the validity of the data. The most common methods are *in-depth interviews*, *focus groups*, *participant observation* and *document-review*. An individual interview looks at personal views on a subject. Focus group looks at agreements and disagreements about a subject within a group. Participant observations looks at what people actually do rather than what they say they do. Document-review can be used when it is impossible to gather primary data, such as other individuals interpretations of a situation or event. (Jacobsen, 2015)

An individual interview is best suited when few units are being surveyed and the interest is to gather what the individuals says and their thoughts on a specific subject. The ways to conduct an individual interview is commonly spilt into *face-to-face interview*, *phone interview*, *chat* or *email correspondence*. (Jacobsen, 2015)

The thesis participants chose to conduct face-to-face interview because of its ability to establish trust and openness and that it gives a good flow in the interview, with few distractions and interruptions, compared to chat or email correspondence. A phone interview could also have been conducted but the thesis participants wanted to easily present parts of some HRAs to give the interviewees a better understanding of this thesis, which would be too difficult over the phone.

Some of the weak point with face-to-face interviews are the fact that it can be resource-demanding, and it might be difficult to access the interviewees, for instance due to geographical isolation. The research required the thesis participants to travel to Svalbard for a two week stay, which was consuming both money wise and time wise.

Another challenge is that people might be reluctant to participate in the interview. The thesis participants were, after conversation with people that had visited Svalbard, under the impression that the people working on Svalbard was very open and helpful. This was confirmed during the stay since there were no problem getting people to patriciate.

Conducting face-to-face interviews often creates challenges in the sense that the interviewer and the interviewee must be in the same place at the same time. The time of the year when the interviews were conducted is a busy period for many and a lot of projects and activity was going on. There were also a British movie crew present, filming a new season of “Life on the Edge”. The thesis participants planned a very flexible schedule for the stay and setting a suitable time for the interviews were not an issue.

4.4.1. Interviews

The structure of interviews varies in level of closure, as shown in **Figure 9**. Some interviews are carried out, to some degree, like a regular conversation, with few limitations and little direction from the interviewer. Other times the interviewer has a list of subjects or questions that should be discussed.

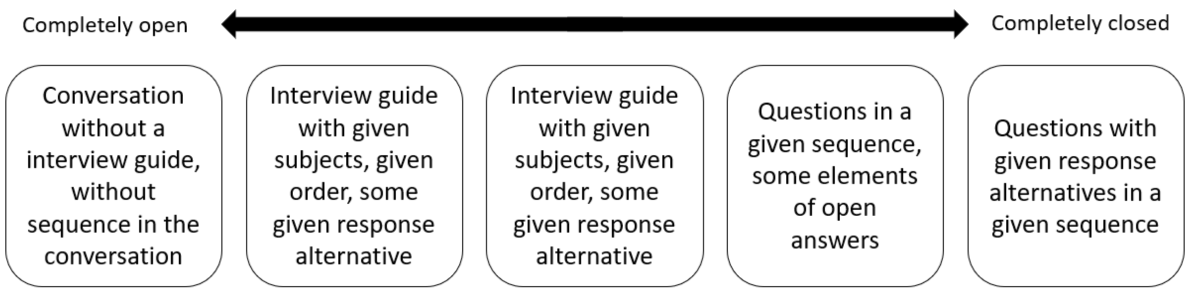

Figure 9 The levels of openness in interviewees (adapted from Jacobsen (2015 p. 150))

It is common to compose an interview guide for the interview in order to ensure that all the desirable subjects have been included. The thesis participants composed a semi structured interview guide, enclosed in **Appendix C**, containing the subjects that were desirable to discuss with mostly open questions. This gave the interviewees the opportunity to unravel about their experience and opinions on the subjects. When something was unclear with the interviewees answers, the thesis participants asked additional questions.

During an interview it can be a challenge to take notes while at the same time keep a good conversation. To be able to gather all the information given during the interviews, the thesis participants chose, with the interviewee’s permission, to record the interviews. Some might react negatively to being recorded, but as mentioned earlier the interviewees were very open and none of them had any objection to being recorded. The thesis participants also made sure to inform that the result would in no way negatively depict any persons or groups. Recording interviews will also remove the chance that the data collected is inaccurate registered, as compared to taking notes with pen and paper.

It is important to consider the context in which the interview is conducted, since this can influence the answers the interviewees give, the so-called *context effect* (Jacobsen, 2015). For instance, artificial surroundings can cause the interviewee to provide artificial answers. To eliminate the context effect, and with that ensure higher reliability, the interviews were mainly conducted in the interviewees’ offices.

4.4.2. Choosing the Interviewees

When a qualitative method is used it is important to remember that the process may take a lot of time. To not make the transcribing and analysis phase to comprehensive it is important not to include to many participants. A higher number of interviewees will result in higher *external validity*, but to not exceed the time available for the research the thesis participants ended up with 11 interviews, which was regarded as sufficient.

The objective of the research ordains who should be interviewed. The sampling is very important for what type of information one receives. There are different methods for sampling, such as *convenience*, *theoretical*, *judgmental* and *snowball* sampling. (Jacobsen, 2015) The thesis participants wanted to interview people with extensive knowledge about the subject and judgmental sampling was therefore used. The participants were picked based on their field of work and roles. During the first few interviews the thesis participants used snowball sampling (asking the interviewees if they knew more relevant people) to gather more participants.

The sampling has a great effect on the research *internal validity*, whether there is accordance between the researcher's description of a subject and the actual subject (Jacobsen, 2015). It is important that the information is gathered from a source that gives correct data. The subjects were chosen for their proximity to the subject of the research to make sure that the information they gave was correct. To further increase the internal validity the thesis participants made sure to interview personnel that represented different actors.

The chosen interviewees are based in Longyearbyen and conducts different tasks all over Svalbard. They have different roles in both non-commercial or commercial operations. Some have over 20 years of experience working in arctic environments.

According to Jacobsen (2015) one of the challenges with the single-case study research design is that it is difficult to generalize the findings outside the studied case itself, giving the study a low external validity. By choosing Svalbard as the study unit it is difficult to generalize the findings for the rest of the Arctic since the conditions on Svalbard differs from some other arctic areas.

As some of the questions required personal information an approval from the Norwegian Centre for Research Data was required before the interviews could start. The application was approved with the following statement; "*The project is comprised by person-opplysningsloven § 31. The personal information that are being collected are not sensitive, the project is consent based and has a low privacy inconvenience*".

The interviews are kept anonymous and will therefore not link answers directly to questions and more important subjects. The duration and word count of the interviews are shown in **Table 3**. There were 377 questions in total trough 11 interviews. Some of the questions were follow-ups, subsequent inquiries and questions regarding the same subjects.

Table 3 Word count, interview duration and number of questions asked during the interviews

Interview subjects	Transcript word count	Interview duration	Questions asked
1	6258	00:58:05	57
2	9409	01:02:26	32
3	2889	00:22:49	42
4	10541	01:06:02	56
5	7574	01:09:25	40
6	7710	00:59:48	38
7	8697	01:02:22	32
8	7137	00:54:06	32
9	4723	00:34:12	19
10	5817	00:42:42	17
11	6299	00:33:04	12

4.5. ANALYSING THE DATA

A qualitative analysis should compare interviews to point out patterns, regularities, deviations or underlying causes. According to Jacobsen (2015) a qualitative analysis is, in brief, divided into four parts:

- ***Document*****:** describe the material received through interviews or observations.
- ***Examine****:* look, fairly unsystematic, through the material to find salient things.
- ***Systematize and categorize*****:** reduce the material and spilt into given categories.
- ***Link*****:** highlight connections and coherence between categories.

The first part of a qualitative analysis is to make a fair copy of the raw data from the interviews and observation (Jacobsen, 2015). As mentioned the thesis participants recorded the interviews and as a part of the analysis these were transcribed. Transcribing all the interview was time-consuming but it was necessary in order to be able to implement the data into the analysis software NVivo. Transcribing the interviews was done partly between execution of the interviews and partly after returning from Svalbard.

Content analysis is based on the assumption that the data from an interview can be coded into general and meaningful categories (Jacobsen, 2015). The categories chosen for the coding are shown in **Table 4**. It might seem complex, but due to amount of data collected by the interviews, it was appropriate to have more categories than PSFs.

The 1st interview screening were done individually to see how the thesis participants interpretation of the data accord. This was done in order to account for possible inaccuracy in the analysis and to increase the *reliability* of the research. Later, the data was compered in one of the functions of NVivo. The data was then combined to form the final 1st screening. The 2nd screening are categorized by question and answers. Having the freedom to ask anything, made the categorizing more difficult which resulted in more categories. On the other hand, a strict and structured interview guide with no room for divergence would most likely give fewer categories, but again increased the probably for less data being retrieved.

4.5.1. Arrangement of categories

The categories in the interview review are based on the question-answer approach as shown in the 2^{nd} interview screening. The direct context is excluded from the interview review to preserve discretion. In NVIVO the comparison in both 1^{st} and 2^{nd} screening was done and is not included in this thesis due to similar causes.

Table 4 is a tool used to easily get an overview of the different topics interviewees respond to and the different context. This table do not show which interviewees said what but rather shows the ratio of context for the interview. As seen in the 2^{nd} screening most of the categories are more or less meaningless by them self, since answers and questions is excluded. The categories in the interview review derived from these and are shown in **Table 5**. Commonly the definitions of content are included to help in the identification of useful data. Researchers can use the definitions to criticize the validity of the data. (Jacobsen, 2015) In this thesis an attempt to have as descriptive subcategories as possible was done and therefore excludes the definitions.

Table 4 NVIVO categorization of the interview 1st transcript and 2nd transcripts screening the sublevel compose of questions and answers not shown in this table.

2nd transcripts screening

Category	Respondents	Context
Accidents, injuries and unwanted incidents	5	7
Attitude to safety	9	15
Challenges with cultural diversity	5	7
Clothing related	4	7
Communication related	9	24
Environment light conditions	8	11
Environment related	8	20
Equipment and food related	7	18
Experience related	9	21
Fatigue related	9	21
Fitness related	6	9
Hazards	3	4
Human error	4	4
Improvisation in equipment related	5	10
Interview subjects background related	10	23
Lack of experience and training problems	5	5
Level of difficulty Guide	1	2
Most critical part in transport	3	3
Perception of risk	5	10
Planning and task management	11	13
Procedures coverage	10	22
Procedures usefulness	6	11
Project related	2	7
Risk acceptance	7	12
Risks with wrong equipment	1	1
Support from management	4	4
Task cancellation	2	3
Task complexity	7	9
Task related challenges	7	11
Tasks and task related	11	23
Teamwork and collaboration	6	14
Time pressure in tasks	10	14
Time use in tasks	7	17
Training scenario related	6	10
Weather related task challenges	5	9

1st transcripts screening

Category	Respondents	Context	1st Sub-category	Respondents	Context	2nd Sub-category	Respondents	Context
Background	5	8	The Arctic Problem	1	1			
Goal Conflicts	4	9						
Hazards	11	36	Avalanche	3	6			
			Frostbite	2	2			
			Glaciers	2	2			
			Hypothermia	2	4			
			Illness	2	2			
			Scooter	4	5			
			Sea Ice	4	6	Cold water	1	1
Human errors	4	9						
PSF	3	4	Attitude to safety	10	90	Cultural differences	6	16
						Individual perception	4	10
						Risk acceptance	5	16
						Support from Management	6	6
						Work and Management Support	4	5
			Environment	10	23			
			Distance	5	16			
			Lighting	2	3			
			Weather	11	29			
			Wildlife	5	7			
			Equipment	10	57	Clothing	7	14
			Experience (exposure to hazards)	11	74	Improvisation	6	13
			Fatigue	8	31	Fitness for duty	9	31
			Procedures	11	54			
			Stress	9	39			
			Task complexity	4	6	Complexity	4	7
			Teamwork	7	29	Communication	9	34
			Threat Stress	3	5			
			Time	10	38			
			Training (no exposure to hazards)	9	37			
Tasks	3	13	Mobile Specific activity	4	6			

Table 5 Final categories based on 2nd screening and 1st screening comparison.

Category	Sub-categories	Page/Chapter
Background and experience among interviewees	Interviewees background, current responsibility and period of current employment. Interviewees experiences with activities away from infrastructure in the Arctic	p. 44 Ch. 5.1.1
Activities and Tasks	Common activities and tasks being conducted at Svalbard Goal conflicts and pressure causing activities and tasks to be carried out even though the risks are high	p. 45 Ch. 5.1.2
Accidents, close calls or unwanted incidents	Accidents, close calls or unwanted occurrences related to fieldwork or traveling in the Arctic	p. 46 Ch. 5.1.3
Planning and preparation	Addressed subjects during planning and preparing for task Causes for cancelation or discontinuing of an activity.	p. 49 Ch. 5.1.4
Time	The significance of time usage in tasks and available time Reasons for time pressures and its effect on safety	p. 50 Ch. 5.1.5
Perception of risk	Perception of risk within experienced and unexperienced individuals	p. 51 Ch. 5.1.6
Risk acceptance	Individuals susceptibility towards threat stress and risk acceptance in relation to experience	p. 51 Ch. 5.1.7
Task complexity	Complexity of tasks and the impact on performance	p. 52 Ch. 5.1.8
Level of difficulty standard at traveling agencies	The main goal and safety challenges associated with the level-of-difficulty-system used by traveling agencies on Svalbard	p. 53 Ch. 5.1.9
Weather and task correlations	The weathers impact on people's ability to perform tasks	p. 53 Ch. 5.1.10
Experience/training	Level of experience and the impact on safety Correlations between training and experience and what's considered most important Knowledge that require individual experience. Challenges with absence of training and experience	p. 53 Ch. 5.1.11
Coverage and Practicality of Procedures	Coverage of the procedures The procedures practicality and relevance to the actual conditions	p. 55 Ch. 5.1.12
Equipment	General equipment Importance of right equipment and the effect on safety Lack of equipment and the possibilities for improvisation Clothing used in field actives and related challenges Food Related Fatigue and Illness	p. 56 Ch. 5.1.13
Fatigue	Occurrence of Fatigue Causes of Fatigue	p. 59 Ch. 5.1.14
Fitness for duty	Physical and Psychological Requirements	p. 60 Ch. 5.1.15
Attitude to safety and safety culture	The Attitude to Safety in the General Population Reporting Culture for Close Calls and Unwanted Occurrences Search and Rescue Initiation Threshold	p. 61 Ch. 5.1.16
Support from management	Support From Management Concerning the Individual's Decisions During Task Planning and Execution and Safety Concerns.	p. 63 Ch. 5.1.17
Communication	Adaption of Communication Factors that Influence the Ability to give Commands and Receive Commands Communication Between Actors with Similar Interests in Safety Communication and Behaviour During a Stressed, Unsafe Situation	p. 63 Ch. 5.1.18
Teamwork and collaboration	Challenges Related to Teamwork and the Distribution of Responsibility Cultural differences and its effect on Safety	p. 65 Ch. 5.1.19
Environmental light conditions	Seasonal Light Conditions Impact on Safety The Effect of Seasonal Darkness and Midnight Sun	p. 67 Ch. 5.1.20
Environment topography	Challenges Regarding the Landscape	p. 67 Ch. 5.1.21
Environmental wildlife	Wildlife and its Influences on Safety.	p. 68 Ch. 5.1.22
Natural hazards	Summarizing of Environmental Hazards.	p. 69 Ch. 5.1.23
Weather	Weather Factor Considered Before and During Fieldwork.	p. 69 Ch. 5.1.24

4.6. Observations on Svalbard

During the thesis participants stay on Svalbard they participated in several activities, like snowmobile driving, safety courses and other field activities. These activities were used to observe how themselves and others acted in given situations. Being involved and exposed to the harsh environment was fortunate in the development of PSF. Gaining some experience on the topic might have influenced the interview analysis and with that some of the thesis participants own interpretation might be present in the result.

4.7. Literature Search

In the preliminary project the thesis participants had a wide scope and focused on a wide range of safety theory. Some literature from the preliminary project was implemented into the master thesis. Literature about Human Factors and research on arctic conditions impact on human performance was essential.

The thesis participants chose to focus mainly on HRAs for this thesis. It was therefore necessary to supplement the literature search from the preliminary project with in-depth literature on HRAs and human performance, shown in **Figure 6**. More sources on HRA methods is shown in **Appendix A.**

To supplement the interviews and to verify the information, insofar it was possible, the thesis participants considered research that were available on the subject. In the development of the performance shaping factors the thesis participants chose to look at PSF definitions and multipliers from other HRAs. This was done to ensure that the multipliers were as valid as possible.

Table 6 Literature supplemented from the preliminary project.

Reference	Information	
Gertman et al. (2005) ***The SPAR-H Human reliability analysis method***	Theory PSFs	- SPAR-H method - Definition - Multipliers
Indereiten et al. (2017) ***Field operations in the high arctic – Experienced feedback and tacit knowledge as key tools for safety management***	Hazards	
Noroozi et al. (2014) ***Effect of Cold Environment on Human Reliability Assessment in Offshore Oil and Gas Facilities***	Hazards Theory	- HEART method
Swain and Guttmann (1983) ***Handbook of Human Reliability Analysis with Emphasis on Nuclear Power Plant Applications***	Theory PSFs	- THERP method - Multipliers
Williams (1988) ***A data-based method for assessing and reducing human error to improve operational performance***	Theory	- HEART method

4.8. ETHICAL CHALLENGES

Social science studies have consequences both for the research units and for society. It is important to consider how the research affects the research units and how the research can be interpreted and used. Research ethics in Norway is built on three fundamental claims concerning the relationship between researcher and those being researched (Jacobsen, 2015);

- ***Informed approval*** is about the one being researched is voluntarily participating, and that the participation is based on the knowledge about the dangers and profits of the research.
- ***Claims to personal life*** is about how sensitive and personal the information that are being gathered is and whether or not it is possible to identify the person from the data.
- ***Claim to correct presentation of data*** is about the results being presented correct and in the right context.

(Jacobsen, 2015)

The thesis participants contacted several people and supplied them with information about the background and intent of the research and an inquiry if they wanted to participate. Every participant gave their approval that their answers could be used in this research.

The research did not require any personal or sensitive information from the participants, but the thesis participants reckoned that some of the questions might make it possible to identify the interviewee. An application was therefore sent to Norwegian Centre for Research Data. The application was approved shortly after.

The results of each interview might vary due to each interviewee’s viewpoint and their interpretation of the questions. Some of the interviewees had incompatible views on certain elements and the thesis participants tried to include all the view. The data is not fumbled with as the thesis participants has nothing to gain on falsely presenting the data.

5. INTERVIEW ANALYSIS AND RESULTS

In this chapter the analysis and result from the interviews are presented. The congregate result from the 11 interviewees are stated as text or in tables, where this is possible.

5.1. COLLECTED DATA

Through the content analysis performed in NVivo the content from the interviews have been categorized. A summary of the most important findings in these categories are presented in this chapter.

5.1.1. Background and Experience Among Interviewees

Interviewees background, current responsibility and period of current employment

The 11 interviewees have a wide range of roles in non-commercial and commercial activity and rescue services. Some have been working in the Arctic for over 20 years. Several of the interviewees have military background or had been conducting activities in the Arctic before they started their current work, others have academic background and had gained the required experience through their current work. Some of the interviewees work were primarily office-based management, where they planed field safety and performed quality assurance and provide support for the ones conducting the activity and tasks outdoor. **Table 7** summarize years of experience, current responsibility's and backgrounds among the interviewees.

Interviewees experiences with activities away from infrastructure in the Arctic

The experience with outdoor activities in the Arctic among the interviewees ranges from a few years to some having spent their whole career of more than 20 years. Typical outdoor activity among the interviewees is conveyance, fieldwork, guided tours, private trips, search and rescue missions and research projects. These activities can last from a couple of hours to a great number of consecutive days.

Table 7 Interviewees experience level, their current work, and their background

Years in The High North (Years with outdoor work)	Current responsibility, field of work	Previous background/experience
22 (22)	Safety planning and risk assessment, rescue service, conveyance and surveys	(n/k)
>20 (>20)	Safety during activity	Other arctic activity
20 (n/k)	Safety planning and risk assessment, quality assurance and management support	Military
20 (7)	Safety planning and coordination of activity	(n/k)
14 (5)	Coordination of activity, safety planning, management support and human resources	Military Other arctic activity
13 (13)	Safety during activity	Other arctic activity
7 (5)	Safety during activity	Academic
6 (n/k)	Coordination and organization of activity	Other non-arctic activity
>3 (n/k)	Safety during activity	(n/k)
3 (3)	Safety during activity	(n/k)
2 (n/k)	Project management	Other non-arctic activity

5.1.2. Activities and Tasks

Common activities and tasks being conducted at Svalbard

During the interviews several different activities and tasks were mentioned. **Table 8** shows typical activities and tasks that fulltime residents, tourists and other short term visiting people are conducting. Hazards related to these activities plus possible countermeasures are included as well.

Table 8 The most common activities and tasks and related hazards and countermeasures.

Activity	Example of tasks	Hazard	Countermeasures
Driving snowmobile	Guide tourist/students to a given destination	Slippery surface, sea ice, difficult terrain, avalanche, low visibility	Spikes on belt, Check thickness of ice, drive slower, navigate by GPS, find alternative route
Driving belt wagon	Take tourist/students to a given destination	Slippery surface, low visibility	Find alternative route
Riding dog sledge	Take tourist to a given destination	Slippery surface	Find alternative route
Conducting fieldwork	Cut/drill hole in ice, set up camp, conduct scientific measurements	Strong winds, low temperature, sea ice, glacier, avalanche, wild animals	Proper clothing, taking breaks inside, checking thickness of ice, keep distance from glacier, find alternative area
Rescue mission	Retrieve injured persons, find missing persons	Strong wind, heavy snowfall, hard to reach places, low visibility	Find alternative route, navigate by GPS
Summit hiking	Guide tourist to summits	Avalanche	Keep a distance to avalanche exposed terrain
Conduct seminars and course	Hold a lecture outside	Depending on activity and location	Depending on hazard

Goal conflicts and pressure causing activities and tasks to be carried out even though the risks are high

People visiting Svalbard for a short period of time in relation to research project and similar, both non-commercial and commercial, would not necessarily finish their task in time because of bad weather conditions. Sometimes project was ordered to procced even with elevated risks because of pressures from stakeholders. Money was seemingly the major motivator to continue with projects despite commercial operators feeling uncomfortably. Non-commercial actors said they were much more conservative in starting a project with elevated risk. For example, the educational institute had turn down several projects in the past due to elevated risk.

In educational institutes, those involved in projects and courses were less likely to see the cost of delaying or even cancelling an activity. For educational institutes, the pressure was time-related rather than money-related since the students were only on Svalbard for a limited time and had to conduct several activities as a part of the courses.

The following statement *"If you're in doubt, you're not in doubt"* were mentioned by several independent individuals, despite the area of professions. There was an underlying agreement to the attitude that nothing was worth dying for.

5.1.3. Accidents, Close Calls or Unwanted Incidents

Accidents, close calls or unwanted occurrences related to fieldwork or traveling in the Arctic

All the interviewees mentioned that they had been involved in one or more unwanted occurrences or knew about one or more. The most common unwanted occurrences arise when people are driving snowmobiles. Typical event related to this activity are tipping, sliding, collisions, driving off edges or into jumbled sea ice. Mostly these occurrences result in no damage but in some cases, they have ended in injuries. Unwanted occurrences appear more frequently at the end of the trip than the rest and more frequently during weekends than weekdays.

Sometimes openings can appear between the snowmobiles in a convoy, which is not very dangerous in itself. These gaps occur when insecure and unexperienced drivers are falling behind in the tracks. The drivers will most commonly cut the turns which will gradually lead to changes in the original route. The leader who is leading the group would lay the tracks away from potential dangers, but somewhere along the tail of the convoy, a snowmobile will drive into the potential danger because of the changes in the route.

Another unwanted occurrence that was often mentioned is people getting frostbite. Frostbite can appear even if the skin is seemingly covered. It was mentioned that frostbite can occur in just a couple of minutes after departure if precautions are not taken. Some of these cases could be treated by covering the skin more thoroughly, others required medical attention. The most common mentioned frostbite-cases occurred during snowmobile rides.

Other unwanted occurrences that was mentioned by the interviewee was avalanches, fall on ice, people doing the opposite of what they were instructed to, tipping or sliding with other means of transportation, hypothermia, panicking, food poisoned and trips having to be cancelled or route having to be changed. **Table 9** summarizes unwanted occurrences, consequences and what the interviewees said might have been the cause.

There was consensus between the interviewees that there were dark figures concerning reporting of unwanted occurrences. One of the mentioned reasons for this was due to the rapid closing of deviations by the group leaders in field activities and tasks. However, some of the incidents was still uncovered later because of pictures being posted on social media.

Table 9 *Unwanted occurrences, consequences, frequency and related underlying causes mentioned by the interviewees*

Underlying causes	**Cause**	**Unwanted occurrences**	**Consequences**	**Frequency**
Experience, Threat stress, Environment	Driving across a steep slope, driving on slippery grounds	Falling off	None, Fractures	Almost daily
Experience, Environment	Driving into ice bumps	Flipping the snowmobile, Falling off	None, Fractures	n/k
Experience, Threat stress, Environment, Task complexity, Fatigue	Driving down a steep slope, Locking of tracks	Flipping the snowmobile	None, Fractures	Almost daily
Experience, Environment	Driving snowmobile into something	Collision	n/k	n/k
Experience, Threat stress, Environment	Driving snowmobile, weather, low visibility	Driving off edge	n/k	n/k
Experience, Threat stress, Environment	Driving into jumbled sea ice	Driving in to water	None, but possible severe	n/k
Equipment, Experience, Attitude to safety	Badly fitted/wrong size, lack of clothing	Frostbite	None, medical attention, person can't attend more outdoor activity	Common
Environment, Experience	Traveling on or under unstable snow slopes	Avalanches	n/k	n/k
Environment, Experience	Thin sea ice	Falling through sea ice	Death, hypothermia	n/k
Equipment, Communication, Teamwork	Contamination of food	Food poisoning	Loss of time, Discomfort	Rare
Weather, Attitude to safety, Support from management	Whiteout	Cancelling trip	Loss of time, not being able to accomplish goal	Common
Threat stress, Experience, Training	Lack of understanding to a situation	Panic	Panic reactions	Rare
Environment, Weather	Falling in water	Hypothermia	n/k	Rare
Environment, Weather	Traveling on or under unstable slopes after rainfall	Land slide	n/k	Rare
Equipment	Breathing in the balaclava	Fogging snow goggles	Reduced visibility	Common
Environment	Polar bears in the proximity, bad weather, risks of avalanches	Change in route while traveling	Loss of time, not being able to accomplish goal	Common
Threat stress, Experience, Training	Unreported incident, individuals discomfort to report, weather	Frostbite, Hypothermia	Hypothermia, not being able to accomplish goal	Rare
Environment, Weather Experience	Icey conditions on the ground	Sliding with belt wagon	Possible injury to the operator or machine	n/k
Environment, Weather	Wind, weather	Door slamming over fingers	Fractures	n/k
Environment,	Tsunami under the ice caused by glacier slide	Ice cracking	Possible crushing of limbs, Fractures	n/k
Attitude to safety, Support from management	n/k	Bad behaviour	n/k	n/k
Environment, Weather	Icy grounds	Falling on ice	Abrasion, Fracture	n/k
Environment,	Hidden crevasse under snow, low visibility	Falling in crevasse	Fracture, death	n/k

5.1.4. Planning and Preparation

Addressed subjects during planning and preparing for task

The planning phase has great value and is often crucial for a successful outcome of a task. The planning usually starts with assessing if the task is in fact doable or not. For instance, a trip to the northern part of Spitsbergen will be too risky before the turn of the months April to May because of the low temperature. Several of the interviewees mentioned that the first thing they check is the weather and avalanche forecast.

The planning starts with going through the specific tasks, discuss how the tasks should be solve, potential challenges and relevant procedures. The planning is dependent of the type and location of the task. If the task requires movement on ice, it is important to discuss the condition of the ice. Several of the interviewees mentioned that they often, if possible, talk to people that have recently been to the area in question.

Another important part of the planning is the discussion of aspects concerning the group. If several people are participating in the task it is important to discuss group size, roles and distribution of responsibility. Everyone that are participating should be part of the planning to ensure that everyone knows what they are going to do and how it should be done. It is important to discuss if the task is possible with those involved, in consideration to their experience and other individual factors.

It was common to do a reconnaissance trip the day before, to make sure that the route was achievable for the group, and if not, try to find a new one.

Several of the interviewees mentioned that it is important to plan the task as close to the scheduled start as possible. Since the weather condition changes so quickly the planning from the day before might not be applicable the next day. It was also important to assess if the safety equipment brought along were sufficient to handle unwanted occurrences. For instance, bringing an avalanche rescue kit while traveling through an avalanche exposed valley.

There are certain factors that are impossible to consider when planning a task. One example that were mentioned was that one can instruct a tourist on how to ride a snowmobile, but one can never be certain how the tourist will act when they get on the snowmobile. The polar bears pattern of movement is difficult to predict so one need to be prepared to encounter polar bears everywhere.

Causes for cancelation or discontinuing of an activity.

There was consensus among the interviewees that the weather and ground conditions was the main cause of cancelation and discontinuing of an activity or task. One of the interviewees mentioned that their planning could be seen as a traffic light. Green light meant that all conditions were normal, and no countermeasures had to be implemented. Yellow light would indicate insecure conditions, and one had to consider countermeasures and consider if these were good enough. Red light meant that the conditions were too bad, and the activity had to be cancelled. A green light doesn't necessarily mean that the activity is possible, because the conditions may change, and it might change to yellow light or even red throughout the task. It was also mentioned that the number of people could influence the decision. For instance, during snowmobile trips, bigger groups, more people in the convoy equals longer exposure time to hazards.

5.1.5. Time

The significance of time usage

Most of the interviewees said that they tried to adjust the available time so that it wouldn't be a factor. They usually included a time buffer that gave them enough time to finish the task. It was mentioned that the forces of nature set the available time and it was no use in planning a tight time schedule because there were so many factors influencing the situation. It is important to be flexible when it comes to time and have the possibility to postpone or cancel an activity.

Reasons for time pressures and its effect on safety

It was consensus between the interviewees that tasks in arctic areas always takes longer time than planned. The interviewees mentioned that a lot of factors influences and shortens the available time. The weather for instance, can result in people having to postpone the start of a task by several days. Tourist often have a fixed schedule from the time they arrive until they must fly back again were they wishes to finish what they have planned. Having to postpone the start creates time pressure to finish everything they have planned.

In some industry lost time results in loss of money. According to several of the interviewees this was often the case during projects, for instance by visiting scientists, since its expensive to have people working in these areas and it was planned to end projects at a certain date.

It was mentioned that time pressure often arises in the mornings because people want to get started as soon as possible. This results in no time for risk assessment and checking the weather and other important factors. It also increases the chances of forgetting essential equipment. Some of the interviewees mentioned that there was a higher time pressure during daytrips than longer excursion. This was especially noticeable in the planning phase, and the planning for daytrips was often sloppier.

Several examples were mentioned where people speeded up the tasks to be able to reach an appointment in time. In one of these examples a group was transporting equipment using snowmobiles and sledges. They had a dinner reservation the same evening and was hurrying to get beck. The group were sloppy while packing the sledges for the ride back, which resulted in the sledges getting destroyed. The group ended up missing the dinner reservation by several hours.

5.1.6. Perception of risk

Perception of risk within experienced and unexperienced individuals

It was consensus among the interviewees that level of experience affects peoples' perception of risk. It was mentioned that this often became clear when people got weather-bound and had to stay overnight in a tent. Experienced people knew that it was not a dangerous situation, but the snow building up outside the tent could make the unexperienced claustrophobic. Another example mentioned was the lighting condition. The reduced visibility during the dark periods could aggravate unexperienced persons' risk perception.

The changing climate on Svalbard, with new heat records and new hazards emerging, has changed people's perception of risk. The way they have done things may not be valid anymore, and they must find new ways to handle risks.

5.1.7. Risk acceptance

Individuals susceptibility towards threat stress and risk acceptance in relation to experience

Svalbard visitors are mostly seeking nature experiences, there are usually few thrill seekers. The tourists were described as cautious and not risktakers. It was said that there were challenges to risk acceptance. Risk acceptance in regarding to achieving one's goal was the main driver.

There were some projects that had been privately financed because some institutions found them too reckless regarding safety. When institutions disagreed on where the red line should go regarding risk, a collaboration would not be possible. One of the interviewees said that neither Nansen or Amundsen would be able to accomplish their achievements with todays safety policies.

One of the interviewees stated that at Svalbard the Norwegian safety standard was applicable. Working with other nationalities with a different risk acceptance could be challenging. It was important to be aware of this, for example to understand that everyone might not know what can go wrong, and address this issue.

It was a common perception that inexperienced individual was more susceptible to threat stress. For examples, the lookout for polar bears. After some years of experience this threat is accepted as real and one usually don't use a lot of energy to be concerned about them. In terms of safety, it only means they are bringing a rifle and a flare gun.

One of the interviewees had this approach to risk. *"If you face a problem that is risky, you have to ask yourself the question; Is the solution I choose now adequate enough that I can do it every day for the next 30 years. If you cannot stand by your decision, then you simply take too much risk".* In the cases where some individual needs to take several safety decisions during a fieldtrip, the risk acceptance can decrease. Some of the factors mention during the interviews were fatigue and external pressure. Some of the interviewees who worked outside had a similar approach. One stated that "*If I think the risk I'm going to take makes it possible for something to go wrong, I've made the wrong decision. I do not have enough margins on my side"*.

Within the Arctic environment there are several hazardous conditions which can change in short periods of time. It is important for everyone who is traveling and working outside infrastructure to accept the there are some risks and conditions in the environment one cannot change. For example, the risk of encountering polar bears, caught in bad weather and so on.

When the interviewees were asked if this thesis should account for personalities, some said they did not have any opinion on this topic, while others said that Svalbard had such few residents that one cannot generalize them.

5.1.8. Task Complexity

Complexity of tasks and the impact on performance

The interviewees mention that most unwanted occurrences happen during conveyance with snowmobiles. Riding a snowmobile is in principle an easy task but can in some cases become difficult. For instance, driving across an incline or other challenging terrain can often result in people tipping or falling of the scooter.

The commercial industry offers trips to several destinations all around Svalbard. These trips vary in difficulty by the length of the trip and type of terrain. It is often required to assign the most difficult trips to the most experienced guides.

Activities in the Arctic often includes several people. The interviewees mentioned that task where they were required to keep track of others often became more difficult if the number of people increased. Some trips were said to be possible with only 4 people, but the same trip would be too difficult if they had to keep track of 20 people. For instance, when leading a big group in a snowmobile convoy, the leader is required to think about how all the individuals follows the tail. This task will get more complex and difficult the longer the convoy is.

Assessing dangers while outside can be challenging and complex, such as estimating the chances of an avalanche. A lot of factors must be considered when assessing avalanche danger, such as weather, stability in the snow layer and the steepness of the hill.

It was mentioned that shorter, easier trips make people sloppy, especially during preparation, which can result in an unsuccessful trip. people plan better for longer and more challenging trips, and in that way, they can avoid unwanted occurrences. This was also said to be the case for easy, repeatable tasks.

5.1.9. Level of difficulty standard at traveling agencies

The main goal and safety challenges associated with the level-of-difficulty-system used by traveling agencies on Svalbard

All the commercial adventure agencies in Longyearbyen has a grading of difficulty on their expeditions and trips. This was recently standardized among all the traveling agencies; the aim was to better pair tourist with the trips according to their skill level and capabilities. This grading ranges from 1, for the easiest trips, to 5, for the most challenging trips.

Tourist can freely choose their preferred difficulty, since there is no control over everyones capabilities. When questioned, the interviewees said that this could be a safety challenge. The guide has the possibility to deny individuals to participate if they were not capable of making the trips. Since the guide have the main responsibility of the group it was important that the guide was comfortable bringing the individuals out.

The main concern with this system was if there were traveling agencies not following the same criteria for the level of difficulty. This could give others a competitive advantage, and have a serious impact on safety. For instance, if one traveling agency going below the fixed norm for a difficulty, more customers might participate on that expedition.

5.1.10. Weather and Task Correlations

The Weathers Impact on People's Ability to Perform Tasks

According to the interviewees the weather affects all outdoor activity. The weather conditions have, in several cases, caused cancelation of activities and it has made several interviewees cancel a task midway. Low temperatures, high winds and heavy snow shower is mentioned as the most important weather factors. The weather impacts the conditions on the ground, making hard packed snowdrift which in turn wear down equipment such as snowmobiles and sledges. Icy ground conditions make it difficult to ride snowmobiles even for experienced drivers. Heavy snow shower and high winds is especially challenging during rescue mission, since it reduces visibility which is essential for a successful mission. The quickly changing weather conditions can make planning of a task unreliable and deviations from the original plan is often necessary.

5.1.11. Experience and Training

Level of Experience and the Impact on Safety

It was consensus among the interviewees that unexperienced visitor has trouble comprehending the conditions that exists on Svalbard and that experience is important for safety. Driving snowmobile can be challenging for people who have never seen snow before. They might not know that there is a difference in friction and hardness between snow and ice and will just try to drive the same way on the ice as they do on snow.

The definition of an experienced Svalbardian was not unanimous among the interviewees. The most important part is that one is exposed to the natural environment and the potential dangers. It is possible to live on Svalbard for several years without having to drive a snowmobile in a whiteout or bad weather. The environment on Svalbard is a lot different form for instance the furthest north of mainland Norway. Even if one has been exposed to snow and mountains one cannot be considered experienced. The most common opinion of what can be considered experienced were at least 4 full seasons.

Being experienced goes two ways. Experience is often needed to complete a task, but it can also make one overconfident and believe that one knows everything, and that way won't learn better practices.

Correlations Between Training and Experience and what's Considered most Important

The interviewee mentions that a lot of safety courses focuses mostly on the rescue phase of an accident, when the most important part should be to avoid the accident. Some of the knowledge needed to handle the conditions in the high north can be acquired by courses, but it should not be considered sufficient. It is important to know how to rescue someone from an avalanche, but it is also important to know how to assess the avalanche danger. The ability to correctly assess the avalanche danger is, according to the interviewees, mainly based on experience.

It is often more enjoyable to go to the shooting range for polar bear safety training than it is to train on how to handle bad weather. It can be difficult to train on certain scenarios because they are hard to bring about, or it is danger to try to bring them about.

The training often results in new experiences, for example if there is an incident during a training scenario, an individual will acquire new insight in that scenario. Therefore, some of the interviewees meant that the experience gained during training was a lot more important than procedures. Also, a lot of the "*lessons learned"* was gained during training and documented for later use, to improve performance. According to some there was many ways to acquire the correct experience, a common practice was to "*train as you fight"*. This approach was used in organizational and collective learning in both SAR Operators and educational institutes. An example of experience that can be hard to reteach to others is how to lead a snowmobile convoy, because of the gradually cutting of turns and how to move the centre of gravity while driving across slopes.

Knowledge that Require Individual Experience.

Whenever people are traveling outside infrastructure, one is required to adapt to the environment. Knowledge that can be hard to reteach without exposing the individuals is stated in a few examples below:

- Stormy and cold weather and how to dress accordingly to the activity.
- To lead a snowmobile convoy.
- Evaluate avalanche hazardous terrain.

- Knowing how far a snowmobile can travel on one full tank. The range stated by the factory is usually not precise.
- Knowing how a snowmobile behaves on slippery ice, steep slopes, cracked ice and how to shift the centre of gravity during driving.

Challenges with Absence of Training and Experience

It was said that it is hard for inexperienced travellers to "*familiarize the physical environment",* because it is a huge contrast to what some are used to. Experienced lecturers can demonstrate actions in a situation, but it is still required for the individuals to experience it to properly familiarize it. Some of the interviewees said that with more practice in a controlled way could drastically reduce the probability for collisions, flips and other driving related unwanted occurrences. Guides and group leaders needs to be aware of the dangers inexperienced travellers can be exposed to. For example, the snowmobile driving has a steep learning curve and inexperienced drivers can become overconfident in their abilities resulting in unwanted occurrences. On the other hand, unconfident drivers can be exposed to the same thing and therefore require encouragement to perform a task in a safe manner.

Example of aspects of inexperience:

- Wrong decisions
- Panic and anxiety
- Lack of control: safe handling of rifles, flare gun and incorrect use of navigation systems.

5.1.12.Coverage and Practicality of Procedures

Coverage of the Procedures

The interviewees mention that there are procedures for most activities, but some say that there is a lack of procedures for more concrete tasks. The actors conducting activity on Svalbard mainly do things the same way and some procedures have become more or less standardized independent of industry. How strict and comprehensive the actors' procedures are might vary. One of the more standardized procedures deals with snowmobile driving on sea ice. If the ice is thinner than 30 cm one should not drive on it.

It is difficult to have procedures that covers every possible scenario, but the interviewees said that the procedures cover the tasks where it is most practical to have a procedure. During task that lacks procedures people must use their experience.

The procedures are especially helpful during planning of activity. Procedures can for instance help during the decision whether to cancel an activity if there are uncertainty concerning the weather conditions.

Some actors have strict procedures on how to dress for the different activities. This is done in order to secure that all the participants have clothes of sufficient quality, and if one person in the group is freezing it is most likely the case for others as well. The same goes with avalanche danger. If the avalanche forecast shows a certain level, cancelation of an activity should be considered.

The Procedures Practicality and Relevance to the Actual Conditions

Some of the main challenges in producing procedures for activity on Svalbard is the quickly changing weather conditions and that all the information that is needed to make the right decision is not necessarily available in each situation. Even if the weather looks good and the activity is doable according to the procedures the actual conditions may indicate that it should not be continued. This is also the case with avalanches. If the forecast says there are no avalanche danger it is not necessarily the situation everywhere.

The procedures are formed after experience. They give a base for the activities but there should be possibility for improvisation in the procedures. They can't be as strict as military procedures or those used in the petroleum industry. According to interviewees there are a lot of factors that should be assessed when an activity is carried out, for instance the distance of a trip and weight of equipment, and it is therefore more practical to use their own judgement rather than procedures.

Even though all the interviewees said that having procedures is beneficial, several of the interviewees mentioned that they at some occasions deviate from the procedures. This was because the procedures are not adapted to the actual situation or it would be more practical to exercise discretion. It was mentioned that one procedure said that one must bring a given amount of emergency tents per participants. On some trips it would be redundant to bring more than one emergency tent, or in some cases it would be better to just drive back rather than putting up a tent. This also applies to the procedure about thickness of the ice. If just a small spot on the ice is a bit thinner than 30 cm while the rest is far above, it could be better to deviate from procedure.

5.1.13.Equipment

General Equipment

What equipment to bring is adapted to the activity that is being conducted. **Table 10** shows a list of equipment mentioned by the interviewees, the use of these and if there are any alternative equipment available that can be used to complete a task.

Table 10 General Field equipment mentioned during the interviewees

Equipment	Main usage	Available alternative (example)
Snowmobile	Transportation of personnel	Yes (belt wagon)
Belt wagon	Transportation of personnel	Yes (snowmobile)
Dog sledge	Transportation of personnel/equipment	Yes (snowmobile)
Skies	Transportation of personnel	Yes (snowmobile)
Sledge	Transportation of personnel/equipment	Yes (dog sledge)
Chainsaw	Cutting holes in ice	Dependent of intention
Ice drill	Drilling holes in ice	Yes (chainsaw)
Crampons	Foothold on ice and hard packed snow	None
Cell phone	Communication	Yes (satellite phone)
Satellite phone	Communication	Dependent of intention
Transceiver	Notifying location/Locate personnel	Dependent of size of avalanche
Emergency beacon	Notifying location	Dependent of communication coverage
GPS	Navigation during transportation	Yes (map)
Glaciers rescue kit	Rescue personnel from crevasse	None
Avalanche probe	Locate personnel	Yes (transceiver)
Shovel	Digging	Yes (hands)
Ice spikes	Self-rescue after falling through sea ice	Yes (ski poles)
Flare gun	Polar bear protection (scare)	Yes (rifle)
Rifle/shotgun	Polar bear protection (shoot/scare)	None
Emergency tent	Shelter while weather-bound/heating for injured personnel	Dependent of distance to settlement (snow cave)
Thermo-bottle	Contain liquid water	Melt ice over open fire or primus

Importance of Right Equipment and the Effect on Safety

Several of the interviewees mentioned that it is important to bring the right equipment. Forgetting to bring the equipment or bringing the wrong equipment can often result in a wasted trip. It was also mentioned that some of the equipment were getting old and were not being maintained, which can result in the equipment breaking down during use.

It is required to bring a rifle for polar bear protection when one is leaving a settlement. It is also common to bring other safety equipment such as a first-aid kit, a transceiver and an emergency beacon. Although the equipment is important, most of it is only useful after an unwanted occurrence but won't help to avoid hazards. For instance, getting caught by an avalanche on

Svalbard will most likely become fatal, and the transceiver will only be useful to retrieve a dead body.

Several of the interviewees pointed out the importance of knowing how to use the equipment. For instance, shooting a signal flare in front of a polar bear and not behind it to avoid scaring it towards the one firing. Bringing a lot of equipment that one does not know how to use will rather be restrictive than helpful.

Lack of Equipment and the Possibilities for Improvisation

Several of the interviewees mentions that they in some situations have completed a task by improvising and used equipment that were not originally meant for the situation. It is very important to be creative and be able to improvise, both when it comes to equipment and actions, when working in the Arctic. As one gradually gains experience one realizes that it wise to bring miscellaneous items, such as duct tape.

A lot of equipment needs modification for it to work in arctic areas, very little works *"out of the box"*. One example that was mentioned were ice spikes. Regular ice spikes would not work on sea ice because they are to short and won't reach the ice through the overlying snow and slush. It was also mentioned that equipment can only assist to a certain point, after that the task is likely to fail.

Clothing used in Field Actives and Related Challenges

Most of the clothes used during activities on Svalbard are used for safety reasons, such as prevention of hypothermia and frostbite. Introduction of a safety measures can create unintended risk. As one of the interviewees said; "*all safety measures that are introduce has a backside*".

The most common clothing used during snowmobile driving, are insulated coveralls, snow boots, mittens, facemask and a helmet. Together with a rifle and several layers of clothing inside the overall one gains a lot of weigh, which in turn leads to increased energy use. It may also cause mobility restrictions and difficulty to complete a task. The helmet may cause restricted visibility, especially if the visor gets foggy.

Several of the interviewees mentions that even with proper clothing it was common that people got frostbite. One of the reasons is poorly fitted clothing which creates gaps. According to the interviewees, if people were lending clothing it was difficult to find the correct size to everyone in a group.

During work on ice and driving small crafts it was common to use a survival suit. The survival suit may cause people to become sweaty and clammy, which can lead to dehydration. Swett in combination with low temperatures causes quick cooling of the skin and may result in frostbite. If the work is performed near a worm location, such as a boat or a house, it would often be more beneficial to use a flotation suit. Even though it is not as hot as the survival suit it will keep the person floating, and other people can bring the person indoors.

Food Related Illness and Fatigue

Almost none of the interviewees had experienced food related fatigue. Some said they had experience low blood sugar, but it was a minor cause for concern in their minds. It was said that most inexperienced individuals visiting Svalbard for shorter periods, were in general decent prepared for the task and fieldwork. They were able to get enough nutrition's and calories before heading out. A different challenge was vegetarian people, since they won't eat meat they need to have other meals with a high energy density. In groups there were always someone that brought a little extra food. This is not a reliable solution, but food related fatigue was rare.

One of the interviewees had experienced food poisoning on a 4-day expedition. This eventually lead to a minor fatigue, but the person was able to finish, without external rescue. The person said it was mostly "*uncomfortable"* and *"I did not feel I was in any significant danger"*. Food was more likely to impact the comfort rather than the fatigue.

5.1.14.Fatigue

Occurrence of Fatigue

The interviewees had a spilt opinion on the topic fatigue. Some said they have experienced fatigue themselves, others said they had not. It was consensus among most of the interviewees that fatigue occurred more often among visitors than full time residents. The focus on fatigue as a contributor to accidents had increased in the last couple of years. **Table 11** gives an overview of the interviewees experience with fatigue themselves and in others.

Table 11 Fatigue experienced by the interviewees and others

Interviewee Mentioning fatigue	Experienced fatigue themselves	Experienced fatigue in others
1	Yes	Yes
2	No	Yes
3	n/k	Yes
4	No	No
5	n/k	n/k
6	Yes	Yes
7	No	Yes
8	No	Yes
9	Yes	Yes
10	n/k	n/k
11	n/k	n/k

Causes of Fatigue

It was mentioned that the dark periods and the accompanying visibility reduction creates natural restrictions of the time available to perform a task, while the Midnight Sun makes it possible to work around the clock. The reduced visibility during the dark periods makes it difficult to detect hazards such as polar bears and avalanches. When individuals are vigilance causing them to concentrate more on the surroundings this will result in a higher energy consumption. The reduced visibility also increases the time it takes to perform a task.

There was consensus among the interviewees that long work hours often occur independent of industry. One example mentioned was that a guided snowmobile ride from Longyearbyen to Barentsburg can take up to 11 hours and with the preparations for the trip and the finishing work the guides workday can last for 12 hours or more. Since a lot of the work on Svalbard are seasonal based it requires a lot of work during a short period.

People have different fatigue thresholds, this will vary allot with individual experience and fitness. As mentioned, visitors' experiences fatigue quicker and to a higher extent than people working on Svalbard. For instance, some of the people working on Svalbard rides snowmobiles every day while some visitors have never driven one before. Visitors uses a lot of energy focusing on the snowmobile driving while the experience people can drive on *"autopilot".*

Several interviewees were under the impression that most of the incidents involving snowmobiles happened towards the end of the trips. It was also mentioned that fatigue hits harder towards the end of the week. The interviewees seemed to recognize fatigue in others more often during longer trips, such as ones lasting a whole day, than the ones lasting a couple of hours.

Planning the time needed for a task and breaks were said to be difficult because of several factors. This often resulted in people not being able to ingest enough energy.

Several of the interviewees mentioned concrete examples of episode where they thought fatigue had played an important part. One of these episodes included a group of tourists that had been traveling for a whole day due to delayed flights. The group had ordered an overnight stay at a location which required a snowmobile trip. Because of the delay they had to drive off in the twilight rather than daylight. One of the tourist got tiered because of all the traveling and snowmobile driving and was not able to control the snowmobile and ended up with a severe injury.

5.1.15.Fitness for Duty

Physical and Psychological Requirements

Many of the activities on Svalbard requires some form of physical work, and people's endurance is often put on test. The requirements to the individual's physical fitness varies with type of task. If the task is to reach a mountain top by skis the physical fitness is very important, while driving a snowmobile to a given destination it is not necessarily physically challenging. Several of the interviewees mentions episodes during summit hikes, both by foot and skies, where the group had to turn around because one or more individuals were not fit enough to continue.

The grading system formed by the traveling agencies specify the requirements for a trip. The challenge is that people have different opinions on level of fitness and might think that they are physically fit for the trip when in fact they are not.

In some cases, people might not have the psychological strength to continue. The interviewees mentioned episodes where people didn't want to drive a snowmobile or ski down a steep hill and they had to find an alternative longer route down.

5.1.16. Attitude to Safety and Safety Culture

The Attitude to Safety in the General Population

The interviewees describe most adventure travellers as cautious and avoidant to undesirable risks. They are traveling to the Arctic with general good attitude to safety and are respectful of the surroundings. There was little to no bad behaviour to compromise safety and they were mostly accountable. However, the fulltime residents have a slightly different approach to risk management due to their experience. It was also mention that the most common accidents involve fulltime residents.

The early days in Svalbard was described as a "*cowboy era*". During this era, benchmarking and bragging about how fast and how far they had driven and how bad weather condition they were able to endure, was common between the fulltime residents. Today in a commercial setting, this will result in an "*occupational suicide"* and death to their reputation. The cultural acceptance to go further away from infrastructure has changed a lot in 20 years. At that time 85-90 km was an expedition, but with today's technology it is only a one-day trip. However, if the equipment fails one are still facing the same challenges with the Arctic environment as one did 50 years ago.

These days individuals are often more concern about fancy equipment and the means of communication than assessing the actual dangers. The desire to have the best and newest equipment such as emergency beacon, transceiver and satellite phone, was considered to be a poor development. This development is described as *"unfortunate*" and will cause a wrong area of attention. The interviewees said that most of the equipment is only put into effect after an accident has happened, which in an arctic context is often too late. They said that there should be more attention towards avoidance of the accident. Avalanches, in particularly, was mention as an example. Avalanches in the Arctic consist mostly of hard packed ice which are fatal. Getting caught in one will most likely kill you, therefore it is better to learn to avoid them.

Another concerning element are the "*self-appointed experts*", they considered themselves as expert in Svalbard after a brief period. They might have been on a couple of excursion, seen polar bears, shot with a rifle and participated in an avalanche course, and then starting to advice less experience individuals themselves.

Individuals with 20 or more years of experience can have some trouble following the guide or group leader's decisions if they consider them less experienced than themselves.

The communication culture across commercial competing companies is described as open and they share knowledge, such as environmental conditions and hazards, among them. Limitations in experience among guides, limits the company's ability to offer some activities. The commercial actors encourage their guides to reject trips where they feel that their experience is inadequate, but inexperienced guides might feel an obligation to carry out the trips regardless.

Some strategies to implement god safety attitude today are scare tactic, encouragement, rule-based management and procedures. It was also mentioned that even if all precautions were made there was always foolish actions done by individuals to compromise the safety.

The following statement was considered as foolish action by some of the interviewees:

- *"Jumping of roof tops into seemingly soft snow, but in reality, it was packed ice".*
- *"Driving zigzag in a snowmobile convoy".*
- *"Holding back the speed in snowmobile convoy, for then to drive fast and close the gap, creating a gap behind them".*

Reporting Culture for Close Calls and Unwanted Occurrences

There were challenges with the reporting culture and how to reach desirable number of reported incidents. All the interviewees that was managing safety, promoted a "no blame culture" and wanted experience feedback from those in the field to improve said subject.

One of the interviewees said that it is important to comprehend that a trivial incident might have a severe outcome, for example tipping over with a snowmobile. Such an incident occurs almost daily, and it is therefore important to report such events even if there is no serious consequence. The cause and the rate of these events can further be used in safety training. It was also mention that it is most certainly a high number of unrecorded incidents, such as seemingly harmless events which could have potential severe outcome.

While driving in a snowmobile convoy, some inexperienced drivers were not stopping and suggesting brakes to adjust the equipment to prevent freezing or frostbite. There was a small disagreement between interviewees regarding this subject. In some of the interviews there were example of incidents where one individual had gotten frostbite in the face. This was due to not diverting or cancelling the current action, but rather continuing. There were suggested some reasons for this behaviour. It could be that the individual did not have the courage to tell the leader of the group, but another more likely reason, is that the discomfort it takes to prevent the problem is perceived as bigger than the problem itself. This was mostly speculation between the interviewees.

The most commonly recorded incidents are with injuries. The cause of this was speculated, some suggested that people were general too lazy to report. Others suggested that there was a misconception between which incidences you should report. But there was consensus that more knowledge of unwanted occurrences could give better preventative safety solutions.

Search and Rescue Initiation Threshold

The interviewees which had experience with Search and Rescue described the initiation threshold as low. The consequences for an accident outside infrastructure combined with the vast distances, was the main motivator. Therefore, Search and Rescue have been initiated for the following mentioned reasons:

- *Strained ankle*
- *Weather-bound, trapped in bad weather*
- *Suspected fracture*
- *Missing person*
- *Snowmobile collisions*

5.1.17. Support from Management

Support from Management Concerning the Individual's Decisions During Task Planning and Execution and Safety Concerns.

Some of the interviewees mentioned that in the non-commercial industry there are few downsides concerning cancelation of a trip and the threshold for cancelation is therefore low. The ones who are conducting the activity or task are always the ones deciding if it is defensible or not to actuate the activity or task and the management support their decisions.

It was mentioned that there had been situation where the management had questioned if the cancelation was caused by «comfort»-reason rather than the fact that it is not defensible. Several of the interviewees mentioned that during the *"cowboy-era"* in the commercial industry earnings were prioritized over safety, but over the years the focus had changed.

The interviewees mentioned that in many cases the management were not able to offer support during fieldwork because of the lack of options for communication. The support is therefore often based on trust. It is not until the person returns that the management can support or question decisions made during a trip.

5.1.18. Communication

Adaption of Communication

The communication is adapted according to group size, experience, noise and nationalities. In different groups the communication is adapted accordingly. Small groups with experienced individual are often less thorough for one-day trips. They make small arrangements in advance, where they mostly agree on who brings what and they also have a small briefing about the hazards. In some of the interviews, the same impression was perceived for some longer trips as well. For instance, were one had planned the food and beverage for a 4-day expedition, and the individual only brought one type of meal and one type of beverage. This is a comfort issue and not a safety issue, but in this case, some of the food-rations were contaminated and resulted in food poisoning.

In bigger groups, usually a more systematic approach is used. Also, it is not always known what experienced level the others have. Therefore, the leaders prepare everything in advance of the trip. This also includes extra clothing and other equipment in case of need. A trip for a big group starts out with an HSE briefing and during the traveling there are more frequent breaks to evaluate the dangers.

After years of experience some interviewees said that a military line of training was best. There is better to have a command and comply approach, then giving inexperienced participants the freedom of self-assessment. This method in communication were considered safest for everyone.

For the educational institutions, English is the primary spoken language. There are around 45 different nations in Longyearbyen at any time. Communication is made as easy as possible, with gestures and monosyllabic words. The HSE briefing also includes pre-agreed procedures, where the lecturer made sure all the participants knew the dangers and how to deal with them. For example, when a snowmobile goes through the sea ice in a convoy, the next in line have a specific procedure to follow.

Factors that Influence the Ability to give Commands and Receive Commands

It was said that the language barrier could be one of the reasons for impairment in communication, but a more likely cause was when the individuals were suppressed by fatigue. Threat stress could also make individual doubt the commands and therefore hesitate to comply. It was mentioned that preparing in advance for the commands which would be given during a trip would make all the individuals more responsive. Things that can affect the responsiveness could be excitement, weather conditions and experience. The interviewees agreed upon that the communication varied during different weather conditions. Only noise was mentioned as a factor which could affect the ability to receive commands.

Communication Between Actors with Similar Interests in Safety

In general, everyone Longyearbyen is open and sharing regarding hazardous conditions. People that lives and work on Svalbard are also experienced with local conditions, that others are less likely to know of.

Before people are heading out, they often call others that they know have recently travelled in the area to ask if there are conditions they need to be aware about. This is mostly done verbal either by cell-phone, satellite phone or face to face. There is a very low threshold for this, partly because everyone knows everyone in the similar line of professions, but maybe more important they know the consequences if something goes wrong.

From the management perspective, the traveling agencies looks after those out in the field. They warn the guides of incoming bad weather and they know their position at any given time with the InReach GPS system. The agencies have procedures to for example evaluate avalanche hazardous slops. If the avalanche-forecast predict a hazard category 3 or more, the procedure states that 3 individuals with experience needs to decide if it safe to proceed or not to. This needs to be decided locally on the site or, for example, a snowmobile convoy needs to take an alternative route.

The traveling agencies are not in direct contact with the SAR operator, but the SAR operator usually knows if there are longer expeditions being conducted. Longer expeditions needs to be reported to Sysselmannen ahead of the trip. This is because the agencies contact the police if there are incidents and then the police and contacts the SAR operator.

Communication and Behaviour During a Stressed, Unsafe Situation

Many of the interviewees could not recall a stressed, dangerous and unsafe situation where communication had been a challenge. Mostly because the group had stopped the tasks before something went wrong. Many of the unwanted occurrence happened fast and was over in a brief moment, making communication insignificant.

But in some of the episode that gradually got more severe over time, threat stress had a huge impact on the ability to communicate. Under threat stress, behaviour also starts to change in less experienced individuals. The ones giving instructions also need to account for the threat stress the individuals are experiencing. The instructor must try to calm them down to make them properly comply the commands. One incident was mentioned where a glacier crated a tsunami under the ice, causing a person to panic and drive into jumbled ice even though the person was instructed to stay just stay still on the snowmobile.

5.1.19. Teamwork and Collaboration

Challenges Related to Teamwork and the Distribution of Responsibility

Some of the challenges mentioned by the interviewees was group size, noise, experience, weather, environment, overestimation of a groups capability and individuals underestimate their own capability.

Field safety was managed from an office but the guide or the lecturer mainly decided the route and how to proceed during the trip. The leader had most of the reasonability during the fieldwork but were supported by the management.

One individual said, that there was sometimes pressure from colleague to start an excursion even if the person were not comfortable doing it.

Some of the interviews stated the factors that could affect the teamwork and who had the responsibility during the event. **Table 12** shows some examples that were mentioned during the interviews. *Contributor* are factors effecting the teamwork. *Effect and impact* describes how the teamwork were affected. *Responsibility* stats how’s in charge of planning, preparation and carrying out the task or activity.

Table 12 Contributing factors and its impact on tasks and activities.

Contributor	Effect	Impact	Responsibility	Task/activity
Lack of experience	Anxiety, panic, behaviour	Lack of control, perception of risk Risk acceptance	Guide, lecturer, Individual	Fieldtrip, others
Noise	Bad attention, lack of hearing	Commands	Guide, lecturer,	Snowmobile driving, others
Weather	Freezing	Preparation	Individual	Fieldtrip
Group size	More responsibility to leaders	Preparation	Management	Fieldtrip, others
Unknown capabilities	Underestimate, overestimation	Decision making	Guide, lecturer,	Rifle handling, snowmobile driving, others
Too much, too little confident	Unable to proceed, compromising safety	Encouragement, doubt, discourage	Guide, lecturer,	Fieldtrip, Rifle handling, snowmobile driving, Others,

Cultural differences and its effect on Safety

Those interviewees who had jobs that requiring them to lead inexperienced groups out in the field, said that some nationalities were more obedient then others. They stated that there were typical aspects to a nations culture which were a bit challenging. Examples of this behaviour were arguing on the leader's decision, disrespect towards the leader and answering yes to question they clearly did not understand.

Most common situations where individual is arguing about leader's decisions were if they felt the decision robbed them from achieving their goal. They would then be persistent to not take a no for an answer, but instead argue to find other ways around. In other situations, an individual can be disrespectful to the leader, either due to age difference or difference in experience level. Some interviewees said that young, unexperienced leaders might find them self in difficult situations because of this pressure.

Another challenge is the language barrier. In a commercial setting, non-English speaking tourist are often denied participation to a snowmobile trip. The snowmobile trips are designed in such matter that there is little to no requirements for unexperienced drivers to take own decisions. The commands used by the leaders are short and consistent so there is less room for misunderstanding. A problem might occur when international tourist does not recognize these commands but do the opposite of what is told. There might be as many as 20 unexperienced drivers operating these machines, so the leader need to trust the person driving.

There was consensus among the interviewees that most of these challenges were not as difficult as they seem. In the commercial setting, it was also accounted for the language barriers in their risk analysis.

5.1.20. Environmental light conditions

Seasonal Light Conditions Impact on Safety

In terms of lighting conditions, the seasonal darkness naturally gives some limitations. Between the interviewees there were a disagreement on how the seasonal darkness affect safety. Some meant that low visibility was not an issue, other described the dangers quite thorough. In dark conditions one can simply not see all the dangers ahead. For example, in complete darkness and only the headlights from a snowmobile as the only light source, one cannot see 1000 meter up on the mountainside. Therefore, one cannot know if there is a high risk of avalanche. Another concern is the wildlife. On Svalbard you have a high risk of meeting polar bears.

The weather can be very local and can change rapidly and become "*surprisingly bad*". It can be opposite conditions in one valley to the next. In the dark one cannot see far ahead and can end up being caught in stormy weather.

The Effect of Seasonal Darkness and Midnight Sun

Most of the interviewees did not think that the light conditions had any impact on their sleep pattern, others however did think that the seasonal darkness had an effect. The ones effected, felt that it was harder to fall asleep and wake up in the morning, and when the sun returned they could feel an energy boost. Some of the interviewees believed that, regarding to sleep patterns, there was little to no effect from seasonal light in the residents Svalbard. It was more common for guest to be influenced by the seasonal light.

The seasonal lighting affects work hours. During the period of midnight sun, work hours were longer, and it became harder for individuals to get enough rest. Therefore, rest time rules were used by both the commercial and non-commercial companies, but deviation from these rules often occurred. It was generally harder for people to limit themselves during the periods with light at all hours. The interviewees said that some days they felt that the work hours were extended to their very limit.

5.1.21. Environment topography

Challenges Regarding the Landscape

Some slopes in Svalbard where people are driving with snowmobiles are considered steep and some of the trails had also been exposed to avalanche.

The landscape in Svalbard is carved out by glacier thousands of years ago. This makes the topography appear in several layers with steep mountainsides. Glacier are often connecting the bottom of the valley to the top of the plateaus, since the glaciers are flowing downwards, crevasses can appear around the glaciers. These crevasses can be hidden by snow cover and be several meters deep, falling in one can be potentially fatal. Glacier can also slide into seawater causing tsunamis. Under sea ice these tsunamis can break the ice causing gaps to appear between the ice sheets. When the ice sheets are closing after such event, anything in between the ice sheet will be crushed.

The mountainsides are often steeper than 30° and the slopes can have many *terrain traps*. Terrain traps are places where snow in an avalanche gathers, which may end up bury people deep in the snow.

Vast distances are general challenging in the Arctic and in the combination with unreliable weather the distances are even more treacherous. The further away from infrastructure one gets, the risk for more severe consequences increases. Some of the interviewees compared a 1-hour ride with snowmobile to a 24-hour walk on foot. In a case where someone is injured, it may even take days for the individual to get help, depending on weather conditions and distance. There was an agreement between all, that cultural acceptance to travel further out, comes with natural challenges in terms of rescue.

Traveling of vast distances requires more of the individuals then shorter trips. The preparation of such an expedition need the account for "*the Arctic Problem" (lack of infrastructure, harsh natural environment and restriction in communication).* The distance between Barentsburg and Longyearbyen is 60km, if the snowmobile brakes down half way one must be prepared to walk almost a day to get back. It was said that the travellers' need to be prepared to take care of themselves if they go out to far. Some of the reasons for this were the natural limitations to SAR helicopter with its needs to refuel somewhere. SAR operators have emergence fuel depots around the archipelago to ensure maximum range. But again, local weather conditions can make them unable to reach them.

Some interviewees, with many years of experience, did not feel they were in dangers when they were stranded far from infrastructure. They said, that they had trust in the equipment and their experience to know what to do.

5.1.22.Environmental Wildlife

Wildlife and its Influences on Safety.

The first interviewees mentioned were polar bears and the hazards of encountering on. Polar bears can be encountered anywhere on Svalbard, footprints have even been seen on top of the highest mountains. They usually hang out on sea ice close to seals. The best conduct when in proximity of polar bears, is to avoid them in the best possible way. Polar bear encounter usually ends in change in traveling route, pausing or aborting the current task or activity. There have been incidents where the bear had been shot, none of the interviewees had been required to do this in their trips, but some had been required to use a flare gun towards a polar bear.

Another situation that might occur, are that the reindeers tear down the road markers. This is not a danger itself but can lead to other challenges like less visible roads. The reindeers apparently like to scratch their antlers on road markers. Since there are no trees at Svalbard the reindeers find other means to scratch themselves. One of the interviewees had experienced the destruction of all the rods after a summer of not traveling on that road.

5.1.23.Natural hazards

Summarizing of Environmental Hazards.

The educational institution (UNIS) classified hazards in to 4 categories. The hazards mentioned before, during and after the recorded interviews, is shown in **Table 13**.

Table 13 Summarizing some of the environmental hazards.

Cryohazards	Weather hazards	Slope hazards	Biohazards
Thin sea ice	Strong winds	Rockslides	Polar bear
Glacier	Whiteout	Land slides	Reindeer tearing down road markers
Frostbite	Frost-add	Avalanche	Tapeworm (parasite)
Hypothermia	Windchill	Flood of meltwater	
Icy grounds	Participation		
Ice sheets			
Low temperatures			

5.1.24.Weather

Weather Factor Considered Before and During Fieldwork.

There are challenges, especially in search and rescue missions, due to the weather conditions. the helicopter has clear limitations in what weather it is defensible to fly. *"What you see is what you get"*. This statement describes how it is to pilot a SAR helicopter. The SAR helicopters usually cannot go into valleys with bad weather. The pilot can go around, fly over or wait for the weather to clear out. Since the weather conditions often are local, it might be possible for the pilot to go through another valley.

Visibility, windchill, whiteout and every other thing concerning the weather conditions needs to be accounted for before starting and during the fieldtrips and expeditions. Adaptations is required all the time, for example when driving a snowmobile, one can try to avoid problematic areas and slow down the speed. While driving a snowmobile the wind from the driving speed and the weather can increase the windchill temperature and with that increase the risk of frostbite.

It was also mentioned how the wind and the cold were perceived different by individuals. But a common practice by the guides and instructors was to stop the current activity and handle the problem. Most likely if someone is freezing there are others doing so as well. Freezing needs to be addressed quickly to prevent hypothermia and frostbite.

The wind conditions can change the environment in hours. The wind can dig out holes in the snow, ranging from small snowdrifts to several meters deep. Driving or falling in one can be serious. Windspeeds, temperature and visibility can change rapidly and because of the changes in the climate it is hard to prepare for these conditions. The interviewees said that the past few years, many had experienced weather conditions never seen before in Svalbard. These conditions do not relate to the data and experience gather over the past decades. The wind is changing, slopes that was not considered to be avalanche hazardous are now considered hazardous. Snowdrift is gathering in new places, making slopes unsafe.

Precipitation in the coldest month of the year can also appear. One’s rain hits the cold ground it freezes to ice. This ice making driving and walking difficult. When snow builds up on top of the ice there is an increased risk of an avalanche. Making avalanches occur even below an angle of 20°.

5.2. RESULT SUMMERY

The results should enlighten the PSFs which will have a significant impact on human reliability and the impacts magnitude.

The interviewees had a wide range of backgrounds and responsibilities. They were employed both at commercial and non-commercial actors. Some had more than 20 years of experience with activities far away from infrastructures in several different places in the Arctic. The most common activities and task was transport with snowmobile and field work.

Some interviewees had experienced goal conflicts and pressure from management during tasks and activities which could cause elevated risks. This was mostly experienced in commercial operators due to time and money pressure. Tourists and researchers often visit Svalbard for a limited time, and their wish to carry out their planned activities causes time pressure.

There were several different aspects to the preparation on an activity or task. Problems addressed during the planning could cause the activity to be postponed or cancelled. The environmental stressors were often the main cause of this, which in turn could lead to time pressure in commercial actors. In non-commercial operator’s, nature set the available time and they were therefore much more conservative.

All the 11 interviewees had either experienced unwanted occurrences during travels or field work in the Arctic themselves or knew someone who had experienced it. Both experienced and unexperienced individuals were susceptibility towards threat stress and they had different perceptions of risk. Perception of risk was closely related to experience but were also influenced by the risk acceptance. The main positive contributor to safety during field work was experience. Exposures to hazards was far more important than training, which could give new knowledge on scenarios which otherwise was unobtainable.

The commercial traveling agencies have implemented a level-of-difficulty-system to better pair tourists with what the trips demands. Some of the trips required good fitness and was physically and mentally challenging. This was said to have an impact on performance among with weather conditions, experience and equipment.

Procedures was made as guidelines and not fixed and inflexible. Room for improvisations both action-wise and equipment-wise was important. Clothing was seen as both a resource and an obstacle. Restrainment from clothing, physical fitness, lack of food and seasonal light condition were contributors to fatigue. The diverse awareness levels to the surroundings among experienced and unexperienced individual was mention as a contributor. Both the physical and psychological requirements to conduct tasks outdoor in the Arctic was significant in terms of human reliability, but also the attitude to safety.

The management mainly supported the individuals' decisions during planning and execution of tasks. This trust was important due to the lack of possibilities to communicate out in the field.

In groups, both cultural differences and the ability to give and receive commands was important. Actors on Svalbard use a military approach to group management.

The environmental topography and the wildlife has hazardous aspects. With the changes in the climate, these hazards caused new unpredictable conditions to appear more frequent. Luckily the search and rescue initiation threshold was considered to be low and people have been picked up by helicopters for strained ankles and small injuries.

6. DISCUSSION

This chapter discuss how the PSFs from other HRAs fits an arctic context, and which changes in the definition are needed in order for them to fit the Arctic. It also elaborates changes in the PSF levels and multipliers used to calculate HEP. Most of the potential scenarios which can occur at Svalbard were considered to be minor incident. The possibilities of major accidents should not be disregard since there are groups of 20 or more individuals traveling over sea ice and in avalanche hazardous terrain. Therefore, the discussion holds a generic approach to accidents.

In many different industries the possibility to measure performance is important. This helps predict the companies reliability in terms of safety and loss. This thesis discuss terms and suggests frames for how to quantify performance and reliability. The arguments found in the following chapters are found be looking at minor group and specified to one location. Nevertheless, this do not limit the findings for usage in other applications.

6.1. PERFORMANCE SHAPING FACTORS

Since almost anything can be seen as a PSF, it is important to establish a clear definition of the PSFs that is included. To help in this process an overview of the different HRA methods were made. **Appendix A** show shortly the domain of use and if the HRA method were empirical validated. The HRA methods elaborated in the theory was chosen after compering the different HRA methods in **Appendix B.** Considering that both SPAR-H and Petro-HRA uses values from THERP as a basis for NHEP, one can discuss whether this task type yields for every condition.

HEART and NARA was added to substitute to empirical data to propose multipliers in an HRA for arctic context. Both HEART and NARA is constructed on different recorded data, were NARA includes data from HEART and other domains such as military aviation and various industries. NARA can be considered as a more diverse application then HEART. HEARTs data-set are mainly constructed by events and research done in nuclear industry with some substituting industries, but the simplicity of the calculation of HEP were adopted by NARA.

THERP table 20-1 and time T=30 minutes NHEP value were used in SPAR-H and Petro-HRA as the primary task value to determine HEP. Regarding this, conducting an HRA with little to no empirical data can be faulty, considering who is conducting the analysis. The perception of the thesis participants is that SPAR-H and Petro-HRA is applying a low generic task type as NHEP for then to adjust the probability with high multipliers. Since the multipliers are ultimately suggested by experts, one cannot assume that the HEP can be statistically proven.

In THERP, NARA and HEART the probability for failure is set by statistics, and research done to verify factors that might influence these factors are applied to adjust the HEP accordingly. Regardless the statistic, having suitable definitions and strict frames on the performance shaping factors, greatly increase a HRA user friendliness. THERP was considered to be the worst HRA in terms of usability. Simplifying the method down to basic task types and what are the performance shaping factors was needed to best present it in this thesis. In **Appendix B** under THERP PSF the population stereotypes, Experience and dependency were set in suitable categories to best represent the PSFs. As mentioned earlier THERP was included due to its vast amount of empirical data on human error probability, the same applies for HEART and NARA.

The HEART and NARA approach had other difficulties, since all were originally constructed to be used in industry the question arise on how it could be used in an arctic outdoor context. More or less the same applies for SPAR-H, Petro-HRA and THERP and this is to be explored in the following chapters

The activities SPAR-H and PetroHRA are intended for is mainly performed indoor, therefore the definition of the PSFs should be changed in order to fit outdoor arctic activities. Petro-HRAs definition was well argumented by the changes done from SPAR-H and therefore some trivial PSFs definitions could fit to an arctic context. Since there are conditions and task types that are highly dependent to each other, THERPs approach to task dependency and population stereotypes could be implemented to fit certain PSFs and better help define the context of one certain PSF.

6.1.1. Dependency

The dependency PSF in THERP affect several tasks. HEP for a single task is independent of the HEP of another task and the dependency PSF is therefore only relevant for calculating total HEP. This PSF can be accounted for in for instance a fault three analysis later in the calculation of a total HEP. On the other hand, knowing that an activity compiles of several tasks, the task analysed in an HRA should be so specific that the operation compiles of only a few actions, for instance, half loading a rifle. Half loading a rifle could be considered as several tasks: Placing bullets in the magazine, checking for bullet in the chamber, closing the bolt while simultaneously holding down the bullets to prevent them from entering the chamber, pulling the trigger. The same applies for driving a snowmobile which consists of several tasks. The definition of task complexity in Petro-HRA covers this area with the implementation of sub-tasks, step complexity, connection complexity and structure complexity. This is seemingly a god approach to an arctic context as well, due to the frame of what a specific task contains in this thesis definition.

For the dependency PSF to be relevant for this thesis it should account for the dependency between PSFs. To make the calculation of HEP easier and to not risk including a PSF twice the dependency PSF should not be included. Since Petro-HRA connection complexity describe the dependency between sub-task or task steps there is no need for dependency as a PSF.

6.1.2. Improvisation

Room for improvisation was mention several times during the interviews. This was mention during elaboration of procedures, equipment and environment. Incorporate improvisation in PSF seemed to be important. The room for improvisation can change the outcome for a task.

Improvisation seemed to be partly covered by task complexity in Petro-HRA. The frames for goal complexity definition states that there are multiple goals, suggesting several sub-tasks. Also, that there are alternative paths to one or more goals. If goal complexity is to cover improvisation it is suggested that goal complexity is described as several paths to reach one goal. Several paths can then mean for example different or alternative equipment, the option to use discretion rather than procedures and choosing alternative traveling routs. The one conducting the HRA need to be aware of all options to reach the specific goal. This also means that several options to reach one goal can be both positive and negative for human performance. If one is to include several sub-goals in the same HRA without making it extensive more complicated, a task goal needs to be detailed specified. Improvisation would then mean that there are alternative ways to reach the task goal though decision making and actions.

In procedures, room for improvisation would mean that there are ways to perform a task without violating the frames of a procedure. How strict and descriptive the procedure is would also indicate if there are any room for improvisation. As the interviewees mention, procedures used at Svalbard were both unalterable and alterable. An example of an unalterable procedure was the sea ice thickness and when it was acceptable to cross. If the only available path is across sea ice thinner than required, one would fail. If there are possibilities to find an alternative route this could be considered as goal complexity. Giving the option to decide which alternativ path could then be considered as improvisation. The chosen route would most likely be influenced by experience and other PSFs, making improvisation unfit for a standalone PSF.

In the Arctic, alternative equipment and the possibility to improvise equipment could mean the difference between failure and success. One interviewees mention that having spare parts laying around, like tape and other miscellaneous objects was always routine, because one never knows if one might need something. This would make improvisation possible regarding for example a quick fix of the equipment needed to fulfil the task. As equipment improvisations falls under the equipment PSF, other miscellaneous objects could increase the probability of success.

Room for improvisation should be incorporated into procedures, equipment and task complexity. This could reduce the possibility for double counting.

6.1.3. Time

Definition

In the Arctic the forces of nature set the available time and the time schedule should be planned thereafter. Although there should be included a time buffer in the planning of a task there will always be time pressure in some tasks. This is especially noticeable for tasks that must be performed during abnormal scenarios, such as avalanches. Serval factors, such as the weather conditions influences and shortens the time available to finish a task.

In a non-commercial setting time is a minor issue. The time it takes to finish a task will in most cases ordains the time planned to finish the task. If the task requires more time, the purposed time is extended. For people visiting Svalbard for a shorter period a postponed start will shorten the available time and create time pressure. A PSF considering time should therefore be added.

THERP and SPAR-H emphasize quantification of time in minutes and the suitability for arctic would therefore be low. The vast variety of tasks and the time they require is too diverse making THERPs approach unfit for an arctic context. Predicting the probability of failure on basis of the diagnosis model for THERP within T minutes by the operator, gives to few options to cover all the possible scenarios. Taken into account that the values seen in THERP and SPAR-H is based on the confined space of a control room they do not yield, since there might be hours between detection, diagnosis and correction. The time phase of these do not necessarily increase or decrees human error probability compared to other tasks, which might only take minutes. Therefore, available time versus required time is seemingly a more suitable approach for an arctic context.

The definition of the Time PSF in Petro-HRA can be used as a basis for the definition in this thesis. Petro-HRA do not emphasize quantification of time in a similar manner as THERP and SPAR-H, making it more applicable for more scenarios and focuses more on time available.

Available time and Required time will be dependent on the situation. In a non-commercial setting the available time can be consider extremely high, while in a commercial setting or during some abnormal events, there will most likely be a set finishing-time for the task. The time it takes to finish a task in the Arctic will vary due to several factors, such as the ground conditions and lighting, and its therefore an uncertainty attended with required time and an uncertainty interval should be added to the definition. Time is only applicable if the analyst has an expected or predicted duration of a task. **Figure 10** shows the connection between required time and available time which would be an appropriate way to address this PSF in the Arctic.

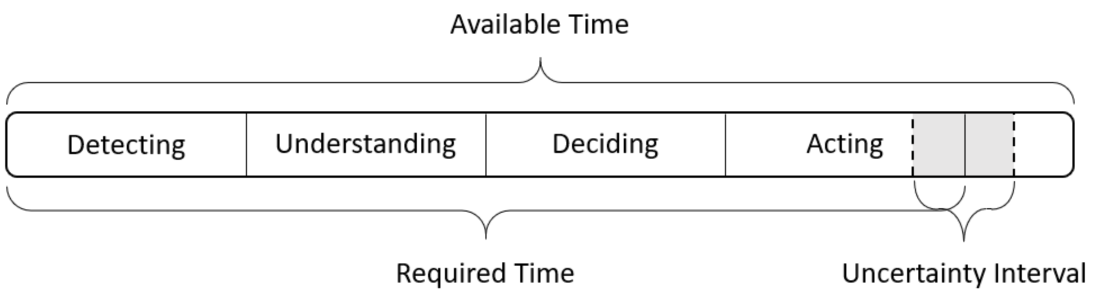

Figure 10 The relationship between Available Time and Required Time

Using avalanche rescue as an example, the available time is the period between the person is caught by the avalanche until the person suffocates. Required time is the time from the person is caught by the avalanche until the person is rescued out from the snow. If the person suffocates, the task has obviously failed. The depth of the avalanche is one of the factors that will influence the required time, thus the uncertainty interval.

Levels and Multipliers

Table 20-1 in **Appendix E** shows the HEP for diagnosis by an operator within different times (T minutes after an initial event). THERP also account for the HEPs for a consecutive event in this table. As mentioned above the HEP for one event should not be affected by the HEP of a different event. This could instead be included in connection complexity within the task complexity PSF. THERP have a more quantified approach to determent the effect of time on HEP. T in minutes after an event is used in diagnosis. The time intervals cannot be defined in similar manners in an and arctic context. Meaning that the diagnosis time and how it will impact human performance in a specific task is hard to predict. Since it is difficult to know exactly how many minutes that is disposal for handling a task or scenario need, the THERP values might not necessarily represent an accurate HEP in an arctic context.

The levels of the Available Time PSF in SPAR-H is based on the above-mentioned THERP table. Petro-HRAs also bases the PSF levels on the THERP table. But whereas SPAR-H exclude the T=10, Petro-HRA includes it as Very high negative effect. As it is argued for in Petro-HRA, Inadequate time and Barely adequate time is similar. This should also be accounted for in the Time PSF in this thesis. The levels from Petro-HRA would therefore fit better for the Time PSF.

EPC no. 2 from HEART and EPC no. 3 from NARA deals with time pressure. It is not stated the level of pressure, but it can be assumed that it equals a moderate amount of time pressure.

A summarization of the arguments for the use of the definitions/multipliers from THERP, HEART, NARA, SPAR-H and Petro-HRA is shown in **Table 14**.

Table 14 THERP, HEART, NARA, SPAR-H and Petro-HRAs suitability for the use in the Time PSF.

SPAR-H level	Petro-HRA Levels	Suitability for the Arctic	Suggested multiplier
Inadequate time	Extremely high negative effect on performance	Some abnormal occurrences create very limited available time and, in some cases, no available time at all. Knowing that Time required >> Time available, this could therefore be considered as Inadequate time.	Not enough available time will result in a failure. The multiplier should therefore be HEP=1
	Very high negative effect on performance:	The time available = time required would most likely lead to failure in an arctic context, knowing that time required always exceeds the time perceived as required. Therefore, this could be considered as Very high negative effect on performance.	A multiplier of 50, as in Petro-HRA, based on T=10 minutes from the THERP table would also fit in an arctic context.
Barely adequate time	Moderate negative effect on performance	This was mention several times during the interviews. This definition in Petro-HRA yields in similar manners. Therefore, it can be directly transfer as a level. Time required < the time available, which might lead to time pressure which can affect the task negatively.	The multiplier of 10 from Petro HRA fits here. This can be backed by multipliers of 11, for moderate time pressure, from HEART and NARA.
Nominal time	Nominal effect on performance	Having the time required to perform should be accounted as nominal and therefore have nominal effect on performance. This definition can be directly transferred from both SPAR-H and Petro-HR.	Nominal effect gives a multiplier of 1.
Extra time.	Moderate positive effect on performance	Applying this level would be more or less useless for the tasks and in an arctic context one can never be sure that time available is much more then time required knowing that wildlife and weather can always disrupt tasks.	Not evaluated
Expansive time		Not evaluated.	Not evaluated

6.1.4. Perception of risk and Threat Stress

Definition

Threat stress is closely related to experience. An unexperienced person might perceive the risk from a hazard as much higher that an experienced person does. That way an unexperienced person might feel stress from a threat that is not present. This might also go the other way and the unexperienced person will not feel any stress from a threat that is present. For instance, an assumption that there is a risk for avalanche in every hill might result in discontinuing of a task. On the other hand, where an experienced person might discontinue a task due to a risk, an unexperienced person might complete the task because the person might not know about the risk.

Threat stress in Petro-HRA is questionable since it only accounts for the anticipation of phycological and psychological harm. In the Perception of Risk PSF one accounts for both anticipation, wrong-anticipation and non-anticipation. As mention during the interviews, overconfident snowmobile drivers could drive reckless not seeing a hazard as real. Replacing Petro-HRAs Threat Stress PSF with the Perceived Risk PSF would better cover such examples. Another example is unconfident drivers that need encouragement to perform. Considering this overconfidence and inconfidence could have a negatively effect on performance. These factors could also be seen part of experience and training, but since experience and training can be empirical validated these were included in the Perception of Risk PSF.

Instead of including “confidence in own abilities” as a PSF, one should rather consider the individuals perception of risk. If the perception of risk is greater than the real risk, most likely an individual will feel threat stress or be unconfident. On the other hand, if the perception of risk is less than the real risk, one could feel overconfident.

To consider reckless behaviour or panic behaviour it is suggested to take Population Stereotypes from THERP into consideration. In the conduction of an HRA the analyst should also observe the performed task and establish some kind of norm on what is considered as reckless behaviour. For example, consider the interviewees examples of the “foolish” behaviour or panic behaviour in the scooter glacier-tsunami-incident as mentioned in **Chapter 5.1.3**.

Threat stress is a part of the stress/stressors PSF from SPAR-H. The stress/stressor PSF is very wide-ranging and as mentioned in Petro-HRA it encompasses elements from most other PSFs in SPAR-H. As it is done in definition in Petro-HRA, the overlapping parts of the stress/ stressor PSF can be included in other PSFs.

Petro-HRA mentions that specific training can reduce threat stress. It will not be possible to provide this type of training to everyone performing tasks on Svalbard due to the limited time of their stay. This type of training would therefore only be relevant for people staying there for a longer period and fulltime residents.

The definition of threat stress used in Petro-HRA is partly applicable in an arctic context. This could for instance be relevant during a polar bear attack. A polar bear has the potential to kill a person, and the persons that must defend themselves or others, would most like feel stressed in this situation. The threat stress could, for instance, contribute to the person missing when firing the rifle.

On the other hand, there were interviewees with several years of experience catching frostbite, due to the lack of threat stress or fear of consequences. Take for example face-protection during driving a snowmobile. Both experienced and unexperienced could feel discomfort or stinging sensation due to improper use, but they did not necessarily stop and address the problem. When delaying this action, the risk of frostbite becomes significant and a frostbite could cause failure in the commenced task.

For a weather-bound group or individual, with not possibility for cover from wind or reheating where frostbite and hypothermia is a real risk, the fear of consequences would be a significant factor. The perception of this situations would be highly diverse considering an individuals experience. Independently of experience, the perception of the risk would most likely be influenced by ones’ comfort.

Levels and multipliers

Disruptive behaviour is considered to have a high impact on performance as the previous examples states, the perception of a risk can considerably alter ones' decisions. In THERP, the modifiers used for estimation of HEP is expressed through both experience level and the effect of stress. Excluding experience, placing this in a PSF on its own, help reduce double counting since experience and training can be empirical validated. Extreme high threat stress for a novice individual is set to HEP=0,5 and skilled 0,25. Assuming overconfident individuals with no experience are more reckless then others, less confident and more experience individuals would most likely have a lower multiplier. Following THERP tables, this would suggest multipliers of 50 for perceived risk is less than real risk where there might be reckless behaviour. This mismatch between real and precede risk will most likely give a high negative effect on performance. In HEART this multiplier is set to 17, after considering the data acquired from Svalbard, this multiplier was considered as insufficient. NARA considered the same EPC but the value were adjusted up in accordance to the DATA-CORE database set to 20.

The suggested levels and some central arguments for change, see **Table 15**. To cover more scenarios in the Arctic and population stereotypes the levels and multipliers were set based on arguments and result in this thesis.

Table 15 THERP, HEART, NARA, SPAR-H and Petro-HRAs suitability for the use in the Perception of Risk PSF.

SPAR-H	Petro-HRA Levels	Suitability	Suggested multipliers
		There have been examples where individuals perception of risk have caused panic and failure of tasks. This suggests the need for an extra negative level.	Obstructed task requires HEP=1
Extreme	High negative effect on performance:	Some unwanted occurrences have the potential to create a feeling that peoples' life is in sever dangers. Directly wrong perception will influence performance negatively. To account for behaviour that might occur, independently of experience it is suggest assuming the following: Perceived risk << Real risk with reckless behaviour, Perceived risk >> Real risk with real threat stress and panic behaviour	Values found in THERP might cover this level. Suggesting something is extreme, as in SPAR-H, the value should be set to around 50
High	Low negative effect on performance:	To account for some degrees of fear, threat stress and outgoing expressive behaviour, they are included as following. Perceived risk > Real risk and extrovert behaviour is present with real fear of consequences present, Perceived risk < Real risk,	As seen in both HEART and NARA both these values is relatively high. 25 is therefore suggested on behalf of NARA
	Very low negative effect on performance:	There are situations where the perceived risk is real and thereby causing threat stress. Perceived risk = Real risk with some threat stress, or overconfident behaviour	To have best possible coverage for all the situation this value is seemingly not as significant and 10 is therefore suggested.
Nominal	Nominal effect on performance:	With the polar bear danger and the quickly changing weather in mind threat stress might always be present Independently of experience, how close is the perceived risk according to the real risk and how do the individual act on this knowledge. Nominal effect would be considered as Perceived risk = Real risk with no outgoing expressive behaviour present.	Nominal values should be set to 1 according to the suitability.

6.1.5. Experience and Training

Definition

From the results of the interview there are no doubt that experience and training have a huge impact on human reliability and safety during activities in the Arctic. This is also backed by the accident concentration analysis by Lorentzen. The “Individual qualifications and experience” and “Education, training of personnel” include 24 and 27 events respectively.

The actors on Svalbard are training for task using different methods. Courses are mentioned as an important part of the training, which gives people knowledge about potential hazards. Practice in a controlled environment can drastically reduce the chances of an accident, like driving snowmobiles in “safe terrain”. Scenario training is also used, but in some cases, it might be difficult to properly recreate a realistic scenario.

Knowledge acquired from courses and training can in some cases be sufficient to solve a task or scenario, but it was often that the task or scenario required the individuals to have past experiences in order to solve the tasks.

Some people visiting Svalbard have little to no experience with the conditions one can encounter, such as snow and ice. As a lot of people visits Svalbard for only a short period of time and they might not want to use any of their available time on safety training. This means that some expose themselves to the natural environment with no training or experience whatsoever.

The most important part of experience is not necessarily how long one has been staying at Svalbard but how much one has been exposed to the natural environment and potential hazards. Even if one has experienced winter conditions, with snow and low temperature, one cannot be considered experienced since the conditions on Svalbard can be totally different.

THERP does not have a separate definition of training, instead it is a part of experience. It is counted that both experienced (skilled) and non-experienced (novice) have adequate training as a basis. SPAR-H does not have a clear definition for training either and only briefly mentions one type of training. Petro-HRA has clearly defined training and list several types of training, and should therefore be used as a basis.

Both THERP and SPAR-H defines an experienced person as a person that has been working with a task for at least 6 months. As mentioned above its not necessarily possible to quantify experience in time. It would therefore be better to use Petro-HRAs definition of experience, that experience is how many times the operator has experienced the task or scenario. It is necessary to find an acceptable norm for the number of times the individual has experienced the task or scenario before the individual can be considered skilled.

As Petro-HRA mentions, the outcome of training and experience is knowledge and skill. This is also applicable on Svalbard. As it was mentioned above, courses give knowledge about hazards on Svalbard, but some skills can often only be acquired through experience.

Levels and multipliers

For the Experience PSF THERP has uses only two levels, novice (under six months of work) and skilled (more than six months of work), shown in table 20-16 in **Appendix E**.

SPAR-H uses three levels, low, nominal and high. These levels are based on the levels in THERP. Less than six months is considered low experience, and 6 months or more is considered nominal experience. There isn't any given number of months relation to High experience, but the operator holds extensive training. If something is to have a positive effect on performance, it must be past experiences. It would therefore not be wise to use the levels provided in THERP and SPAR-H. Basing the level description on those provided in Petro-HRA is a more reasonable choice.

A summarization of the arguments for the use of the definitions/multipliers from THERP, HEART, SPAR-H and Petro-HRA is shown in **Table 16**.

Table 16 THERP, HEART, SPAR-H and Petro-HRAs suitability for the use in the Experience and Training PSF.

Petro-HRA level	Suitability for the Arctic	Suggested multipliers
Extremely high negative effect on performance:	The conditions on Svalbard varies a great deal from other cold places, and this can lead to a mismatch between the persons skills and knowledge and the actual requirements. Some visitors on Svalbard has never seen snow before which results in them having no comprehension of the ground conditions, and hazards.	As HEART stats the probability for failure is 0.55 for total unfamiliar tasks which are performed at speed with no real idea of likely consequences. The suggested importance for this level should be higher, suggesting a value of 75
Very high negative effect on performance:	The people visiting Svalbard has various backgrounds and some might expose themselves to the natural environment without any knowledge about the potential hazards and has no skills to handle different scenarios.	Lack of training or experience in an extreme environment would suggest that HEART GTT fits better, stating the same argument as in Extreme negative effect performance, a multiplier of 50 is suggested.
Moderate negative effect on performance:	One example is snowmobile safety courses. An indoor course and instructions on how to drive is not sufficient to avoid flipping or falling of the snowmobile.	Some training or experience would suggest that the individual has been in the arctic before or at least trained for it. In comparison to 4 full seasons of exposure, 6 months of exposure could be taken from THERP suggesting a multiplier of 25.
Low negative effect on performance:	There are some knowledge and skills that cannot be thought through training and courses but requires experience. As mentioned earlier the ability to successfully assess the avalanche danger requires experience.	Some exposure and adequate training is considered as a minimum requirement, this suggests there are some uncertainty in sense making and detection signifying some negative effect on performance, 10 is suggested to describe these conditions.
Nominal effect on performance:	Experienced and well trained in task or scenario. Several exposures. 4 full seasons with exposure is considered sufficient.	Nominal values stating that there are good training and several exposures giving the individual enough experience.
Moderate positive effect on performance:	As in Svalbard there were some with over 20 years of field work. Some had experienced death of others and know very well what could go wrong. The mindset these individuals had can be considered extreme and they were prepared for anything that could happened both mentally and physically. The time and the exposure amount one would require giving a positive effect on performance in an extreme environment, must be considered extensive.	Undebatable if there is a positive effect on performance this must be low. As for other PSF, 0.1 should be considered as the level where there is extremely high positive effect on performance.

6.1.6. Procedures

Definition

A procedure itself and the use of procedures are independent of context and it would therefore be possible to use the definition found in other HRAs. SPAR-H does not have a specific definition for a procedure, and the definition from Petro-HRA should therefore be used as a basis. As it is difficult to plan a stepwise action process some changes should be made to the definition. Procedures in the Arctic would mainly be used in preparation for a task, as it can be difficult to access them during a task.

Although procedures are not considered as decisive by most of the interviewees the "*Instructions, work procedures*" category, with 15 events, from Lorentzens analysis shows that some events can be related to procedures.

The procedures used in the petroleum and nuclear power plant industry are comprehensive and gives a strict step-by-step guidance on how a task or scenario should be handled. This is challenging in an arctic context since there are so many factors affecting how the task or scenario should be handled. There are so many possible scenarios, which all can play out in different ways, and it would not be practical to cover all. For instance, taking the quickly changing weather conditions into account makes it difficult to produce procedures. Having a procedure for every weather condition seems obstructive in terms of performance. This would imply that an operator needs to know every procedure in order to perform correctly.

The changes in the natural environment over the last year has produced new hazard. It cannot be taken for granted that these changes have been accounted for in all procedures making them no longer valid. Some procedures can hinder the personnel from performing a task, and it would be more suitable to exercise discretion.

In a petroleum or NPP context it will be possible to access the procedures easily through a tablet or a paper version. Outdoor in the Arctic the cold can cause electrical equipment to malfunction. Factors such as precipitation and high wind requires a paper version to be stored away in a backpack or other secure places, restricting quick access. The difficulties of bringing procedures on activities will require personnel to remember the procedures which can be challenging if the procedure is comprehensive.

Levels and Multipliers

Both SPAR-H and Petro-HRA uses four levels of describing the availability and suitability of the procedures. This is also a suitable approach in an arctic context. There are examples where there is a lack of procedures for specific less comprehensive tasks. In these cases, its required sufficient knowledge of how to handle the task or scenario, and it will have a negative effect for people lacking this knowledge. Considering the difficulties in producing procedures they might be deficient. It does not seem that procedures are considerably important during tasks in the Arctic, rather that they build a basis for the work. Therefore, it is safe to say that procedures have a low impact on performance compared to other contexts.

EPC no. 16 from HEART and EPC no. 12 from NARA, seen in **Appendix D**, deal with procedures. These EPCs are given low multipliers, 3 in both, which would be a more suitable value for an arctic context.

A summarization of the arguments for the use of the definitions/multipliers from THERP, HEART, NARA, SPAR-H and Petro-HRA is shown in **Table 17**.

Table 17 THERP, HEART, NARA, SPAR-H and Petro-HRAs suitability for the use in the Procedures PSF.

SPAR-H Levels	Petro-HRA Levels	Suitability for the Arctic	Suggested multipliers
Not available	Very high negative effect on performance	Missing procedures will have a negative effect when required knowledge is not acquired. Misleading procedures, due to them no longer being valid also has a negative effect on performance.	The usefulness of procedures is low, and the multiplier should be lower than 50 from Petro-HRA. HEARTs GTT (b) with HEP=0.26 is more suited as a basis. 25 is suggested as a multiplier.
Incomplete	High negative effect on performance	Including all possible outcomes of a scenario in the procedures are difficult if not impossible. A stepwise approach is generally not possible to use. An incomplete procedure will only have an effect in a minority of tasks.	EPC no. 16 from HEART and EPC no. 13 from NARA fits here. 5 is suggested as multiplier.
Available, but poor	Low negative effect on performance	This level can be combined with the one above as they are, to some degree, alike.	A multiplier between 1 and 5 have minimal influence regarding the overall HEP.
Nominal	Nominal effect on performance	In most cases the procedures are sufficient for the tasks, there is no need for a stepwise plan or the task does not necessarily require procedures.	Sufficient procedure or no need for procedures should give a multiplier of 1.
	Low positive effect on performance:	The difficulty of accessing procedures makes it unlikely that procedures will have a positive effect. Using it in planning phase does not necessarily increase chances of completing the task. This level should not be included.	Not evaluated

6.1.7. Equipment and Human-Machine Interface

Definition

Lorentzens analysis show a total of 21 events related to equipment, which suggests adding a PSF covering equipment. As the Human-Machine Interface PSF from Petro-HRA refers to equipment and physical workstation layout it is relevant for an arctic context. As the HMI PSF also include aspects that are not relevant in an arctic context, such as software, some changes are needed for it to be valid for the Arctic. Changing the name to Equipment will first give a better descriptive purpose of the content than Human-Machine Interface.

When considering the objects seen in **Table 10**, a better more suitable PSF definition is necessary if it is to be included in an HRA for an arctic context.

The physical workstation layout could in an arctic context be considered as the design of snowmobiles and belt wagon, with placement of the steering, throttle and so on. If the design of a snowmobile is hard to understand, for instance if the throttle is placed somewhere illogical, it will have a negative effect on performance. Physical workstation could also describe the layout inside a tool box, what tools are available during the specific task and somewhat the tools reliability. The tools reliability will corelate to HEP, but one must be careful to consider this in an HRA since this involves System reliability theory which is a different topic then human reliability theory. Systems and equipment mean time to failure is not a part of an HRA and should therefore be excluded.

Some examples of HMI problems from an industrial context can be transferred to an arctic context. For example, communication difficulties due to communication technology, could be satellite phones, emergency beacons, avalanche beacons and similar equipment. The design of these types of equipment can be interpret different by other population stereotypes.

Parts of the Physical Work Environment PSF from Petro-HRA can also be used as it also deals with equipment. Centrally in this PSF is the accessibility to equipment. As equipment is often necessary for the completion of a task in the Arctic, this would also be applicable in this thesis.

This thesis suggests that clothing is included as equipment, since use of special clothing often is necessary. Dressing accordingly to the weather conditions can contribute either positively or negatively to performance. Clothing will have a negative impact on performance if they create mobility restrictions. Keeping this in mind, clothing used during a task should be considered independently of the weather conditions even if there is a significant correlation.

Because of individual differences as in population stereotypes there is a possibility that individuals overdress and underdress depending on expectations. Commercial and non-commercial industries use similar type of dress code to eliminate the population stereotype factor and avoid some unwanted occurrences. This dress code could be considered as a nominal value.

Levels and multipliers

Considering the equipment in **Table 10**, some are significant harder to handle than others without knowledge or experience. Therefore, one should consider how self-explanatory the equipment is, the design and the ability to improvise if the equipment is missing.

The multipliers from SPAR-Hs Ergonomics/HMI PSF and Petro-HRAs Human-Machine Interface PSF are used to evaluate levels for the Arctic. There are many situations where equipment is necessary to perform a current task. If the equipment fails or there is an absence of the right equipment and if there is no way to improvise, the task will certainly fail. As Petro-HRA states the grading of this PSF should be based on how the available equipment works for this specific task.

As mentioned during the interviews most of the equipment do not work "*out of the box*", THERP suggests a HEP 0.52 to recognizing deviant indications in first day of inspections. This would also indicate that "*out of the box*" equipment would fail without trial and errors. THERPs estimated probabilities that basic inspection will fail to detect deviant indications of equipment also suggests that longer usage and additional inspections would reduce the HEP. Even if this probability not directly connected to the equipment itself, it could be seen as a part of the macrocognitive mechanisms in humans for usage of the equipment. This PSF should account for the need for equipment modifications, how self-explanatory it is and its reliability. In this way grading the equipment according to the described level is possible after some time of usage.

The number of times the equipment is tested could correlate to the THERPs table 20-27. Seeing that 2 inspections reduces the HEP to 0.25, a multiplier of 50 and 25 for very high negative and moderate negative is suggested.

For example, Snowmobile fuel indicator are not accurate. To exactly know the fuel consumption for the cold air in the Arctic the snowmobile needs to be tested in the field. After some time of usage, the operator will get a feel for the fuel consumption and the exact consumption is known. This knowledge can be passed down to others or marked directly on the snowmobile as a part of the HMI.

It is significant harder to decide HEP without including a system reliability analysis to give the equipment its nominal MTTF values. Knowing how long each equipment lasts, help eliminate the possibility for an individual to choose outdated and worn out equipment to bring out in the field, which is more described by the maintainability in system reliability. One could consider how well the equipment is maintained during and after operations as proximate cause for human errors. Including this in a HRA would make it extensive more complex therefore the one conducting the HRA should only account for the equipment's state at the time conducting the HRA without knowledge from past maintenance.

A summarization of the arguments for the use of the definitions/multipliers from THERP, SPAR-H and Petro-HRA is shown in **Table 18**.

Table 18 THERP, SPAR-H and Petro-HRAs suitability for the use in the Equipment PSF.

SPAR-H level	Petro-HRA Levels	Suitability for the Arctic	Suggested multiplier
	Extremely high negative effect on performance	Some tasks in the Arctic requires specific tools. If these are not accessible, or there is no possibility to improvise a substitution for the equipment the task fails	Not being able to complete the tasks should give HEP=1
Missing/ misleading	Very high negative effect on performance:	Equipment requires several actions to operate and there is no self-explanatory information, there are no way to improvise a replacement and there must be a requirement for equipment. The equipment will cause major problems considering human performance	Suggesting 50 following THERP equipment inspection / detection table
Poor	Moderate negative effect on performance	Equipment not working "out of the box" requires adaptations and modifications. Will most likely cause problems as it is. Some self-explanatory information and some possibilities to improvise.	Suggesting 25 following THERP equipment inspection / detection table
Nominal	Nominal effect on performance	Equipment can in some degree be improvised. A lot of equipment is poorly adapted for the harsh environment, meaning it must be modified to some extent. Modification and adaptations on equipment could affect the performance positively and therefore reducing its impact on human error probability. Self-explanatory information is included	If the equipment does not influence performance the multiplier should be 1.
Good	Low positive effect on performance	Adapted and modified equipment is designed to be as reliable as possible for its purpose. Positive impact on human performance. Self-explanatory information	In extreme cases, equipment can work as a multitool, if the equipment is very easy to use. Suggesting 0.1.
	Not applicable	Traveling in the Arctic always require some type of equipment. Considering clothing make this PSF always applicable.	Not considered

6.1.8. Teamwork

Definition

It is fair to assume that the "Supervision, instruction" and the "Informal information" categories from Lorentzens analysis relate to teamwork. With a total of 16 events it is clear that a PSF covering Teamwork should be included.

For all the interviews, the ability to communication was promoted as the most important factor in order to describe the collaboration as successful or not. Petro-HRA divides teamwork into 8 factors with behavioural markers which are descriptive question in order to identify the right category. These factors do fit seemingly good for teamwork in regard to the interviews conducted on Svalbard.

During a guided snowmobile trip with several guides, team leadership is essential. It is important that the guide takes control and clarify that the guide is in charge. The group leader need to continuously assess the team members capabilities in order to proceed without failure. The ability to coordinate the group is highly impacted by population stereotypes, language barriers and environmental noise. These challenges could compromise the ability for a team to perform.

As some interviewees mentioned, there were sometimes a need to motivate and encourage group members to perform. This can be considered good leadership and would most likely impact performance positively, whether this should be considered as a positive level or nominal is questionable.

The communication between the field operator and the management would not be that significant due to the isolation the environment provides. This can rather be described as the mutual trust between the management and the operators. When guide companies rent out snowmobiles they also need to trust the one renting the snowmobile to act responsible to not harming themselves or others. This trust also is present during a snowmobile convoy during a guided trip. The interaction is often vocal, by phone or satellite phone. The direct communication can be considered as close loop communication as the management tries to follow up on the ones working in the field. The communication in a group can be consider as a closed loop, the communication how the gestures and vocal words are perceived and responded to indicate how well the teamwork is running. The commands and requests from a group leader needs to be adapted in order to reach every population stereotype. The same applies for the group participants to give warnings about hazardous conditions. There must be some adaptability in the group in order to proper perform in task where external and internal factors influence the ability to cooperate.

In teamwork where there is a common goal, performance indicators should measure the state of the collaboration. Petro-HRA suggest using mutual performance monitoring, which should identify slips, lapses and mistakes in the other team members actively provide feedback to others during the task. This would influence the collaboration and the performance positively.

The definition of teamwork in Petro-HRA is directly transferable to an arctic context. Arguably, this PSF could seemingly fit better even for an arctic context then in a petroleum production plant. Petro-HRA might exaggerate the impact of the teamwork PSF would have on control room and offshore petroleum facilities tasks, but this needs further research in order to be confirm.

This thesis suggests that the same definition is applied to an arctic context, but multipliers is adjusted to cover more scenarios with bigger diversity of population stereotypes.

Levels and multipliers

As Petro-HRA have defined teamwork the definition of the levels is equally applicable. As poor teamwork would not explicitly mean that a task will fail, it will most certainly negatively influence performance. As SPAR-H stats in poor performance there is inadequate communications between the shift turnover, which could also refer to the participants in a group. Petro-HRA argument for changes for poor teamwork states that it was appropriate to change it to 50 compared to the other PSFs.

THERP states among others in the HEPs as a function of items that needs to be remember. Table 20-8 in **appendix E** shows the HEP for oral detailed instructions and general instructions. Since there is a military approach to leading a group on Svalbard this seems more suitable then just the presumption of 50, as in Petro-HRA. Considering nominal population stereotypes these values would be applicable for team leadership. Considering group size and number of oral instruction for instance during snowmobile driving the probability for human error would increase. Without going directly into mathematics, the best guess for a suited fit in terms of poor teamwork could be considers as detail oral instructions within a large group size. One could use the HEP 0.4 to recall 5 detailed oral instructions in the right correct order. Take for example half loading a rifle. The actions need to be in the correct order in order to succeed and detailed in order to be perform correctly as seen in THERP table 20-8. It would be significant harder to perform the rifle half loading without detail instructions for where the chamber, the bolt, magazine and so on is. This could be seen as general oral instructions where significant information is excluded due to improper instructions. This would make this task significant harder. THERP suggest a HEP of 0.7 for the same conditions without detail instruction. This scenario would be described as bad mutual performance monitoring. Using this example to cover language barriers it is suggested that a multiplier of 50 is set to describe worst case scenario where there is no mutual understanding between the group members.

THERP implies HEP of 0.2 for 5 oral detailed instructions without any order, and HEP of 0.1 for 5 instructions were given and only a few was recalled. This could fit well to the command and comply approach used for both commercial and non-commercial actors operating in the Arctic. Using HEP 0.2 to describe moderate negatively and HEP 0.1 to describe low negatively teamwork performance.

A summarization of the arguments for the use of the definitions/multipliers from THERP, SPAR-H and Petro-HRA is shown in **Table 19**.

Table 19 THERP, SPAR-H and Petro-HRAs suitability for the use in the Teamwork PSF.

SPAR-H level	Petro-HRA Levels	Suitability for the Arctic	Suggested multipliers
Poor	Very high negative effect on performance:	Many of the activities on Svalbard often include several unexperienced persons, for instance during guided trips. This makes, inter alia, communication difficult, and team leadership will be extremely important.	Using THERP as a basis for this identification a 50 is suggested.
	Moderate negative effect on performance	the team leader cannot rely on the other participants to share information about hazards or other important aspects. This makes it difficult to have the required information to be able to complete the task.	THERP stats that the HEP for recalling 5 detailed instructions with no significant order have a HEP of 0.2. A magnitude of 25 is suggested.
	Low negative effect on performance	If there are many experienced people in the group, completion of the task does not rely on everyone to finish their task, as the most experienced can complete those.	A magnitude of 10 is suggested.
Nominal	Nominal effect on performance	This level should apply when the team cooperate to a adequate level where teamwork does not contribution negatively or positively.	Nominal effect gives a multiplier of 1
Good	Low positive effect on performance	This level applies when few teammates with the same background and the same mentality travels together.	There might be scenarios where the team members contribute positively in overall the task performance. 0.1 is suggested.
	Not applicable	This would describe a scenario where only one individual is operating without any attachment to management or support.	

6.1.9. Environment Stressors

Definition

The environment on Svalbard can be extreme and very demanding. Low temperature, high winds, icy surfaces are just a few of the factors that may affect performance. As previous literature shows there is a need to include environmental stressors as a PSF because of the cold temperatures and harsh environments impact on human reliability.

Neither NARA, HEART, SPAR-H or THERP has definitions that are suitable for use in an arctic context. Petro-HRA accounts for tasks performed outside control rooms with its Physical Work Environment PSF. A central part of the Physical Working Environment PSF is the accessibility to equipment. This aspect of the PSF will be handled in the Equipment PSF. The PSF also cover physically demanding manual tasks, which will fit better in the Fitness PSF. The rest of the aspects of the Physical Working Environment PSF can be used in the definition of the Environmental Stressors PSF for this thesis.

Levels and multipliers

Environmental factors are the main cause of discontinuing and cancelation of tasks on Svalbard. Therefore, the levels should have a high multiplier. Except for Extremely high negative effect on performance, Petro-HRA uses low multipliers for their PSF. Another level with a high multiplier should therefore be added. As the weather conditions are significant for human performance correlations between visibility in a whiteout or bad light conditions caused by darkness can correlate to task performance in other scenarios. THERP uses estimates of HEP to read analog and digital meters with difficult to see limit marks. These estimates of HEPs can be used in some cases where the task is seemingly similar in terms of cognitive detection which suggests a HEP = 0,006. These errors can also be seen as wrong interoperation or overlooking errors of commission caused by the environment. Considering this the closes to nominal can be set to 5 as a multiplier to account for the uncertainty that someone could overlook errors of commission.

THERP table 20-8 can represent nominal values for no noise caused by the wind. HEARTs EPC low signal noise ratio, can be seen as the possibility to detect errors of commission as in warning signs and hazards. HEART have a multiplier of 10. Seeing the different values used within the HRA method for noise and communication these values can supplement the level for moderate negative performance. Keeping in mind the possibilities to encounter polar bears all over Svalbard and the rapid changes in the snow-covered terrain the multiplier is adjusted accordingly and a multiplier of 25 is suggested. As some of the interviewees mentioned, there were scenarios of total whiteout and freezing cold weather where tasks still were completed. A higher level of negative effect on performance is suggested with a multiplier of 50.

A summarization of the arguments for the use of the definitions/multipliers from, Petro-HRA is shown in **Table 20**.

Table 20 Petro-HRAs suitability for the use in the Environmental Stressors PSF.

Petro-HRA Levels	Suitability for the Arctic	Suggested multipliers
Extremely high negative effect on performance	The environment can in many cases make it impossible to reach the desired goal. This can be due reduced visibility, too high winds, extremely low temperatures and that the place for the work is impossible to reach.	If a task cannot be completed the multiplier should be HEP = 1
	There are several examples where the environment can make the tasks extremely difficult to complete. For instance, low visibility will make it a lot harder to spot obstacle while driving a snowmobile	Suggested multiplier is 50, since there are scenarios with whiteout, blizzards and other conditions which was considered to be extreme where the task still was completed.
Moderate negative effect on performance	In most task the environment lowers the level of performance. For instance, wind can make it difficult to communicate and the cold impacts cognitive functions.	A multiplier of 25 would fit here.
	As this level accounts for the uncertainty during nice weather, this could be considered common for an arctic context.	5 is the considered close to nominal but accounts for the uncertainty level.
Nominal effect on performance	Implying that the weather will not impact performance, could be considered rare for an arctic context. This level can apply if the task is brief in an area that seldom experience quickly changing weather.	When the environment does not affect performance, multiplier should be 1
Not applicable	Rapid changes caused by the wind and the extreme conditions in the Arctic outdoor make this always applicable.	Not evaluated

6.1.10. Fitness and Fatigue

Definition

Fatigue is common and might be experienced by both visitors and full-time residents at Svalbard. Since people have different basis fatigue occur more often and to a higher extent among visitors than full-time residents. There are tasks on Svalbard, such as summit hiking, where peoples' fitness is essential. Therefore, a PSF covering fitness and fatigue should be included.

In the petroleum and NPP industry there are usually set work hours. This is not the case in an arctic context where some task requires prolong, consecutive work. The midnight sun makes it possible to work around the clock, which results in long workhours. The dark periods make it more difficult to detect hazards. This requires people to concentrate more which in turn results in mental exhaustion. Although it is not scientifically proven, some find it challenging to fall asleep during the dark periods and some also experience lack of energy during the day.

SPAR-H does not have a separate definition for fatigue in its Fitness for duty PSF, but since peoples' fitness is important for tasks in the Arctic some of the definition in SPAR-H should be considered.

As the Fatigue PSF was excluded from Petro-HRA there are no definition for the PSF in the guideline. M. Rasmussen and K. Laumann analysed four aspects of fatigue as part of the evaluation of Fatigue as a PSF; *sleep deprivation, shift length, non-day shift and prolonged task performance*. As mentioned, some people on Svalbard experiences a challenge to fall asleep during the dark period. This will reduce the quantity of sleep, and it can be assumed that this will contribute to fatigue. Often there are no limit for workhours and some task last for a prolonged time. This shows that shift length and prolong task performance is applicable. During the periods with midnight sun work continue during the night, which might correspond to night-shift.

Level and Multipliers

SPAR-H uses 3 levels for the Fitness for duty PSF, unfit, degraded fitness and nominal. Fatigue is a central part of SPAR-Hs Fitness of duty PSF among drug and alcohol impairment, mental distractions, physical and mental capabilities and boredom. Drug and alcohol use is not a problem on Svalbard, and people are aware of the danger it might involve. A lot of tasks on Svalbard can be physically challenging, such as summit hiking by skies and not everyone is capable to finish them. Some people do not have the mental strength to finish a task, such as driving a snowmobile down a steep slope.

M. Rasmussen and K. Laumann presented one table for each of the four aspects of fatigue with different levels. These levels are relevant for the levels in this thesis as the four aspects are experienced on Svalbard.

A summarisation of the arguments for the use of the definitions/multipliers from SPAR-H and Petro-HRA is shown in **Table 21**.

Table 21 THERP, SPAR-H and Petro-HRAs suitability for the use in the Fitness and Fatigue.

SPAR-H levels	Suitability for the Arctic	Suggested multipliers
Unfit	People would probably not start a task if they experience illness, therefore it does not fit in the level description. Physical and mental incapacities should be included here, since several tasks requires some degree of fitness to be completed.	Since there has been occurrences where people had to discontinue a task due to lacking sufficient fitness, P=1 should be used.
	Since more accident seems to happen at the end of a trip, extremely prolong tasks should be included here. It does not fit in the Degraded fitness level because prolong tasks can clearly have a considerable negative effect on performance.	In M. Rasmussen and K. Laumanns article they present 120 minutes as the highest level for prolonged tasks. Some tasks on Svalbard last far longer than that, therefore the Prolonged task effect on the multiplier should be far more than 5 as presented. The other multipliers in the article should also be included in this multiplier. 50 is suggested as a multiplier.
Degraded Fitness	Drug use does not seem to be a problem and should not be included, the same goes with illness, as explained above. It was mentioned in the interview that people were clearly exhausted when they returned from trips, which will lead to degraded performance. Long duty hours are common on Svalbard. Sleep deprivation should be included here since some people on Svalbard experience loss of sleep during the dark period.	Long duty hours occur on Svalbard, therefore the multiplier 5 from SPAR-H can be used in the suggestion of multiplier. This also apply to Sleep deprivation and shift length multiplier, 5 and 1.98, from M. Rasmussen and K. Laumanns article. 10 is suggested as a multiplier.
Nominal	This level should apply when people are hydrated, fed and well rested and the task is neither physically or mentally challenging enough to influence.	When fitness and fatigue has no influence, the multiplier should be 1.

6.1.11.Task Complexity

Definition

A lot of accidents on Svalbard happens during snowmobile drives. Driving a snowmobile is in principle an easy task, but different factors can increase the difficulty, such as where people are driving. It easy to consider the environmental topography as complex but to avoid double counting one must consider this in the environmental PSF. Several tasks on Svalbard requires a person to keep track of other people while performing other sub-tasks, which makes the task more difficult. The diversity of tasks on Svalbard suggests that some are more difficult to perform than others and a PSF covering the difficulty of a task should therefore be included.

Both SPAR-Hs Complexity PSF and Petro-HRAs Task Complexity PSF refers to the difficulty of the task at hand. That way these definitions can be used as basis for the definition of the PSF in this thesis. The environment is included as a factor in the two PSFs. To avoid double counting, the environment has to be removed from this PSF and added to layout in the Equipment PSF and topography in the Environmental Stressors PSFs. As it is stated in Petro-HRA the parts of the Complexity PSF from SPAR-H overlaps and the Task Complexity PSF from Petro-HRA would give a better basis for the definition for the PSF in this thesis.

Petro-HRA divides Task complexity into six factors; goal, size, step, dynamic, connection and structure complexity. As the dynamic complexity deals with unpredictability in the environment this factor should be excluded as mentioned above. See **Appendix G** for Petro-HRAs Task complexity.

As it is elaborated in **Chapter 6.1.2** some tasks might include several goals and several paths to theses goal and therefore goal complexity can be included in the definition.

Size complexity can be included in the definition since tasks like guided trips on snowmobile requires the guide to process a great amount of information at a time. The guide has to keep track of the people in the group and look out for hazards, like jumbled sea ice and avalanches, while be attentive of their own driving.

As many of the tasks on Svalbard includes several steps the step complexity can be included in the definition. Half loading a rifle includes several sub-steps that are qualitatively different and continuously. Putting the bullets into the magazine requires a different approach than checking the barrel for undesirable elements.

The subtasks of half loading a rifle are highly connected to each other and connection complexity can therefore be included in the definition. For example, Opening the bolt is required to be able to put bullets in the chamber.

Using polar bear attack as an example it is clear that structure complexity should be included in the definition. Although this task has a logical structure, bring forth the rifle, load, aim and fire, it requires conflicting rules, speed and accuracy.

Levels and Multipliers

Tasks in the Arctic does not require the same amount of information handling as in the petroleum/ nuclear industry, which suggests a relatively low multiplier. SPAR-H, which bases the multipliers on THERP Table 20-23, see **Appendix E**, have very low multipliers compared to other HRAs. The part of the table where the multipliers is gathered from only include a relatively low number of annunciations, which does not suggest a very complex task. Suggesting that the complexity correlate to the THEAPs the number of annunciations, a multiplier of 25 is considered to be better suited then Petro-HRAs multiplier of 50.

Looking at THERP dependency levels these values could supplement for the connection complexity. HEART EPC no. 8 and NARA EPC no.10 can supplement structure and size complexity. Adjusting Petro-HRAs very high negative effect to 25 based on THERP with supplemental descriptions based on HEART and NARA, a more fitting multiplier is suggested. The summarization of the arguments for the use of the definitions/multipliers from THERP, SPAR-H and Petro-HRA is shown in **Table 22**.

Table 22 THERP, SPAR-H and Petro-HRAs suitability for the use in the Task complexity PSF.

SPAR-H level	Petro-HRA Levels	Suitability for the Arctic	Suggested multiplier
Highly Complex	Very High Negative Effect on Performance	As some tasks in the Arctic requires the handling of several cues and simultaneous actions, for instance guided snowmobile trips with several guests. A level for high negative effect should therefore be included.	Petro-HRAs multiplier of 50 is too high for the use in the Arctic. Basing the multipliers on the >40 annunciations, which gives HEP=0.25, in THERPs Table 20-23 would suggest a highly complex task. 25 is suggested as multiplier.
Moderately Complex	Moderate negative effect on performance	Moderate negative can be used for tasks like half-loading a rifle, which is a small task with few paths and goals and has several connected steps with a logical structure.	SPAR-Hs multiplier for Highly Complex of 5 would rather fit here since it should be considered moderately complex rather than highly complex.
	Very low negative effect on performance	Task complexity is not considered as a decisive factor by the interviewees nor the thesis participants and it is therefore considered that two levels are sufficient.	
Nominal	Nominal effect on performance	A nominal level should be used when the task isn't considered complex and has no effect on performance.	When performance is not affected the multiplier should be 1.
	Low positive effect on performance	The thesis participants does not consider that tasks in the Arctic can be so simplified that they can provide positive effect	
	Not applicable	The tasks will always have some complexity bound to them	

6.1.12. Attitude to Safety, Work and Management Support

Definition

Lorentzens "Individual norms and attitudes" and "Workplace norms" categories from his concentration analysis can be considered as a part of a PSF accounting for attitude and management support. With a total of 24 and 15 events registered in these categories it indicates that attitude is an important factor. The "Supervision, instructions", with 8 events, could be considered as management support, but might fit better in the Teamwork PSF.

Although Petro-HRAs definition is adequate to cover the attitude to safety there were some concerns about double counting this PSF as Perception of risk. The evaluated behaviour to perform versus the changes in ones' perception to perform. For instance, the individuals' evaluation is right on how to perform, factors not foreseen can change the individuals' performance such as spontaneously outbursts. As seen in the example with the glacier-tsunami-snowmobile-incident.

Perception and interpretation of a situation can be wrong even if the attitude is right to perform. This might occur du to population stereotypes, as in the example where one individual jumps from a roof top into seemingly soft snow and in the reality, is was packed ice. This will impact attitude to safety negatively due to wrong evaluation towards safety, causing the individual to jump in the first place. The individual did also have the wrong perception towards risk, because of the ice.

Another example with the right attitude but wrong perception as in the incident where some tourists travelled down a steep slope with snowmobiles. Were the attitude towards safety was to drive slowly, the perception on how to brake was wrong causing the belts to lock up flipping the snowmobile over. The same example applies towards driving on ice, braking can cause the snowmobile to slide. This scenario can be pre-covered in an HRA by experience, but even experienced drivers can have the wrong perception. Therefore, one need to be aware of this to not cause double counting.

Wrong attitude and right perception can occur when highly experienced individuals behave recklessly. The individual has the correct perception of risk but due to other factors the make individuals behaves in an unsafe manner which is causing failure in task. Knowing which factors that can lead up to this behaviour needs to be further investigated to reach a conclusion. Speculating in such factors lead to think that the following could have a negative effect on performance: pressures from friends, competitions and thrill seeking.

Other factors which will impact attitude to safety is money pressures from stockholders in project. This might lead to wrong attitude towards safety due to prioritising task completion above other important factors. This will not necessarily lead to failure but work pressures will most likely have a negative effect on performance and work moral. HEART is also using this as an error producing conditions and it would most likely have an impact in the Arctic as well.

Management support is considered as how an individual feel the management entrust the individual with that specific task. How would the individual experience support from management in consideration to those decisions required to perform the task. In an arctic context those decisions cannot be surveillances by the management when out in the field. It is therefore required, from a management perspective, to entrust the individual. If this trust is absent, the individual performing the task would most likely feel “alone”. this would have a negative effect on performance.

Being secure of backup would give a nominal effect on performance. This would reduce the fear of economical or fear of material loss if a task is to be performed far from infrastructure. When an individual is working far from infrastructure, getting directly support from management would be considerable harder in an arctic context, due to the lack of communication. Therefore, on could consider the support leading up to the task as a part for the HRA. To evaluate the probability to succeed in a task, all factors influencing this probability should be considered. Regardless if the task fails or succeed, getting support when returning could be considerably important for the individuals ability to perform in the next task.

Levels and multipliers

HEART states that work force moral will have a negative impact giving this a multiplier of 1,2 whereas NARA uses 2. This could effectively be considered as a part of the management support leading up to a task and after a task is finished in the Arctic. For an HRA it needs to be considered in the initiation of the task. Knowing the management entrusts the decisions to the individual give would most likely give a nominal effect on performance. This was confirmed during the interviews and the practise of a no blame culture in both commercial and non-commercial operators. SPAR-Hs poor performance multiplier is significant lower than the values set by Petro-HRA.

A summarization of the arguments for the use of the definitions/multipliers from THERP, SPAR-H and Petro-HRA is shown in **Table 23**.

Table 23 THERP, HEART, NARA, SPAR-H and Petro-HRAs suitability for the use for the Attitude to Safety, Work and Management Support PSF.

SPAR-H level	Petro-HRA Levels	Suitability for the Arctic	Suggested multiplier
Poor	Very high negative effect on performance:	There have been episodes where people have prioritised thrill before safety. In some cases, there might also be pressure from management and the persons themselves to complete a task even when a risk is present.	As it is in the Arctic the one conducting the field work is mostly far away from the management, so the influence is minimal. How the individuals attitude is towards safety is the significant factor and should only account for half the one in Petro-HRA, 25 is suggested.
	Moderate negative effect on performance	The individual has inadequate attitude towards safety There is inadequate support from management partly entrusting the field decisions to employees.	To account for bad safety attitude without significant negative performance, the value of 10 is suggested.
Nominal	Nominal effect on performance	The individual has adequate attitude towards safety. There is adequate support from management entrusting the field decisions to employees.	Nominal considering what was expected from the different actors' nominal performance was considered good performance.
Good	Low positive effect on performance	There is very god attitude towards safety and work is conducted in such manner. The management entrusts its employs giving allot of freedom in task commencements.	Considering this as a more organizational PSF the Petro-HRA and SPAR-H should be adequate to predict a positive influence on HEP setting this to 0.1. But since there was a general good attitude it is hard to see how this could influence performance positively.
	Not applicable	This was not considered since attitude to safety always is applicable in an outdoor arctic context	

6.2. DISCUSSION SUMMERY

As there are many possible performance shaping factors which would influence activity in the Arctic, the ones discussed in the past chapter was considered to have an influence with the highest magnitude. PSF discussed to influence human performance in the Arctic were Time, Perception of Risk, Experience and Training, Teamwork, Environmental Stressors, Fitness, Task Complexity and Attitude to Safety, Work and Management Support. The order of magnitude discussed in theses PSFs derived from the interviews, supplementary literature and personal observations. The supplementary literature was among other different HRA methods such as SPAR-H, Petro-HRA, THERP, HEART and NARA. The nominal human error probability from these methods were discussed in order to see how well they fit in accordance with the tasks and activities conducted at Svalbard, by both commercial and non-commercial actors.

The dependency used by THERP would not be applicable since it only account for the dependency between task and it is covered by task complexity. Another aspect of work in the Arctic discussed was the possibilities to improvise. This should be included in several PSFs since it could mean the difference in success or failure. Major PSFs which were discussed to be significant influenced by the possibilities to improvise were Procedures, Equipment and Task Complexity.

Experience and exposure time were discussed as one of the major contributor to human success since there were situations where training was sufficient. There were scenarios where training could be too hazardous, and the approach in these types of scenarios were to "train as you fight". The multiplier suggested was set in accordance to the answers in the interviews and supplementary literature. The performance in teamwork and the influencing factors and how teamwork is conducted was similar in both commercial and non-commercial actors. They both had a command and comply approach method which corresponds to the HEPs used by THERP. Fitness was discussed to be of significant since the Arctic environment was found to be both more physical and mental challenging than other places and since this thesis is limited the outdoors only. Environmental stressors, fitness and task complexity was discussed in order to cover scenarios where complex tasks were conducted in challenging terrain and good fitness is required. Attitude to safety vary a lot with experience and perception of risk, this was still seen as an independent PSF in order to cover aspects that could not be cover otherwise. Work management support was discussed to be the weakest PSF but still significant. The suggestive reason for this was that the distances and the lack of communications far from infrastructure could pose a challenge and therefore the management needs to entrust everything to those working out in the field.

7. SUMMARISATION OF RESEARCH QUESTIONS AND PSFS

Which performance shaping factors will have a significant impact on human reliability in the Arctic, and to what extent?

There are several performance shaping factors that will have a significant impact on human reliability in the Arctic. The following 10 factors are derived from personal experience and interviews. The most significant performance shaping factors was found to be Time, Perception of Risk, Experience and Training, Teamwork, Environmental Stressors, Procedures, Fitness, Equipment, Task Complexity and Attitude to Safety, Work and Management Support. These PSF is further elaborated with their respectively levels and multipliers in the following conclusions, see **Table 24**

- *How relevant are today's HRA for operations in the Arctic?*

Off all the methods compered in **Appendix A** and **Appendix B** only a few had a wider general application, which was used to supplement the PSF found in this thesis. None of the HRA methods` purpose was to analyse work outdoors in an arctic context. Therefore, changes had to be made.

- *How would the PSFs be defined in order to fit in an arctic context and work outdoors?*

The PSFs needs to be defined in favour of the environment and the challenges in the Arctic. Time favours the time required and is not specified to a numerical size. Perception of risk is the individual's comprehension of a hazards. Experience and training is in favour of actual exposure to the natural environment. Teamwork describes interactions, and Petro-HRA was considered sufficient to cover the arctic context. Environmental stressors describe external strains from weather, wildlife and topography. Practicality and suitability in terms of human performance determines the procedure PSF. Availability of the right equipment for the task at hand is described by the equipment PSF. Fitness is defined in favour of the environment and its mental and physical requirements. Task complexity covers special challenges in the task performed in this extreme environment. Attitude to safety, work and management support covers the organizational and individual conduct. This is further elaborated in the following chapters seen in **Table 24**

- *What would be order of magnitude on the PSFs used outdoors in an arctic context.*

The levels and multipliers found to fit the Arctic Problem can be seen in the following chapters. Time was best considered with 4 levels and multipliers ranging from 1 as nominal to HEP=1. Perception of risk was best considered with 5 levels and multipliers ranging from 1 as nominal to HEP=1. Experience and training was best considered from 0.5 as positive to 75 as extremely high negative. Teamwork was best considered with 6 levels and multipliers ranging from 0.1

as low positive to 50 as high negative. Environmental stressors were best considered with 4 levels and multipliers ranging from 1 as nominal to HEP=1 where the task is obstructed. Procedures were best considered with 3 levels and multipliers ranging from 1 as nominal to 25 as high negative. Equipment were best considered with 5 levels and multipliers ranging from 0.1 as low positive to HEP=1. Fitness was best considered with 4 levels and multipliers ranging from 1 as nominal to HEP=1. Task complexity was best considered with 3 levels and multipliers ranging from 1 as nominal to 25 as high negative. Attitude to safety, work and management support was best considered with 4 levels and multipliers ranging from 1 as nominal to 25 as high negative. This is further elaborated in the chapters seen in **Table 24**

- *What needs to be done in order to fulfil the work required for an ArcticHRA?*

From **Figure 7** and the four steps provided by Rausand (2013) one can see that there are still a lot of work to be done in order to develop a complete HRA. A step-by-step guidance should be developed to make it usable. Throughout this thesis several scenarios have been mentioned, but only to a minor extent. The people currently working on Svalbard has an extensive knowledge about the dangers of operating in harsh environments. Consultation with these people would give a good base for a scenario description and provide input to the qualitative data collection and the task analysis. A visit to the area where the task is to be performed may not be possible.

The work done in this thesis would support the step of identifying human errors and the human error modelling and would especially be helpful during the process of human error quantification. The thesis participants have not provided a recommend NHEP, since there is a lack of statistics. A NHEP needs to be established to quantify human errors, which is further elaborated in **Chapter 9.2.** The actors currently operating in the Arctic already holds a lot of knowledge about how the dangers in the Arctic can be handled. This knowledge should be utilized in development of measures to reduce human error.

Table 24 The most significant performance shaping factors and the chapters they are defined and further elaborated.

PSF	Page / Chapter
Time	p. 101 Ch. 7.1
Perception of risk	p. 101 Ch. 7.2
Experience and training	p. 101 Ch. 7.3
Environmental Stressors	p. 102 Ch. 7.4
Procedures	p. 103 Ch. 7.6
Equipment	p. 103 Ch. 7.7
Fitness	p. 104 Ch. 7.8
Task Complexity	p. 104 Ch. 7.9
Attitude to Safety, Work and Management	p. 105 Ch. 7.10

7.1. TIME

The Time PSF refers to the difference between the *Available time, Required time* and the *uncertainty* in required time. Available time is the period between the starting point and the point where consequences are inevitable, and required time is the time it takes to successfully perform the task. Levels and multipliers for the Time PSF is shown in **Table 25**.

Table 25 Level, level definition and multipliers for the Time PSF

Time		
PSF levels	Definition	Multiplier
Inadequate time	Available time is less than the time required to complete the task. (Available time < Time required)	HEP=1.0
Very high negative	Available time is the minimum to complete the tasks. High time pressure is experienced. (Available time = Time required)	50
Low negative	Available time is sufficient to complete task, but some degree of time pressure is experienced. (Available time > Time required)	10
Nominal effect	Available time is considerably higher than Time required	1

7.2. PERCEPTION OF RISK

Perception of risk is the individuals' comprehension of a hazards in the task and scenario laid at hand. The perception can influence the performance negatively causing threat stress or wrong perception of risk can cause ignorant, irresponsible and thoughtless behaviour. Levels and multipliers for the Perception of Risk PSF is shown in **Table 26.**

Table 26 Level, level definition and multipliers for the Perception of Risk PSF

Perception of Risk		
PSF levels	Definition	Multiplier
Task is obstructed	Perceived risk is considerably lower than the Real risk with reckless behaviour. Perceived risk is considerably higher than Real risk with real threat stress and panic behaviour	HEP=1.0
High negative effect	(Perceived risk << Real risk with reckless behaviour), (Perceived risk >> Real risk with high threat stress and panic behaviour)	50
Moderate negative effect	(Perceived risk > Real risk and extrovert behaviour is present), (Perceived risk < Real risk with real fear of consequences)	25
Low negative effect	(Perceived risk = Real risk with some threat stress)	10
Nominal effect	The hazard is real and the risk is excepted as real and there is no behaviour related to detection and understanding. (Perceived risk = Real risk with no outgoing expressive behaviour is present)	1

7.3. EXPERIENCE AND TRAINING

Experience refers to how much an individual has been exposed to hazards and how many times the individual has performed the task or scenario, including failures and successes. Training is defined as a systematic approach for practicing the task or scenario, it is a way to acquire knowledge and skill on how to perform in the task or scenario. This is considered as preparation and will impact performance positively. The training is task specific, meaning different task has different training. Levels and multipliers for the Experience and Training PSF is shown in **Table 27**.

Table 27 Level, level definition and multipliers for the Experience and Training PSF

Experience and training		
PSF levels	Definition	Multiplier
Extremely High negative effect	No training or experience, and no comprehension of the scenario or task at hand. This also applies when the knowledge and skills held mismatches those required.	75
High negative effect	No training or experience but some comprehension of the scenario or task at hand	50
Moderate negative effect	Some training but a lack of experience	25
Low negative effect	Adequate training but some lack of experience	10
Nominal effect	Adequate training and experience	1
Positive effect	Highly trained and experienced, Several exposures to hazardous conditions.	0.1

7.4. TEAMWORK

Teamwork is defined as the interaction and communication between two or more individuals. This applies for individual with a common task goal which are shearing thoughts, feelings and performing actions in a coordinated manner. This is done in order to ensure that all participants perform their intended functions. Teamwork also describe the interaction between the leader and participants of the group, group coordination, adaptiveness and trust between the team members. Teamwork involves five primary components: *Team leadership*, *Mutual performance monitoring*, *Backup behaviour*, *Adaptability*, *Team orientation*, *Shared mental models*, *Mutual trust*, *Closed loop communication* as *in Petro-HRA.* Levels and multipliers for the Teamwork PSF is shown in **Table 28**

Table 28 Level, level definitions and multipliers for the Teamwork PSF

Teamwork		
PSF levels	Definition	Multiplier
High negative effect	One or more teamwork factors are identified as important and influence performance very negatively.	50
Moderate negative effect	One or more teamwork factors are identified as important and influence task performance negatively to some degree.	25
Low negative effect	One or more teamwork factors are identified as important and influence task performance negatively to a small degree.	10
Nominal effect	One or more teamwork factors are identified as important but do not influence task performance negatively or positively	1
Low Positive effect	One or more teamwork factors are identified as important and influence task performance positive.	0.1
Not applicable	Teamwork is not relevant for the specific task or scenario. Single individual is performing a task without any support.	1

7.5. ENVIRONMENTAL STRESSORS

The environment is the surroundings of which a person operates. This include terrain, hard to reach places and weather conditions. The environment also considers light conditions, wildlife and sea ice as part of the ground conditions. The Environmental Stressors PSF refers to all undesirable conditions caused by the environment that obstruct or hinders the person, physically or mentally, from performing a task at the preferred level. Levels and multipliers for the Environmental Stressors PSF is shown in **Table 29**.

Table 29 Level, level definitions and multipliers for the Environmental Stressors PSF

Environmental stressors		
PSF levels	Definition	Multiplier
Task is Obstructed	The environmental stressors obstruct the attainment of a goal	HEP=1
High Negative Effect	The environmental stressors greatly reduce performance level	50
Moderate Negative Effect	The environmental stressors hinder a preferable performance level	25
Low Negative Effect	The environmental stressors reduce performance to a small degree	10
Nominal Effect	The environmental stressor is at a level where performance is not affected	1

7.6. PROCEDURES

A procedure is a written document that represents decisions and actions to be performed to accomplish a goal ether by following a fixed procedure or a guidance with the room for improvisation. It is used to increase the likelihood that the actions will achieve the goal and therefore one must consider the procedures practicality and suitability for the specific task. Levels, level descriptions and multipliers for the Procedures PSF is shown in **Table 30**.

Table 30 Level, level definitions and multipliers for the Procedures PSF

Procedures		
PSF levels	Definition	Multiplier
High Negative Effect	Procedure is misleading or no longer valid with little room for improvisation.	25
Low Negative Effect	Procedure lacks information of important aspect of the task or scenario but gives room for some improvisation.	5
Nominal Effect	Procedure is sufficient or there is no need for a procedure.	1

7.7. EQUIPMENT

The Equipment PSF refers to all equipment, including clothing, used to achieve a goal. The interaction between the person using equipment and the equipment itself is essential. This PSF also includes the possibilities to improvise needed equipment and the use of miscellaneous objects to achieve the goal. Levels, level descriptions and multipliers for the Equipment PSF is shown in **Table 31**.

Table 31 Level, level definitions and multipliers for the Equipment PSF

Equipment		
PSF levels	Definition	Multipliers
Task is Obstructed	Required equipment is missing and cannot be substituted.	HEP = 1
High Negative Effect	Equipment requires several actions to operate and is not self-explanatory. Equipment design create clear challenges and clothing causes considerable mobility reduction.	50
Moderate Negative Effect	Some self-explanatory information. Equipment design causes some challenge and clothing causes some mobility reduction.	25
Nominal Effect	Equipment can be substituted, and clothing does not have the potential to create mobility reduction.	1
Low Positive Effect	Equipment is so self-explanatory and well-designed for its purposed task that it can increase performance.	0.1

7.8. Fitness

Fitness deal with whether the individual is mentally or physically fit enough to perform the task at hand. An individual's general condition is decisive for whether fatigue is experienced. Fatigue is a state of tiredness both physically and mentally. Levels and multipliers for the Fitness PSF is shown in **Table 32**.

Table 32 Level, level definition and multipliers for the Fitness PSF

Fitness		
Level	Definition	Multiplier
Inadequate Fitness	Mental or physical fitness is not adequate to complete task.	HEP=1
High Negative Effect	Considerable reduction in performance due to extremely prolong or demanding tasks.	50
Moderate Negative Effect	Some reduction in performance due to lack of sleep, long duty hours, night work or prolonged tasks.	10
Nominal Effect	General condition has no negative or positive effect on performance.	1

7.9. Task Complexity

Task Complexity is defined as the level of difficulty of the task at hand. Task complexity can be broken down into five factors: *Goal complexity, Size complexity, Step complexity, Connection complexity, Structure complexity* as in Petro-HRA. Levels and multipliers for the Task Complexity PSF is shown in **Table 33**.

Table 33 Level, level definitions and multipliers for the Task Complexity PSF

Task complexity		
PSF levels	Definition	Multipliers
High Negative Effect	The task is highly complex and several of the complexity factors influences.	25
Moderate Negative Effect	The tasks are moderately complex, few of the complexity factors influence.	10
Nominal Effect	The complexity of the task has no effect on performance	1

7.10. Attitude to Safety, Work and Management Support

Attitude to safety is defined as the mind setting one has towards safety. Attitude is a termed for the sustained preparedness to respond positively or negatively to particular objects, ideas and values in the performance of a task or scenario. Levels and multipliers for the Attitude to Safety, Work and Management Support PSF is shown in **Table 34**.

Table 34 Level, level definitions and multipliers for the Attitude to Safety, Work and Management Support PSF

Attitude to Safety, Work and Management		
PSF levels	Definition	Multipliers
High Negative Effect	There is no support from management. Safety is not a priority. High pressure from management.	25
Moderate Negative Effect	The individual has inadequate attitude towards safety There is inadequate support from management partly entrusting the field decisions to employees.	10
Nominal Effect	The individual has adequate attitude towards safety. There is adequate support from management entrusting the field decisions to employees.	1
Low Positive Effect	There is very god attitude towards safety and work is conducted in such manner that it increases performance. The management entrusts its employs giving a lot of freedom in task commencements.	0.1

8. CONCLUSION

The Arctic poses new challenges to the actors who wishes to conduct operations there. This requires new approaches in their safety management. During arctic operation the human element in the system is even more essential than in other context due to “the Arctic Problem”. This requires a higher focus on human reliability in safety management in the Arctic.

The possibility to improvise and be flexible is an important part of working in the Arctic. This leads to challenges for many industries who bases their operations on strict procedures and rules. A new approach is required for them to conduct their operations in an effective and safe manner. The quickly changing weather conditions and changes in the arctic environment require a strong focus on resilience.

In this thesis the factors that influences humans the most in the Arctic has been identify. The most influential factors are impact from the environmental, available time, risk perception, availability of equipment, peoples’ fitness, skills and knowledge, teamwork, procedures, task complexity and peoples attitude towards safety.

These findings are useful in both theoretical and practical contexts. The factors identified must be taken into account when operations in the Arctic is being planned. It is important that the people operating in the Arctic are aware of the challenging conditions found in these areas. The result is implementable in educational contexts to enlighten the present dangers.

There is still a lot of work remaining in the development of safety management for arctic conditions. HRAs are develop for industries where major accidents may occur. Several operations in the Arctic does not involve the risk of major accidents, and for many actors an HRA would be too comprehensive. The result from this thesis can be used in the development of an HRA but could advantageously be used in the development of other methods.

The result from the thesis is not limited for use in the arctic. A lot of the factors identified is also present in other contexts. Harsh environment is experienced in other places around the world, and the environmental factors identified in this thesis will also be relevant there.

9. FURTHER WORK

9.1. VALIDITY OF THE RESEARCH

The fact that all the research units are based on Svalbard makes it difficult to evaluate the external validity of the research, if it is generalizable for the Arctic. To further increase the validity of the research the thesis participants suggests conducting similar interviews with personnel on Greenland (Denmark), northern Canada and in other “Arctic eight” countries.

9.2. NOMINAL HEP

The nominal HEP for THERP is outdated according to how work is conducted in the modern society. To update these values an extensive study on unwanted incidents should be conducted properly, in order to identify nominal values for all incidents that might occur in the Arctic. This can be done by looking at reported incident over the years and proper perform an accident cause analysis regarding human errors and human errors only. Looking how experienced individuals error probability versus inexperienced individuals there is the possibility to verify the experience PSF multipliers and levels. There are several other approaches to find the human error probability, such as

9.3. ARCTIC-HRA

This thesis does not in any way present a complete HRA, and comprehensive work is still required for development of an HRA for arctic areas. Considering the increased human activity in the High North it should be consider if an HRA should be used for work there in the future. As Lorentzen (2017) show the biggest concentration of accidents on Svalbard occurs due to human errors. It could therefore be argued that there is a need for an HRA for onshore arctic activity.

9.4. OTHER AREAS OF APPLICATION

The range of application of the results from this thesis does not necessarily restrict to HRA but could also be used in other methods focusing on the human element. HRAs are often used as a part of a QRA in industries where major accidents may occur, such as petroleum and nuclear. Although major accidents may occur during onshore activity in the Arctic, such as large groups caught in avalanche, it could be more advantageous to use a less comprehensive method when estimating risk.

The results can for instance be used in methods similar to the OTS-method. OTS is used to monitor the status of operational safety barriers and to develop risk reducing measures by assessing the compliance with seven performance standards; Work practice, Competence, Procedures and documentation, Communication, Workload and physical working environment, Management and Management of change. (Sklet et al., 2010) The PSFs in this thesis can be used in the same way as OTSs performance standards. For instance, the Experience and Training PSF matches Competence and the Procedures PSF matches Procedures and documentation.

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Appendix A - HRA overview.

Method	Description	Sources	Generation	Developer	Year	Domains	Qualitative/ quantitative	Comments
THERP	Technique for Human Error Reliability Prediction	Swain, A.D. (1987)	1st	Swain & Guttmann, Sandia Laboratories	1983	Nuclear industry with wider use	Partially experts' judgement and category selection and supplemented by recorded data.	Tables made from observations
ASEP	Accident Sequence Evaluation Programmed	Swain, A.D. (1987)	1st	US Nuclear Regulatory Commission, Sandia National Laboratories	1987	Nuclear industry		
SLIM	Success Likelihood Index Method	Bell and Holroyd (2009)	1st	Embrey et al	1983	Nuclear industry	Extensive use of expert judgement is required, No empirical validation	
HEART	Human error assessment and reduction technique	Bell and Holroyd (2009)	1st	Williams	1985	General industry	Empirically validated.	
HCR	Human cognitive reliability correlation	John Wiley & Sons (1994)	1st	Hannaman et al.	1984	General industry	Quantifying post accident with normalized time reliability curve. Simulation of time reliability with small-scale tests	Individual determination of human cognitive failure, Stress, experience and quality of the human machine interface.
HRMS	Human Reliability Management System "is a fully computerized HRA system that contains a human error identification module which is used by the assessor on a previously prepared and computerized task analysis." (Bell and Holroyd)	Bell and Holroyd (2009)	1st	Kirwan	Late 80s	Nuclear sector (data based on nuclear chemical plant operation)	Expert judgements and industrial data	Individual?
JHEDI	Justification of Human error data Information. Based on HRMS methodology, as a quicker screening technique.	Bell and Holroyd (2009)	1st	Kirwan	Late 80s	Nuclear industry	Industrial data supplemented by expert judgements, empirically validated	Individual?
SPAR-H	Standardized Plant Analysis Risk Human Reliability Analysis	Bell and Holroyd (2009)	1st	Accident Sequence Precursor Program (ASP) and US Nuclear Research Commission, Office of Regulatory Research (USNRC) in conjunction with Idaho National Laboratory (INL)	1994	Nuclear sector and risk informed regulatory activities with wider use	Quantification of PSFs and HEP based on experts' judgments, indirectly evaluated by Various NRC groups	Operational as a whole system, Available time, Stress and stressors, Experience and Training, Complexity, Ergonomics (and Human Machine interface), Procedures, Fitness for duty, Work processes.
ATHEANA	A Technique for Human Event Analysis	Bell and Holroyd (2009)	2nd	US nuclear industry regulatory commission	2000	Nuclear industry with wider use	Errors based on time-reliability curves, No empirical validation	Reduce the likelihood of errors occurring within a system, prospective and retrospective
CREAM	Cognitive Reliability and Error Analysis Method	Erik Hollnagel (1993)	2nd	Eric Hollnagel	1993	Nuclear industry with wider use	Assessment of CPCs and generic failure types and partially experts' judgement, Not yet proper validity	Probability of human errors throughout the completion of a specific task, focused on the level of the situation or working conditions rather than on the level of individual actions. Quantification in two steps
MERMOS	Assessment Method for the Performance of Safety Operation (in France "*Méthode d'Evaluation de la Realisation des Missions Opérateurs pour la Sûreté*")		2nd	Le Bot et al	1998	Nuclear specific and emergency operating system only	Simulation, past records and experts,	Operating system as a whole. Quantification takes account of all elements identified by the qualitative analysis. The total probability of failure of the HF mission is defined as the sum of all probabilities of occurrence of all failure scenarios identified, plus the residual probability Formula, representing possible unforeseen scenario
PetroHRA	Analysis of human actions as barriers in major accidents in the petroleum industry	Bye et. al (2017)			2016	Petroleum industry	Quantification of PSFs and HEP based on expert s judgments, based on SPAR-H	
PC	Paired Comparison	Bell and Holroyd (2009)	1st	Credited to several, may have originated from Rook	1984	General industry	Expert judgements (Simple comparative judgement)	16 steps
APJ	Absolute Probability Judgements	Bell and Holroyd (2009)	1st	Seaver and Stillwell	1983	General industry	Expert judgement	Reduce the likelihood of errors occurring within a system
NARA	Nuclear Action Reliability Assessment	Kirwan at. Al (2004)	2nd	British Energy	2004	Nuclear industry	quantifying operator reliability in relation to long time-scale events	Based on probability of past events to find future events

APPENDIX B - PSF MULTIPLIERS AND LEVELS

TIME

PetroHRA	SPAR-H	CREAM	SLIM	PetroHRA	SPAR-H	CREAM	PetroHRA	SPAR-H	CREAM	SLIM	HEART	NARA	ASEP	THERP	THERP	THERP	HEART	NARA	HCR
PSFs	**PSFs**	**CPCs**	**PSFs**	**Level**	**Level**	**Level**	**Multipliers**	**Multipliers (THERP tables)**	**Performance influence index**	**PSF Weights (Scaled by multiplying 0 to 10)**	**Multipliers**	**Multipliers**	**Multipliers**	**PSFs**	**Level**	**Multipliers**	**EPCs**	**EPCs**	**PSFs for response time** $K=(1+K_1)(1+K_2)(1+K_3)$
				Extremely high negative	Inadequate Time		**HEP=1**	**P(failure) = 1.0 (20-1, 1)**					**P(failure) = 1.0**			**P(failure) = 1.0**			
				Very high negative		Continuously inadequate	**50**		**2.4**		**11**	**11**	**10**			**50**	**2)**	**3)**	
				Moderate negative	Barely adequate time	Temporarily inadequate	**10**	**10 (20-1, 3 = 0,1)**	**1**							**10**			
Time	Available time	Available time	Adequacy of Time to Accomplish Action	Nominal	Nominal time	Normal	**1**	**1 (20-1, 4 = 0,01)**	**0**	**0.1**	**1**	**1**	**1**	External		**1**			Time adjustment, $T_{1/2} = T_{1/2,nominal} * K$
				Moderate positive	Time available > 5 x time required	Adequate	**0.1**	**0.1 (20-1, 5 = 0,001)**	**-1.4**										
					Time available > 50 x time required			**0.01 (20-1, 6 = 0,0001)**					**0.01**			**0.01**			
				Not applicable			**1**	**1**	**0**		**1**	**1**	**1**			**1**			

THREAT STRESS

PetroHRA	SPAR-H	CREAM	SLIM	PetroHRA	SPAR-H	CREAM	PetroHRA	SPAR-H	CREAM	SLIM	HEART	NARA	ASEP	THERP	THERP	THERP	HEART	NARA	HCR
PSFs	**PSFs**	**CPCs**	**PSFs**	**Level**	**Level**	**Level**	**Multipliers**	**Multipliers (THERP tables)**	**Performance influence index**	**PSF Weights (Scaled by multiplying 0 to 10)**	**Multipliers**	**Multipliers**	**Multipliers**	**PSFs**	**Level**	**Multipliers**	**EPCs**	**EPCs**	**PSFs for response time** $K=(1+K_1)(1+K_2)(1+K_3)$
				High negative	Extreme		**25**	**5 (20-16, a5 = 5)**					**5**		Extreme high				
												3						**13)**	
				Low negative	High		**5**	**2 ((20-16, a4 = 2)**			**1.3**	**2**			High stress	**5**	**29)**	**18)**	
											1.15				Moderately high	**5**	**33)**		
Threat stress	Stress/Stressor		Stress	Very low negative			**2**			**0.05**				Stressors and Stress (Physiological and Psychological)		**2**			Stress level = K_2
				Nominal	Nominal		**1**	**1**				**1**			Optimum	**1**			
															Very low	**2**			
				Not applicable			**1**	**1**			**1**	**1**	**1**			**1**			

TASK COMPLEXITY

PetroHRA	SPAR-H	CREAM	SLIM	PetroHRA	SPAR-H	CREAM	PetroHRA	SPAR-H	CREAM	SLIM	HEART	NARA	ASEP	THERP	THERP	THERP	HEART	NARA	HCR
PSFs	**PSFs**	**CPCs**	**PSFs**	**Level**	**Level**	**Level**	**Multipliers**	**Multipliers (THERP tables)**	**Performance influence index**	**PSF Weights (Scaled by multiplying 0 to 10)**	**Multipliers**	**Multipliers**	**Multipliers**	**PSFs**	**Level**	**Multipliers**	**EPCs**	**EPCs**	**PSFs for response time** $K=(1+K_1)*(1+K_2)*(1+K_3)$
				Very high negative	Highly complex	More than capacity	**50**	**5**	**1.2**		**6**	**6**	**5**		Complete dependence	**5**	**8)**	**10)**	
											5.5		**2.5**		High dependence	**2**	**10)**		
				Moderate negative	Moderately complex		**10**	**2**							Moderate dependence	**1**			
Task complexity	Complexity	Number of simultaneous goals	Task complexity	Very low negative			**2**			**0.1**				Dependence, Independence, and Coupling	Low dependence	**0,1**			
				Nominal	Nominal	Current capacity	**1**	**1**	**0**		**1**				Zero dependence	**1**			
				Moderate positive		Fewer than capacity	**0.1**	**0.1**	**0**										
				Not applicable			**1**	**1**	**0**		**1**	**1**	**1**			**1**			

EXPERIENCE/ TRAINING

PetroHRA	**SPAR-H**	**CREAM**	**SLIM**	**PetroHRA**	**SPAR-H**	**CREAM**	**PetroHRA**	**SPAR-H**	**CREAM**	**SLIM**	**HEART**	**NARA**	**ASEP**	**THERP**	**THERP**	**THERP**	**HEART**	**NARA**	**HCR**
PSFs	**PSFs**	**CPCs**	**PSFs**	**Level**	**Level**	**Level**	**Multipliers**	**Multipliers (THERP-tables)**	**Performance influence index**	**PSF Weights (Scaled by multiplying 0 to 10)**	**Multipliers**	**Multipliers**	**Multipliers**	**PSFs**	**Level**	**Multipliers**	**EPCs**	**EPCs**	**PSFs for response time** $K=(1+K_1)*(1+K_2)*(1+K_3)$
Experience/ training	Experience/ training	Adequacy of training and experience	Training and Experience	Extremely high negative			**HEP=1**			**0.2**				Experience levels					Operator experience = K_1
				Very high negative		Inadequate	**50**		**1.8**										
				Moderate negative	Low	little inadequate	**15**	**3 (20-16, 7→ nom/ nov=2)**	**1**		**17**		**10**		Novice	**2**	**1)**		
											8						**6)**		
											6	**24**					**9)**	**1)**	
											4						**12)**		
											3	**9**					**15)**	**9)**	
											2.5	**2,5**					**18)**	**14)**	
											2						**20)**		
											1.6						**24)**		
				Low negative			**5**												
				Nominal	Nominal	Adequate low experience	**1**	**1**	**0**		**1**	**1**	**1**		Skilled	**1**			
				Moderate positive	High	Adequate high experience	**0.1**	**0.5 (20-16, exp/nov=0,5 ?)**	**-1.4**				**0.1**						
				Not applicable			**1**	**1**	**0**		**1**	**1**	**1**			**1**			

PROCEDURES

PetroHRA	SPAR-H	CREAM	SLIM	PetroHRA	SPAR-H	CREAM	PetroHRA	SPAR-H	CREAM	SLIM	HEART	NARA	ASEP	THERP	THERP	THERP	HEART	NARA	HCR
PSFs	**PSFs**	**CPCs**	**PSFs**	**Level**	**Level**	**Level**	**Multipliers**	**Multipliers (THERP tables)**	**Performance influence index**	**PSF Weights (Scaled by multiplying 0 to 10)**	**Multipliers**	**Multipliers**	**Multipliers**	**PSFs**	**Level**	**Multipliers**	**EPCs**	**EPCs**	**PSFs for response time** $K=(1+K_1)(1+K_2)(1+K_3)$
				Very high negative	Not available	Inappropriate	**50**	**50 (20-7, 5 = 0,05)**	**1.4**				**P(failure) = 1.0**			**50**			
											5						**11)**		
											3						**16)**		
				High negative	Incomplete		**20**	**20 (20-7, 4 = 0,01)**			**3**						**17)**		
											1.4						**28)**		
											1.2						**32)**		
Procedures	Procedures	Availability of procedures	Procedural Guidance							0.15	**5**			External		**10**	**11)**		
											3	**3**					**16)**	**12)**	
				Low negative	Available, but poor		**5**	**5 (20-7, 4 = 0,01)**			**3**	**10**					**17)**	**5)**	
											1.4						**28)**		
											1.2						**32)**		
				Nominal	Nominal	Acceptable	**1**	**1**	**0**		**1**	**1**				**1**			
				Low positive		Appropriate	**0.5**	**0.5**	**-1.2**										
				Not applicable			**1**	**1**	**0**		**1**	**1**	**1**			**1**			

HUMAN-MACHINE INTERFACE

PetroHRA	SPAR-H	CREAM	SLIM	PetroHRA	SPAR-H	CREAM	PetroHRA	SPAR-H	CREAM	SLIM	HEART	NARA	ASEP	THERP	THERP	THERP	HEART	NARA	HCR
PSFs	**PSFs**	**CPCs**	**PSFs**	**Level**	**Level**	**Level**	**Multipliers**	**Multipliers (THERP tables)**	**Performance influence index**	**PSF Weights (Scaled by multiplying 0 to 10)**	**Multipliers**	**Multipliers**	**Multipliers**	**PSFs**	**Level**	**Multipliers**	**EPCs**	**EPCs**	**PSFs for response time** K=(1+K₁)(1+K₂)(1+K₃)
Human-machine interface	Ergonomics/ HMI	Adequacy of MMI and operational support	Significant Preceding and Concurrent Actions.	Extremely high negative			**HEP=1**			0.1			**P(failure) = 1.0**	External		**100, 1000**			Human-machine interface level = K_3
				Very high negative	Missing/Misleading	Inadequate	**50**	**50**	**1.4**										
				Moderate negative	Poor		**10**	**10 (table 20-9, -10, -11, -12, -13, -14)**			**10**	**10**				**10**	**3)**	**4)**	
											9	**9**					**4)**	**7)**	
											8						**5)**		
											8	**9**					**7)**	**8)**	
											4	**4**					**13)**	**11)**	
											4					**6**	**14)**		
											2.5						**19)**		
											1.6						**23)**		
											1.4	**2**					**26)**	**17)**	
											1.2						**32)**		
				Nominal	Nominal	Tolerable	**1**	**1**	**0**		**1**	**1**	**1**						
				Low positive	Good	Adequate	**0.5**	**0.5**	**-0.4**										
						Supportive			**-1.2**										
				Not applicable			**1**	**1**	**0**		**1**	**1**	**1**						

WORK AND MANAGEMENT SUPPORT

PetroHRA	SPAR-H	CREAM	SLIM	PetroHRA	SPAR-H	CREAM	PetroHRA	SPAR-H	CREAM	SLIM	HEART	NARA	ASEP	THERP	THERP	THERP	HEART	NARA	HCR
PSFs	**PSFs**	**CPCs**	**PSFs**	**Level**	**Level**	**Level**	**Multipliers**	**Multipliers (THERP tables)**	**Performance influence index**	**PSF Weights (Scaled by multiplying 0 to 10)**	**Multipliers**	**Multipliers**	**Multipliers**	**PSFs**	**Level**	**Multipliers**	**EPCs**	**EPCs**	**PSFs for response time** **K**=(1+K₁)(1+K₂)(1+K₃)
Attitudes to Safety, Work and Management Support	Work Processes	Adequacy of organization		Very high negative	Poor	Bad effect	**50**	**2**	**1**					Internal					
				Moderate negative		Inefficient	**10**		**0.6**										
				Nominal	Nominal	Efficient	**1**	**1**	**0**										
				Low positive	Good	Very efficient	**0.5**	**0.8**	**-0.6**										
				Not applicable			**1**	**1**			**1**	**1**							

TEAMWORK

PetroHRA	SPAR-H	CREAM	SLIM	PetroHRA	SPAR-H	CREAM	PetroHRA	SPAR-H	CREAM	SLIM	HEART	NARA	ASEP	THERP	THERP	THERP	HEART	NARA	HCR
PSFs	**PSFs**	**CPCs**	**PSFs**	**Level**	**Level**	**Level**	**Multipliers**	**Multipliers (THERP tables)**	**Performance influence index**	**PSF Weights (Scaled by multiplying 0 to 10)**	**Multipliers**	**Multipliers**	**Multipliers**	**PSFs**	**Level**	**Multipliers**	**EPCs**	**EPCs**	**PSFs for response time** $K=(1+K_1)(1+K_2)(1+K_3)$
						Deficient			**1.4**			**10**						**6)**	
											2	**2**					**21)**	**15)**	
											1.6						**25)**		
				Very high negative	Poor		**50**	**2**			**1.4**						**27)**		
											1.2	**2**					**31)**	**19)**	
Teamwork	Work Processes	Quality of crew collaboration									**1.06**			Populational stereotypes			**36)**		
											1.03						**37)**		
				Moderate negative			**10**												
				Very low negative		Inefficient	**2**		**0.4**										
				Nominal	Nominal	Efficient	**1**	**1**	**0**		**1**	**1**							
				Low positive	Good	Very efficient	**0.5**	**0.8**	**-1.4**										
				Not applicable			**1**	**1**	**0**		**1**	**1**							

PHYSICAL WORKING ENVIRONMENT

PetroHRA	SPAR-H	CREAM	SLIM	PetroHRA	SPAR-H	CREAM	PetroHRA	SPAR-H	CREAM	SLIM	HEART	NARA	ASEP	THERP	THERP	THERP	HEART	NARA	HCR
PSFs	**PSFs**	**CPCs**	**PSFs**	**Level**	**Level**	**Level**	**Multipliers**	**Multipliers (THERP tables)**	**Performance influence index**	**PSF Weights (Scaled by multiplying 0 to 10)**	**Multipliers**	**Multipliers**	**Multipliers**	**PSFs**	**Level**	**Multipliers**	**EPCs**	**EPCs**	**PSFs for response time** $K=(1+K_1)(1+K_2)(1+K_3)$
				Extremely high negative	Missing/Misleading		**HEP=1**	**50**											
				Moderate negative	Poor	Incompatible	**10**	**10**	**1**		**1.15**	**8**					**33)**	**16)**	
Physical working environment	Ergonomics/ HMI	Working conditions	Plant Interface and indications of Conditions /HMI	Nominal	Nominal	Compatible	**1**	**1**	**0**	**0.3**	**1**	**1**		External					
					Good	Advantageous		**0.5**	**-0.6**										
				Not applicable			**1**	**1**			**1**	**1**							

FATIGUE

PetroHRA	SPAR-H	CREAM	SLIM	PetroHRA	SPAR-H	CREAM	PetroHRA	SPAR-H	CREAM	SLIM	HEART	NARA	ASEP	THERP	THERP	THERP	HEART	NARA	HCR
PSFs	**PSFs**	**CPCs**	**PSFs**	**Level**	**Level**	**Level**	**Multipliers**	**Multipliers (THERP tables)**	**Performance influence index**	**PSF Weights (Scaled by multiplying 0 to 10)**	**Multipliers**	**Multipliers**	**Multipliers**	**PSFs**	**Level**	**Multipliers**	**EPCs**	**EPCs**	**PSFs for response time** $K=(1+K_1)(1+K_2)(1+K_3)$
					Unfit			**P(failure) = 1.0**											
						Night-time (unadjusted)			**0.6**										
											1.8						**22)**		
											1.2						**30)**		
Fatigue (excluded)	Fitness for duty	Time of the day	Other PSFs		Degraded Fitness			**5**			**1.1**	**3**		Internal			**34)**	**13)**	
											1.1						**35)**		
					Nominal	Day-time (adjusted)		**1**	**0**		**1**	**1**							
					Insufficient information			**1**	**0**		**1**	**1**							

APPENDIX C - INTERVIEW GUIDE

Semi-structured interview guide

THE PURPOSE OF THIS INTERVIEW

This interview is carried out in connection with our master's thesis at NTNU. The purpose of the interview is to map performance impact factors (PSF) in connection with human activity in the Arctic. These are physical and mental factors that affect human performance, and thus the outcome of a task, negative or positive.

The results will be used in research on safety during activities in the arctic. The goal is to be able to use the data in an Human reliability analysis (HRA). Hopefully this analysis will make it possible to calculate the possibility for human error and assist in the design of barriers to reduce the possibility.

BACKGROUND

- How long have you been working with the sort of work you are doing now?
- How many annual excursions do you participate in?
- What is your primary task during field work? Transport, stay, repair etc.?

PLANNING

- During the planning of an excursion how do u assess the dangers that might arise? What dangers are the most common?
- At what point do you choose to abort an execute? Do you consider “worst case scenarios”?

CRITICAL TASKS

- What tasks do you consider to be the most critical in your work (the ones who has to be done correctly for the excursion to be successful)?
- Why are these so critical?

UNWANTED OCCURRENCES

- Have you experienced any episodes where people’s life and health has been in danger? (avalanches, weather-bound etc.)
    - What was the reason for that?

  - Why did it end “bad”/good?
  - What kind of measures where implemented to avoid similar accident?

MAPPING OF PSFS (BASED ON ONE OR MULTIPLE SCENARIO)

Time

- Was the available time critical to avoid any unwanted consequences? (Did you have to speed up?)

Experience/Training

- Have you experienced similar episodes prior to this one?
- Do you think the outcome would have been the same if you **had/ had not** experienced it before?
- Have you received training on this type of episodes? How important has the training been?

Teamwork

- Do you think the number of people had any impact on the outcome? Where there too **many/few** people helping?
- How was the responsibility and roles distributed throughout the group? Where there any clear roles?
  - Did this contribute to the outcome?
- How did the groups communication- and collaboration- skills contribute to the outcome?
  - Was it sufficient or did it make the episode worse?

Physical stressors

- Did the weather and surroundings impact the episode (temperature, wind, hard to reach places etc.)?
- Did the weather have any effect on the communication?
- Did the terrain and topography have any influence? Do you think the outcome would have been the same if the terrain had been different?

Procedures

- Did UNIS have any procedures on these kinds of episodes?
- Did the procedures match with the reality or was improvisation needed?
- How important was the procedures? / Could the outcome have been another if you had procedures you could have followed?

Fatigue

- Did this episode occur during the **night/dark**? Would the outcome have been another if the work had been done during the **day/daylight**?

- Did you experience factors that reduces your physical or mental abilities (Hunger, thirst, feeling of cold etc.)?

Threat stress

- Did you consider the possible consequences during the situation? Did this effect your work?

Task complexity

- Did the complexity of the situation impact the outcome?

Clothes and equipment

- What kind of equipment was essential for handling the situation? was these accessible?
- Would the outcome have been different if the equipment had/ had not been accessible?
- Did the clothing effect the outcome? Was the clothing adapted to the weather etc.?

Attitude to safety

- Could peoples attitude to safety be a part of the reason the situation occurred?

Summary of PSFs

***Time*, time available to complete the task. Detect - plan – act**

***Experience and training*: experience is the number of times the person has been in a similar situation.: preparation for a situation.**

Task complexity

***Procedures*, documents describing how to reach "goals."**

***Equipment*, tools, clothing, communication equipment, safety equipment etc.**

***Physical working environment*, wind, temperature, terrain, etc.**

***Teamwork* (Cooperation and Communication),**

***Fatigue* (sleep deprivation, lack of breaks, night work, length of "working day"),**

***Fear of consequences*, material or persons may be harmed.**

Other factors?

APPENDIX D - GTT AND EPC INCLUDED IN HEART AND NARA

EPC no:	Error producing Conditions (EPC) HEART	Multipliers
1	Unfamiliarity with a situation which is potentially important but which only occurs infrequently or which is novel	17
2	A shortage of time available for error detection and correction	11
3	A low signal-noise ratio	10
4	A means of suppressing or over-riding information or features which is too easily accessible	9
5	No means of conveying spatial and functional information to operators in a form which they can readily assimilate	8
6	A mismatch between an operator's model of the world and that imagined by the designer	8
7	No obvious means of reversing an unintended action	8
8	A channel capacity overload, particularly one caused by simultaneous presentation of non-redundant information	6
9	A need to unlearn a technique and apply one which requires the application of an opposing philosophy	6
10	The need to transfer specific knowledge from task to task without loss	5,5
11	Ambiguity in the required performance standards	5
12	A mismatch between perceived and real risk.	4
13	Poor, ambiguous, or ill matching system feedback	4
14	No clear, direct and timely confirmation of an intended action from the portion of the system over which control is exerted.	3
15	Operator inexperience (e.g., a newly qualified tradesman but not an expert)	3
16	An impoverished quality of information conveyed by procedures and person-person interaction	3
17	Little or no independent checking or testing of output	3
18	A conflict between immediate and long-term objectives	2,5
19	No diversity of information input for veracity checks	2,5
20	A mismatch between the educational achievement level of an individual and the requirements of the task	2
21	An incentive to use other more dangerous procedures	2
22	Little opportunity to exercise mind and body outside the immediate confines of a job	1,8
23	Unreliable instrumentation (enough that it is noticed)	1,6
24	A need for absolute judgements which are beyond the capabilities or experience of an operator	1,6
25	Unclear allocation of function and responsibility	1,6
26	No obvious way to keep track of progress during an activity	1,4
27	A danger that finite physical capabilities that will be exceeded.	1,4
28	Little or no intrinsic meaning in a task	1,4
29	High level emotional stress	1,3
30	Evidence of ill health amongst operatives especially fever.	1,2
31	Low workforce morale	1,2
32	Inconsistency of meaning of displays and procedures	1,2
33	A poor or hostile environment	1,15
34	Prolonged inactivity or highly repetitious cycling of low mental workload tasks first hour (x1,05 for each hour thereafter)	1,1 first hour 1.05
35	Disruption of normal work sleep cycles	1,1
36	Task pacing caused by the intervention of others	1,06
37	Additional team members over and above those necessary to perform task normally and satisfactorily. (per additional team member)	1,03x /add. Pr.
38	Age of personnel performing perceptual tasks	1,02

GTTs HEART	NHEP
Total unfamiliar, performed at speed with no real idea of likely consequences	0,55
Shift or restore a system to a new or original state on a signal attempt without supervision or procedures	0,26
Complex task requiring high level of comprehension and skill	0,16
Fairly simple task performed rapidly or given scant attention	0,09
Routine, highly-practiced, rapid task involving relatively low level of skill	0,02
Restore or shift a system to original or new state following procedures, with some checking	0,003
Completely familiar, well designed, highly practiced, routine task occurring several times per hour, performed to highest possible standards by highly. motivated, highly trained and experienced persons, total aware of implications of failure, with time to correct potential errors, but without the benefit of significant work aid.	0,0004
Responds correctly to system command even when there is an augmented or automated supervisory system providing accurate interpretation of system stat	0,00002
Miscellaneous task for which no description can be found	0,03

EPC no:	Error producing Conditions (EPC) NARA	Multipliers
1	A need to unlearn a technique and apply one which requires the application of an opposing philosophy.	24
2	Unfamiliarity, i.e. a potentially important situation which only occurs infrequently or is novel.	20
3	Time pressure.	11
4	Low signal to noise ratio.	10
5	Little or no independent checking or testing of output (when normally present)	10
6	Difficulties caused by poor shift hand-over practices and/or team co-ordination problems or friction between team members.	10
7	A means of suppressing or over-riding information or features which is too easily accessible.	9
8	No obvious means of reversing an unintended action.	9
9	Operator inexperience.	8
10	Information overload, particularly one caused by simultaneous presentation of non-redundant information.	6
11	Poor, ambiguous or ill-matched system feedback.	4
12	Shortfalls in the quality of information conveyed by procedures.	3
13	Operator under-load/ boredom.	3,0
14	A conflict between immediate and long-term objectives.	2,5
15	An incentive to use other more dangerous procedures.	2
16	Poor environment.	8
17	No obvious way of keeping track of progress during an activity.	2
18	High emotional stress and effects of ill health.	2
19	Low workforce morale or adverse organizational environment.	2

NARA GTT	**NHEP**
Task Execution	
Carry out simple single manual action with feedback. Skill-based and therefore not necessarily with procedure.	0.006
Start or reconfigure a system from the Main Control Room following procedures, with feedback.	0.001
Start or reconfigure a system from a local control panel following procedures, with feedback.	0.003
Reconfigure a system locally using special equipment, with feedback e.g. closing stuck open boiler relief valve using gagging equipment. Full or partial assembly may be required.	0,03
Judgement needed for appropriate procedure to be followed, based on interpretation of alarms/indications, situation covered by training at appropriate intervals.	0,01
Ensuring correct plant status and availability of plant resources	
Routine check of plant status.	0.03
Restore a single train of a system to correct operational status after test following procedures.	0,007
Set system status as part of routine operation using strict administratively controlled procedures	0,0007
Calibrate plant equipment using procedures, e.g. adjust set-point.	0,003
Carry out analysis.	0,03
Alarm/ indication Response	
Simple response to a key alarm within a range of alarms/indications providing clear indication of situation (simple diagnosis required). Response might be direct execution of simple actions or initiating other actions separately assessed.	0,0004
Identification of situation requiring interpretation of complex pattern of alarms/indications. [Note that the response component should be evaluated as a separate GTT)	0,2
Communication	
Verbal Communication of Safety-Critical Data.	0,006

APPENDIX E - SIMPLIFIED THERP TABLES

Source: Swain and Guttmann (1983)

Initial-screening model of estimated HEPs and EFS for diagnosis within time T by control room personnel of abnormal events annunciated closely in time. **20-1**

T in minutes after T=0	HEP for diagnosis for single or first event	Error factor (EF)
1	1	1
10	0.5	5
20	0.1	10
30	0.01	10
60	0.001	10
1500	0.0001	30
	HEP for diagnosis for second event	
1	1	1
10	1	1
20	0.5	5
30	0.1	10
40	0.01	10
70	0.001	10
1510	0.0001	30

Nominal model of estimated HEPs and EFs for diagnosis within time T by control room personnel of abnormal events annunciated closely in time. **20-3**

T in minutes after T=0	HEP for diagnosis for single or first event	Error factor (EF)
1	1	1
10	0.1	10
20	0.01	10
30	0.001	10
60	0.0001	10
1500	0.00001	30
	HEP for diagnosis for second event	
1	1	--
10	1	--
20	0.1	10
30	0.01	10
40	0.001	10
70	0.0001	10
1510	0.00001	30
	HEP for diagnosis for third event	
1	1	--
10	1	--
20	1	--
30	0.1	10
40	0.01	10
50	0.001	10
80	0.0001	30
1520	0.00001	30

Estimated HEP per item (or perceptual unit) in preparation of written material.			**20-5**
	HEP	EF	
Omitting a step or important instruction from a formal or ad hoc procedure or a tag from a set of tags	0.003	5	
Omitting a step or important instruction from written notes taken in response to oral instructions	0	--	
Writing an item incorrectly in a formal or ad hoc procedure or on a tag	0.003	5	
Writing an item incorrectly in written notes made in response to oral instructions	0	--	

Initial-screening model of estimated HEPs and EFs for rule-based actions by control room personnel after diagnosis of an abnormal event.			**20-2**
Failure to perform rule-based actions correctly when written procedures are available and used:	HEP	EF	
Errors per critical step without recovery factors	0.05	10	
Errors per critical step with recovery factors	0.025	10	
Failure to perform rule-based actions correctly when written procedures are not available or used:			
Errors per critical step with or without recovery factors	1	1	

Estimated HEPs related to failure of administrative control.			**20-6**
	HEP	EF	
Carry out a plant policy or scheduled tasks such as periodic tests or maintenance performed weekly, monthly, or at longer intervals	0.01	5	
Initiate a scheduled swiftly checking or inspection function	0.001	3	
Use written operations procedures under normal operating conditions	0.01	3	
Use written operations procedures abnormal operating conditions	0.005	10	
Use a valve change or restoration list	0.01	3	
Use written test or calibration procedures	0.05	5	
Use written maintenance procedures	0.3	5	
Use a checklist properly	0.5	5	

Estimated probabilities of errors of omission per item of instruction when use of written procedures is specified. 20-7

When procedures with checkoff, provisions are correctly used	HEP	EF
Short list: less than 10 items	0.001	3
Long list: more than 10 items	0.003	3
When procedures without checkoff provisions are used, or when checkoff provisions are incorrectly used		
Short list: less than 10 items	0.003	3
Long list: more then 10 items	0.01	3
When written procedures are available and should be used but are not used	0.05	5

HEPs as a function of number of items to be remembered. 20-8

Number of Oral Instruction Items or Perceptual Units	Pr[F] to recall item "N, " order of recall not important		Pr[F] to recall all items, order of recall not important		Pr[F] to recall all items, order of recall is important	
			Oral instructions are detailed:			
	HEP	EF	HEP	EF	HEP	EF
1	0.001	3	0.001	5	0.001	3
2	0.003	3	0.004	5	0.006	3
3	0.01	3	0.02	5	0.03	5
4	0.3	3	0.04	5	0.1	5
5	0.1	3	0.2	5	0.4	5
			Oral instructions are general:			
1	0.001	3	0.001	3	0.001	3
2	0.006	3	0.007	3	0.01	3
3	0.02	5	0.3	5	0.06	5
4	0.6	5	0.9	5	0.2	5
5	0.2	5	0.3	5	0.7	5

Estimated probabilities of errors in selecting unannunciated displays for quantitative or qualitative readings.			**20-9**
Selection of Wrong Display:	HEP	EF	
when it is dissimilar to adjacent displays	0	--	
from similar-appearing displays when they are on a panel with clearly drawn mimic lines that include the displays	0.0005	10	
from similar-appearing displays that are part of well-delineated functional groups on a panel	0.001	3	
from an array of similar-appearing displays identified by labels only	0.003	3	

Estimated HEPs for errors of commission in reading and recording quantitative information from unannunciated displays.				**20-10**
Display or Task:	HEP	EF	High stress HEP	
Analog meter	0.003	3	0.03	
Digital readout with less than 4 digits	0.001	3	0.01	
Chart recorder	0.006	3	0.06	
Printing recorder with large number of parameters	0.05	5	0.5	
Graphs	0.01	3	0.1	
Values from indicator lamps that are used as quantitative displays	0.001	3	0.01	
Recognize that an instrument being read is jammed, if there are no indicators alert the user	0.1	5	1	
Recording task:				
Number of digits or letters to be recorded less than 3	0	--	0	
Number of digits or letters to be recorded more then 3	0.001	3	0,01	
Simple arithmetic calculations with or without calculators	0.01	3	0.1	
Detect out-of-range arithmetic calculations	0.05	5	0.5	

Estimated HEPs for errors of commission in check-reading displays.		**20-11**
Display or Task:	HEP	EF
Digital indicators (these must be read - there is no true check-reading function for digital displays)	0.001	3
Analog meters:		
with easily seen limit marks	0.001	3
with difficult-to-see limitmarks, such as scribe-to-see lines	0.002	3
without limit marks	0.003	3
Analog-type chart recorders:		
with limit marks	0.002	3
without limit marks	0.006	3
Confirming a status change on a status lamp	0	--
Misinterpreting the indication on the indicator lamps	0	--

Estimated probabilities of errors of commission in operating manual controls.		**20-12**
Potential Errors.	HEP	EF
Select wrong control on a panel from an array of similar-appearing controls		
identified by labels only	0.003	3
arranged in well-delineated functional groups	0.001	3
which are part of a well-defined mimic layout	0.0005	10
Turn rotary control in wrong direction (for two positions switches		
when there is no violation of populational stereotypes	0.0005	10
when design violates a strong populational stereotype and rating conditions are normal	0.05	5
when design violates a strong populational stereotype and operation is under high stress	0.5	5
Turn a two-position switch in wrong direction or leave it in the wrong way leave it in the wrong setting		
Set a rotary control to an incorrect setting (for two-positions switches)	0.001	10
Failure to complete change of state a component if switch must be held until change is completed	0.003	3
Select wrong circuit breaker in a group of circuit breakers		
densely grouped and identified by labels only	0.005	3
in which the PSFs are more favorable	0.003	3
Improperly mate a connector (this includes failures to seat connectors completely and failure to test locking features of connectors for engagement)	0.003	3

Modifications of estimated HEPs for the effects of stress and experience levels.					**20-16**
Stress Level			HEP Skilled/Novice	Modifiers for Nominal HEPs	
Extreme high	Threat stress	Dynamic	0.25/0.5 EF =5	Skilled	Novice
		Step-by-step		5	10
Moderately high	Heavy task load	Dynamic		5	10
		Step-by-step		2	4
Optimum	Optimum task load	Dynamic		1	2
		Step-by-step		1	1
Very low	Very low task load			2	2
			Skilled = 6 months or more		

Estimated HEPs in detecting stuck locally operated valves.			**20-14**
Potential Errors	HEP	EF	
Given that a locally operated valve sticks as it is being changed or restored, the operator fails to notice the sticking valve, when it has			
A position indicator only	0.001	3	
A position indicator and a rising stem	0.002	3	
A rising stem but no position indicator	0.005	3	
Neither rising stem nor position indicator	0.01	3	

Estimated HEPs for selection errors for locally operated valves.			**20-13**
Potential Errors:	HEP	EF	
Making an error of selection in changing or restoring a locally operated valve when the valve to be manipulated is:			
Clearly and unambiguously labeled, set. Apart from valves that are similar in all of the following: size and shape, state, and presence of tags	0.001	3	
Clearly and unambiguously labeled, part of a group of two or more valves that are similar in one of the following: size and shape, state, or presence of tags	0.003	3	
Unclearly or ambiguously labeled, set apart from valves that are similar in all of the' following: size and shape, state, and presence of tags	0.005	3	
Unclearly or ambiguously labeled, part of a group of two or more valves that are similar in one of the following: size and shape, state, or presence of tags	0.008	3	
Unclearly or ambiguously labeled, part of a group of two or more valves that are similar in all of the following: size and shape, state, and presence of tags	0.01	3	

Estimated probabilities that the basic walk-around inspection* will fail to detect a particular deviant indication of equipment outside the control room within 30 days.		**20-27**
Number of days between walk-arounds per inspector	Cumulated probability of failure within 30 days given on inspection per shift Pr[F]	
1 (daily walk-around for each inspector)	0.52	
2	0.25	
3	0.05	
4	0.003	
5	0.0002	
6	0.0001	
7 (weekly walk-around for each inspector)	0.0001	

Estimated HEPs for annunciated legend lights.			**20-24**
Task	**HEP**	**EF**	
Respond to one or more annunciated legend lights	See Table 20-23		
Resume attention to a legend light within 1 minute after an interruption (sound and blinking cancelled before interruption)	0.001	3	
Respond to a legend light if more than 1 minute elapses after an interruption (sound and blinking cancelled before interruption)	0.95	5	
Respond to a steady-on legend light during initial audit	0.90	5	
Respond to a steady-on legend light during other hourly scans	0.95	5	

The Annunciator Response. Model: estimated HEPs for multiple annunciators alarming closely in time											**20-23**
	HEP are for the failure to initiate some kind of intended corrective action as required. For each completely dependent set successively addressed by the operator.										
Number of alarms of n alarms	1	2	3	4	5	6	7	8	9	10	HEP
1	0.0001										0.0001
2	0.0001	0.001									0.0006
3	0.0001	0.001	0.002								0.001
4	0.0001	0.001	0.002	0.004							0.002
5	0.0001	0.001	0.002	0.004	0.008						0.003
6	0.0001	0.001	0.002	0.004	0.008	0.016					0.005
7	0.0001	0.001	0.002	0.004	0.008	0.016	0.032				0.009
8	0.0001	0.001	0.002	0.004	0.008	0.016	0.032	0.064			0.02
9	0.0001	0.001	0.002	0.004	0.008	0.016	0.032	0.064	0.13		0.03
10	0.0001	0.001	0.002	0.004	0.008	0.016	0.032	0.064	0.13	0.25	0.05
11 - 15											0.1
16 - 20											0.15
21 - 40											0.2
> 40											0.25

Appendix F - The PSFs in SPAR-H, levels for these PSFs

Source: Whaley et al. (2012)

PSF	PSF Levels
Available time	*Inadequate Time* - the time margin is negative because less time is available than is required. *Barely Adequate Time* - the time margin is zero because the time available equals the time required. *Nominal Time* - there is a small-time margin because the time available is slightly greater than the time required. *Extra Time* the time margin is greater than zero but less than the time required; the time available is greater than the time required. *Expansive Time* - the time margin exceeds the time required; the time available is much greater than the time required.
Stress/Stressors	*Extreme* - a level of disruptive stress in which the performance of most people will deteriorate drastically, the so-called stress performance cliff. This is likely to occur when the onset of the stressor is sudden and the stressing situation persists for long periods. This level is also associated with the feeling of threat to one's physical well-being, self-esteem, or professional status, and is considered to be qualitatively different from lesser degrees of high stress (e.g., catastrophic failures can result in extreme stress for operating personnel because of the potential for radioactive release). *High* -a level of stress higher than the nominal level (e.g., instruments with anomalous readings or unexpected alarms; loud, continuous noise impacts ability to focus attention on the task; the consequences of the task represent a threat to plant safety). This level basically encompasses any situation where there is a perceived threat that can result in significant health or financial consequences. *Nominal*—the level of stress that is conducive to good performance. Also, this level should be assigned whenever stress is judged to not be a performance driver.
Complexity	*Highly Complex* - very difficult to perform. There is much ambiguity in what needs to be diagnosed or executed. Many variables are involved, with concurrent diagnoses (or actions). *Moderately Complex* -somewhat difficult to perform. There is some ambiguity in what needs to be diagnosed or executed. Several variables are involved, perhaps with some concurrent diagnoses (or actions). backup power supplies. *Nominal* - not difficult to perform. There is little ambiguity. An easily managed number of variables or inputs are involved. The organization of information or execution of steps is relatively straightforward with little potential for confusion. Also, nominal should be chosen when this PSF is judged as not being a performance driver.
Experience/Training	*Low* less than 6 months of relevant experience and/or training. This level of experience/training does not provide the level of knowledge and deep understanding required to adequately perform the required tasks, does not provide adequate practice in those tasks, or does not expose individuals to various abnormal conditions. *Nominal* - more than 6 months of relevant experience and/ or training. This level of experience/training provides an adequate amount of formal schooling and instruction to ensure that individuals are proficient in day-to-day operations and have been exposed to abnormal conditions. Also, this level should be assigned if the analyst judges Experience/Training to not be a performance driver. *High* - extensive experience; a demonstrated master. This level of experience/training provides operators with extensive knowledge and practice in a wide range of potential scenarios. Good training makes operators well prepared for possible situations.

Procedures	*Not Available* - the procedure needed for a particular task or tasks in the event is not available. However, this level should be used only if the analyst judges that the lack of procedures materially affects the error probability. If the analyst judges the Procedures PSF not to be a performance driver, then the Nominal level should be selected even though procedures might not be available. *Incomplete* - information is needed that is not contained in the procedure or procedure sections; sections or task instructions (or other needed information) are absent. *Available but Poor* - a procedure is available but it is difficult to use because of factors such as formatting problems, ambiguity, or such a lack in consistency that it impedes performance. This also includes procedures that are poorly designed, such as an important step being buried too deep within the procedure for operators to reach it in a timely manner. *Nominal* - procedures are available and enhance performance, or judged as not a performance driver.
Ergonomics/HMI	*Missing/Misleading* - the required instrumentation fails to support Diagnosis or post Diagnosis behavior, or the instrumentation is inaccurate (i.e., misleading). Required information is not available from any source (e.g., instrumentation is historically so unreliable that operators ignore the instrument, even if it is registering correctly at the time). Note that this PSF level also includes failed and faulty instrumentation and indications. *Poor* - the design of the plant negatively impacts task performance (e.g., poor labeling, needed instrumentation cannot be seen from a work station where control inputs are made, or poor computer interfaces). *Nominal* - the design of the plant supports correct performance, but does not enhance performance or make tasks easier to carry out than typically expected (e.g., operators are provided useful labels; the computer interface is adequate and learnable, although not easy to use). Again, as with all PSFs, the nominal level should be assigned whenever the analyst judges the PSF as not a performance driver. *Good* -the design of the plant positively impacts task performance, providing needed information and the ability to carry out tasks in such a way that lessens the opportunities for error (e.g., easy to see, use, and understand computer interfaces; instrumentation is readable from workstation location, with measurements provided in the appropriate units of measure).
Fitness for Duty	*Unfit* - the individual is unable to carry out the required tasks, due to illness or other physical or mental incapacitation (e.g., having an incapacitating stroke). *Degraded Fitness* - the individual is able to carry out the tasks, although performance is negatively affected. Mental and physical performance can be affected if an individual is ill, such as having a fever. Individuals can also exhibit degraded performance if they are inappropriately overconfident in their abilities to perform. Other examples of degraded fitness include experiencing fatigue from long duty hours; taking cold medicine that leaves the individual drowsy and inattentive; or being distracted by personal bad news (such as news of a terminal illness diagnosis of a loved one). *Nominal* - the individual is able to carry out tasks; no known performance degradation is observed. Nominal should also be used when the analyst judges the PSF as not a performance driver.
Work Processes	*Poor* - performance is negatively affected by the work processes at the plant (e.g., shift turnover does not include adequate communication about ongoing maintenance activities; poor command and control by supervisor(s); performance expectations are not made clear). *Nominal* - performance is not significantly affected by work processes at the plant, or work processes do not appear to play an important role (e.g., crew performance is adequate; information is available, but not necessarily proactively communicated). The analyst should select nominal when the PSF is judged as not a performance driver. *Good* - work processes employed at the plant enhance performance and lead to a more successful outcome than would be the case if work processes were not well implemented and supportive (e.g., good communication; well-understood and supportive policies; cohesive crew).

Appendix G - The PSFs in Petro-HRA, levels for these PSFs

Source: Bye et al. (2017)

PSF	PSF Levels
Time	*Extremely high negative effect on performance* - Operator(s) does not have enough time to successfully complete the task. *Very high negative effect on performance* - The available time is the minimum time required to perform the task or close to the minimum time to perform the task. In this situation the operator(s) has very high time pressure or they have to speed up very much to do the task in time. *Moderate negative effect on performance* - The operator(s) has limited time to perform the task. However, there is more time available than the minimum time required. In this situation the operator(s) has high time pressure, or they have to speed up much to do the task in time. *Nominal effect on performance* - There is enough time to do the task. The operator(s) only has a low degree of time pressure, or they do not need to speed up much to do the task. When comparing the available time to the required time the analyst concludes that time would neither have a negative nor a positive effect on performance. *Moderate positive effect on performance* - There is extra time to perform the task. In this situation the operator(s) has considerable extra time to perform the task and there is no time pressure or need to speed up to do the task in time. *Not applicable* -This PSF is not relevant for this task or scenario.
Threat stress	*High negative effect on performance* -The operator(s) experiences very high threat stress. In this situation the operator's own or other person's life is in immediate danger. *Low negative effect on performance* - The operator(s) experiences moderate threat stress. The operator experiences that there is a threat to their own or others' personal safety or a very high threat to self-esteem or professional status. *Very low negative effect on performance* - The operator(s) experiences some threat stress. The operators experience some threat to their self-esteem or professional status. *Nominal effect on performance* - Operator(s) does not experience threat stress. Threat stress has not a negative effect on performance. *Not applicable* - This PSF is not relevant for this task or scenario.

Task Complexity	*Very high negative effect on performance* - The task contains highly complex steps. One or several of the complexity categories are present and influence performance very negatively. *Moderate negative effect on performance* - The task is moderately complex. One or several of the complexity categories are present and influence performance negatively. *Very low negative effect on performance* - The task is to some degree complex. One or several of the complexity categories are to some degree present and are expected to have a low negative effect on performance. *Nominal effect on performance* - The task is not very complex and task complexity does not affect operator performance. Task complexity has neither a negative nor a positive effect on performance. *Low positive effect on performance* - The task is greatly simplified and the problem is so obvious that it would be difficult for an operator to misdiagnose it. E.g., detecting a single alarm, or sensory information such as clear visual and auditory cues. *Not applicable* - This PSF is not relevant for this task or scenario.
Experience/Training	*Extremely high negative effect on performance* - There is a strongly learned knowledge or skill (either from experience or training) that is a mismatch with the correct response to this task step in this scenario. An example could be that the operator(s) during experience or training has developed a strong mindset about the development of a scenario and actions that do not fit with the scenario in question and therefore cannot be expected to perform the task correctly. *Very high negative effect on performance* - The operator(s) does not have any experience or training and does not at all have the necessary knowledge and skills to be prepared for and to do the task(s) in this scenario. *Moderate negative effect on performance* - The operator(s) has low experience or training and does not have the necessary complete knowledge and experience to be prepared for and to do the task(s) in this scenario. *Low negative effect on performance* - The operator(s) has experience or training but this is lacking, and they do not have the complete knowledge and experience to be fully prepared for and to do the task(s) in this scenario. *Nominal effect on performance* - The operator(s) has experience and/or training on the task(s) in this scenario and has the necessary knowledge and experience to be prepared for and to do the task(s) in this scenario. Experience/Training does not reduce performance nor to a large degree improve performance. *Moderate positive effect on performance* - The operator(s) has extensive experience and/or training on this task and the operator(s) has extensive knowledge and experience to be prepared for and to do the task(s) in this scenario. *Not applicable* - This PSF is not relevant for this task or scenario.

Procedures	*Very high negative effect on performance.* - No procedures available or the procedures are not used during the scenario or training. This level should also be used if the procedures are strongly misleading in such a way that they are not helpful for the operator(s). *High negative effect on performance* -The procedure lacks steps and important information that is needed to do the task or the procedures are briefly used during scenario or training. An example could be that they are briefly looked at in the beginning of the scenario. This level should also be used if the procedures themselves are highly complex or it is very difficult for the operators to navigate between different procedures *Low negative effect on performance* - The procedures are complete but there are some problems (formatting, language, structure) with the procedures or the procedures are not followed in an optimal way. This level should also be used if the procedures are complex (e.g., revealed through interviews) or if there are some problems to navigate between different procedures *Nominal effect on performance* - The quality of the procedures is adequate and they are followed. The quality of procedures does not affect performance either positively or negatively. *Low positive effect on performance* - Procedures are exceptionally well developed, they are followed, and they enhance performance. *Not applicable* - This PSF is not relevant for this task or scenario.
Human-Machine Interface	*Extremely high negative effect on performance* - A situation where it is not reasonable to assume that the operator/crew will be successful in carrying out the task. An example of this would be a situation where the HMI does not provide the operator/crew with the required information or possibility to perform the task. Alternatively, the information provided is misleading to the extent that the operator will not correctly carry out the task. *Very high negative effect on performance* -The HMI causes major problems in either obtaining relevant information or carrying out the task. For example, the HMI is not designed for the task leading to a difficult work-around, some of the relevant information required for a reliable decision is not made available or, the inter-page navigation creates severe difficulties in obtaining the relevant information or carrying out the task. *Moderate negative effect on performance* - The HMI causes some problems in either obtaining relevant information or carrying out the task. For example, the HMI does not conform to the stereotypes the operators are used to (e.g., icons, colors, and intuitive placements) or, several page changes in the inter-page navigation increases the difficulty in obtaining the required information or carrying out the task. *Nominal effect on performance* - While the HMI is not specifically designed for making the human performance as reliable as possible for this task/tasks of this type, it corresponds to the stereotypes held by the operators. All of the safety critical information is easy available and no HMI related issues are interfering with carrying out the task. HMI does not reduce performance nor to a large degree improve performance. *Low positive effect on performance* - The HMI is specifically designed to make human performance as reliable as possible in this task/tasks of this type. *Not applicable* - This PSF is not relevant for this task or scenario.

Attitudes to Safety, Work and Management Support	*Very high negative effect on performance*- In this situation safety is not at all prioritized over other concerns when it is appropriate or there are extremely negative attitudes to work conduct (for example the operators are not monitoring or awake when they should be). There is very low mindfulness about safety. The operators do not experience management support, for example in strong management pressure for production even if safety is clearly in question. *Moderate negative effect on performance* - In this situation it is not specified by management that safety should be prioritized when that is appropriate. The operators are uncertain if safety should be prioritized or not, or the operators are uncertain about rules and regulations that are important for performing the task. *Nominal effect on performance* - The operators have adequate attitudes to safety and work conduct and there is management support to prioritize safety when that is appropriate. The operator(s) shows mindfulness about safety. Attitudes to safety, work and management support have neither a negative nor a large positive effect on performance. *Moderate positive effect on performance* - The operator(s) has very good attitudes to safety and work conduct and there is explicit management support to prioritize safety when that is appropriate. The operator(s) shows a very high degree of mindfulness about safety. *Not applicable* - This PSF is not relevant for this task or scenario.
Teamwork	*Very high negative effect on performance* - The teamwork is very poor on one or several teamwork factors that have been identified as important for the performance of the task or scenario in question. *Moderately negative effect on performance* -The teamwork is poor on one or several teamwork factors that have been identified as important for the performance of the task or scenario in question. *Very low negative effect on performance* - The teamwork is to some degree poor on one or several teamwork factors that have been identified as important for the performance of the task or scenario in question. *Nominal effect on performance* - The teamwork is adequate on one or several teamwork factors that have been identified as important for the performance of the task or scenario in question. Teamwork has neither a negative nor a large positive effect on performance. *Low positive effect on performance* - The team is very good on one or more teamwork factors that have been identified as important for the task(s) or scenario in question and teamwork increase performance. *Not applicable* - This PSF is not relevant for this task or scenario.
Physical Working Environment	*Extremely high negative effect on performance* - The task cannot be completed due to the tools required or the area in question being inaccessible or unavailable. *Moderate negative effect on performance* - There are clear ergonomic challenges in completing the task. This could be due to the area where work is conducted being hard to reach, the manual field activation is difficult or physically demanding, or there are extreme weather conditions that decrease performance. *Nominal effect on performance* - Physical working environment does not have an effect on performance. *Not applicable* - This PSF is not relevant for this task or scenario.