Mapping of Process Hazard Analyses in Swedish Process Industries and How the Work Can Be Improved

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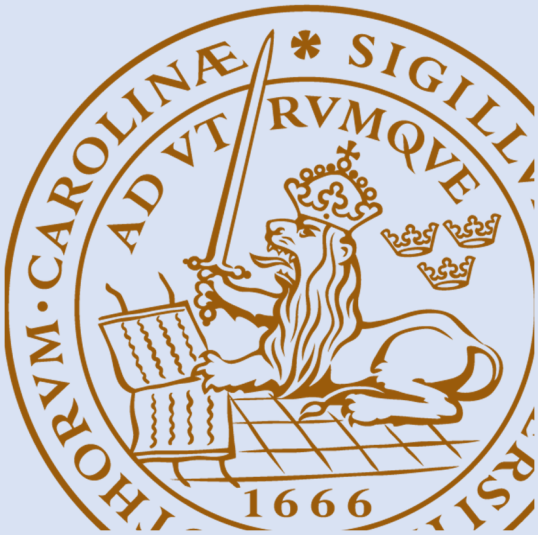

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Abstract
This study aims to map how Swedish process industries use qualitative risk analyses, such as process hazard analyses (PHA), to assess risks. Beyond the Seveso legislation, which requires all facilities classified as upper tier to perform a safety report each fifth years, there are no Swedish legislation or regulations regarding how and when PHAs should be executed. Hence, Swedish process industries are allowed to perform their risk assessments in several ways. Based on this, the objective of this study is to map how Swedish process industries work with PHAs and identify potential improvements. The improvements were identified based on Swedish process industries' thoughts and lessons learned from the Norwegian Oil and Gas (O&G) industry. The Norwegian O&G industry was used as a reference since it has been characterized by large disasters which have resulted in extensive resources spent on performing risk assessments. Semi-structured in-depth interviews of representatives from Swedish process industries and safety experts working within the Norwegian O&G industry formed the basis of the methodology. The study identifies preliminary hazard analysis, Hazard and Operability (HAZOP) study, and What-If as the most common PHA methods within the Swedish process industry. These analyses are mainly performed for modifications of existing facilities, for new designs, or as part of the Seveso safety report. The analyses intend to identify safety improvements of proposed or existing designs. The main lesson learned from the Norwegian O&G industry is described as working in a structured and synchronized way within the companies through all steps of the risk assessments.

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Summary

Process industries are characterized by extensive risks which makes risk management central in these organizations. According to ISO 31000 (2018), the risk management process can be divided into three steps. Firstly, decide the extent, conditions, and criteria, secondly, perform the risk assessment based on the first step, and finally, define measures based on the risk assessment. The risk assessment consists of risk identification, risk analysis, and risk evaluation (ISO 31000, 2018). It can be performed in various ways, quantitatively and qualitatively, and with different purposes. Qualitative risk assessments are usually performed as Process Hazard Analyses (PHA) which focus on all three stages of the risk assessment. PHAs are used as part of the Seveso safety report, which is required for all companies with large inventories of hazardous substances, according to the Swedish Seveso legislation. Beyond, the Seveso legislation, there are however no Swedish laws for how and when PHAs should be performed. Hence, the purpose of this study is to identify to what extent and in which way Swedish process industries use PHAs.

The study also aims to identify how the use of PHAs could be improved. This was mainly done by identifying lessons learned from the Norwegian Oil and Gas (O&G) industry which could be applicable to Swedish process industries. The Norwegian O&G industry has a long history of risk management and has been characterized by considerable disasters. These disasters had significant effects on the safety within the Norwegian continental shelf (Midttun, 2020) and today the safety work within the Norwegian O&G industry is extensive and a central part of the industry (Ryggvik, 2015). Consequently, extensive resources are spent on performing risk assessments, which makes it a suitable industry to benchmark the Swedish process industries against.

The study methodology is based on semi-structured in-depth interviews and analyses of the answers. Employees with positions related to risk management in several Swedish process industries and safety experts working within the Norwegian O&G industry were interviewed. The study was initiated by a selection of possible Swedish process industries to contact. For the Norwegian O&G part of the study, consultants from ORS Consulting with extensive experience within the industry, were selected. Interviews were scheduled with each of the companies interested to participate in the study and after the interviews, all answers were compiled and analysed. The interviews of participants working within the Norwegian O&G industry were based on the answers from the Swedish interviews, as the focus was limited to identifying applicable lessons learned rather than performing a survey of the Norwegian O&G industry.

Preliminary hazard analysis, Hazard and Operability (HAZOP) study, and What-If is identified as the most common PHA methods within the Swedish process industries. Using Hazard Identification (HAZID) rather than What-If is described, based on the Norwegian interviews, as more beneficial due to the comprehensiveness and traceability of the method. Layer of Protection Analysis (LOPA) is identified as the most common barrier analysis.

However, other barrier analyses such as Failure Mode and Effects Analysis (FMEA) and bowtie are used to a lower extent.

PHAs are mainly performed for modifications to existing facilities, for new designs, or as part of the Seveso safety report. The main reasons for performing PHAs are to achieve safe facilities and secondary to meet legislative requirements. This is done by identifying safety improvements to the proposed or existing design, which are recorded as actions. However, the results of the PHAs are in general not used for other fields such as health or environment.

The main lesson learned, identified from the Norwegian O&G industry, is to work with PHAs in a standardized and synchronized way within the companies. This includes having guidelines for all parts of the risk assessment, including choosing the type of PHA method, how to perform the analyses, and how the results should be handled. Working in a standardized and synchronized way is also identified as an area of improvement by the Swedish process industries and highlighted as important by multiple standards such as the ISO 31000 (2018) guideline for risk management.

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List of Acronyms

EPSC	European Process Safety Centre
FMEA	Failure Mode Effect Analysis
FTA	Fault Tree Analysis
HAZID	Hazard Identification
HAZOP	Hazard and Operability
IPS	Swe. Intresseföreningen för Processäkerhet
NCS	Norwegian Continental Shelf
AEA	Action Error Analysis
HRA	Human Reliability Analysis
IPS	Swe. Intresseföreningen för Processäkerhet
SFS	Swe. Svensk författningssamling
MA	Major Accident
MAPP	Major Accident Prevention Policy
MAHB	Major Accident Hazards Bureau Security Technology Assessment Unit
LOPA	Layer of Protection Analysis
PHA	Process Hazard Analysis
SMS	Safety Management System
ORS	ORS Consulting
O&G	Oil and Gas
QRA	Qualitative Risk Assessment

1 Introduction

Risk analyses can be performed in multiple ways, either qualitatively or quantitatively, and thus with different purposes. For Quantitative Risk Assessments (QRA) there is no Swedish legislation regarding how and when QRAs should be performed (Nassiri, Bergstrand, & Lindblom, 2021). This is also the case for qualitative risk assessments, such as Process Hazard Analyses (PHAs). Based on the Seveso directive (2012/18/EU) all facilities, classified as upper tier, must perform a safety report every fifth years including the main risk factors, risks for surroundings, and prevention and mitigation measures. But beyond the Seveso legislation there are no legislation or regulations for how and when PHAs should be performed. This could be dangerous as vague requirements and guidelines increase the variation of extensiveness and quality of risk assessments, which affects the reliability of the studies (Ingvarson, 2020). However, as companies have own incentives for analysing risks, e.g., to have safe workplaces, risks are analysed at sites as a basis for decision making and improving safety. Due to the somewhat unclear Swedish legislation and regulations, this study aims to map how Swedish process industries work with PHAs and identify areas of improvement.

The study also includes a comparison with the Norwegian Oil and Gas (O&G) industry to identify lessons learned which could be applicable to the Swedish process industry. The Norwegian O&G industry has a long history of risk management and has been characterized by large disasters such as when the Alexander L Kiellan capsized in 1980. The Kielland disaster had a significant effect on the safety within the Norwegian Continental Shelf (NCS), primarily concerning regulations, authorities, and company responsibilities (Midttun, 2020). The safety work within the industry is today extensive and a central part (Ryggvik, 2015). The risk management is embossed of extensive risks affecting both the safety of employees, the environment, and assets (Brandsæter, 2002). Therefore, extensive resources are spent on performing risk assessments. Based on the author's personal experience as scribe during several qualitative risk assessments within the Norwegian O&G industry, there was a curiosity of how Swedish process industries work with qualitative risk assessments. This curiosity also included an investigation of whether it is possible to share experiences between the Norwegian O&G industry and the Swedish process industry.

1.1 Objectives and Research Questions

The objectives of the study are to identify how Swedish process industries work with qualitative risk assessments, especially PHAs, and identify applicable lessons learned from the Norwegian O&G industry. Ideally, Swedish process industries will get inspiration from this study which can help them improve the risk management at their sites. The study also contributes scientifically by providing additional perspectives on how PHAs are performed in practice among Swedish process industries. To achieve the study objectives, the following key questions are assessed:

- Which PHA methods are used by Swedish process industries?
- How and when are the PHAs performed and what are the reasons for performing them?
- How are the results from the PHAs used in the organisation?

- How can methods and lessons learned from the Norwegian O&G industry be applied in Swedish process industries?

1.2 Limitations

Only facilities classified as upper tier according to the Seveso legislation are included in the study. Facilities classified as lower tier are not covered as they are not exposed to the same magnitudes of risks. Since the study refers to the Norwegian O&G industry, it is important that the gap between the extensiveness of hazards is limited. Input from all upper tier facilities was however not possible as the study was limited in terms of time and depending on companies´ interests to participate. As the study aims to include a representative picture of process industries in Sweden, companies of several sizes, ages, and sectors are covered. The nuclear industry, food industry, and pharmaceutical industry are excluded from the study as they generally work under different legislation and standards. Based on this, it is important to keep in mind that this study reflects how PHAs are used in Swedish process industries, which may not be applicable for all upper tier facilities in Sweden.

The study is limited to addressing qualitative risk assessments focusing on process risks and process safety. In this study process safety is defined as per the EPSC guideline *Process Safety Fundamentals* (2021), which defines process safety as "avoiding loss of containment". Hence, the focus is on avoiding loss of containment which could harm people, environment, and assets, rather than focusing on for example working environmental risks. To limit the extensiveness of the study and focus on the author's practical experiences with PHAs, QRA is excluded from the study. However, methods with quantitative and qualitative interphases, such as Layer of Protection Analysis (LOPA), Fault Tree Analysis (FTA), or similar methods, are included. The study also aims to focus on organisational and structural factors affecting how PHAs are performed. Meaning that outside factors such as type of PHA method, timing of PHAs and handling of results are covered rather than details about for instance human behaviour related to PHAs.

2 Background

The following sections aim to provide a theoretical background to the study. This includes information about the Swedish legislation and regulations associated with the topic, methods defined as PHA and factors affecting the quality of PHAs.

2.1 Legislation

During the 1970s many severe process safety incidents happened in Europe, including the Seveso disaster in 1976. This came to be the triggering factor of the European safety law for sites with large amounts of hazardous substances, and thus the name Seveso directive (European Commission, 2022). The objectives of the Seveso directive are to prevent and mitigate the consequences of chemical accidents. Hence, it requires that all sites, classified as upper tier, perform a safety report explaining how their Major Accident Prevention Policy (MAPP) has been implemented with help of a Safety Management System (SMS) for preventing chemical accidents. The MAPP should be supported by the SMS, and amongst others include procedures to systematically identify and evaluate hazards, as well as preventing and mitigating measures (Mcdonald, 2004). The Seveso directive applies to all countries in the EU, but also Norway by the EEA agreement. Each country secures that its legislation is following the directive (The Swedish Environmental Protection Agency, 2022). Thus, differences may exist in how the Seveso directive is implemented in several countries.

The Seveso directive is for instance included in the legislation (1999:381) about measures to prevent and mitigate consequences of serious chemical accidents, but it is not the only legislation putting pressure on companies to conduct risk assessments. Table 2-1 summarizes the main Swedish legislation and regulations that require qualitative risk assessments to be performed. This is expressed by statements claiming that the affected companies should analyse risks (Karlsson & Käck, 2018). However, there are no rules regarding which PHA methods should be used and when.

Table 2-1 Overview of Swedish legislation and regulations, but not limited to process risks

Type	SFS-number	Name (Swe.)	Description
Legislation	1998:808	Miljöbalk	The Swedish Environmental Code
Legislation	2003:778	Lagen om skydd mot olyckor	The legislation about protection against accidents
Legislation	2010:1011	Lag om brandfarliga och explosive varor	The legislation about flammable and explosive goods
Regulation	AFS 2011:19	Kemiska arbetsmiljörisker	Chemical work environment risks
Regulation	AFS 2001:1	Systematiskt Arbetsmiljöarbete	Systematic work environment management
Regulation	AFS 2015:18	Organisatorisk och social arbetsmiljö	Organizational and social work environment
Regulation	AFS 2017:3	Användning och kontroll av trycksatta anordningar	Use and control of pressurized contrivances
Regulation	AFS 2003:3	Arbete i explosiv och farlig miljö	Working in an explosive and dangerous environment

Regulation	1998:899	Miljöfarlig verksamhet och hälsoskydd	Environmentally hazardous activities and health protection
Regulation	2003:789	Skydd mot olyckor	Protection against accidents
Regulation	SRVFS 2004:7	Explosionsfarlig miljö vid hantering av brandfarliga gaser och vätskor	Explosive environment when handling flammable gases and liquids
Regulation	SIÄFS 2000:2	Hantering av brandfarliga vätskor	Management of flammable liquids
Regulation	1998:901	Förordning om verksamhetsutövarens egenkontroll	Regulation about the operator's self-monitoring

Suggested risk assessments for meeting the legislation and regulations are presented in IPS's guidance for risk assessments (Karlsson & Käck, 2018). For most legislation and regulations presented in Table 2-1 a preliminary hazard analysis followed by a detailed analysis such as a Hazard and Operability (HAZOP) study or What-If study, and checklists during normal operation are suggested (Karlsson & Käck, 2018). But by reading the legislation and regulations, it is not possible to identify any specific PHA methods that should be used or when they should be used. What is clear is the legal responsibility, as the legislation holds the owner of the facility as the main responsible person (Karlsson & Käck, 2018). In addition to the legislation and regulations presented in Table 2-1, there are several directives requiring certain analyses to be performed, e.g., the Machine directive (2006/42/EC) which is crucial for CE marking. Harmonised standards, such as the ISO guideline for risk management (ISO 31000, 2018) can also be used as a basis for performing risk assessment, but they are not requirements as such.

2.2 Process Hazard Analysis

One way to meet the Swedish legislation regarding analysing risks is to perform PHAs. The objectives of PHAs are to identify hazardous scenarios, before they occur and evaluate if there are enough safeguards in place, and if not suggest actions for improvement (European Commission (MAHB), 2020). The identified scenarios are addressing all risks from human factors to equipment failures, but on different levels depending on the applied PHA method. In general, the PHA methods are based on initiating causes, consequences, safeguards and eventual risk ranking. The main PHAs methods mentioned by Karlsson and Käck (2018) are briefly described in the following sections.

2.2.1 Preliminary Hazard Analysis

A Preliminary hazard analysis is often used early in the design phase, e.g., during concept phase, to evaluate hazards (American Institute of Chemical Engineers, 1992). Generally, it focuses on large process areas within the plant and records a list of potential hazards based on process characteristics. A preliminary hazard analysis can be performed by both experienced process safety personnel and less experienced personnel (American Institute of Chemical Engineers, 1992).

2.2.2 Hazard Identification (HAZID)

A HAZID study is a structured review methodology to identify Major Accidents (MA) such as fire, explosions, or loss of containment. This is done by identifying initiating causes, that could cause MAs and affect the selection of a concept option (ISO 17776, 2016). A HAZID shall be performed early in projects to prevent risks of MAs. HAZIDs can also be applicable for modifications to an existing process, to ensure that the modifications are not introducing any new hazards. Generally, HAZIDs are performed based on a set of guidewords, e.g., related to external impact and process hazards, which aim to stimulate brainstorming. For each guideword, the identified scenarios are recorded with a clear structure between the causes leading to the hazardous event, consequences, and safeguards. If the safeguards are not considered enough to prevent and mitigate the scenario, recommendations can be recorded (ISO 17776, 2016).

2.2.3 Hazard and Operability study (HAZOP)

Just like a HAZID, a HAZOP study is a structured review performed based on a set of guidewords. The difference is mainly on level of detail, both regarding the available documentation and identified scenarios. For each section of the system being reviewed different process deviations from the design intent are discussed to identify hazards and operating problems. A HAZOP is usually performed after a HAZID since it requires more information about the system. It is however possible to perform it both in an early stage of a project as well as during normal operation (Crawley & Tyler, 2015).

2.2.4 What-If

What-If analyses are recorded in the same way as a HAZID or a HAZOP, with causes, consequences, safeguards, and recommendations. However, the guidance to identify hazardous scenarios differs from the guidewords used for HAZIDs and HAZOPs. Typically damaging events are used to assist creative thinking (Davidsson, Haeffler, Ljundman, & Frantzich, 2003). The review can be performed during process design phase, detailed phase, and when addressing modifications, as well as during normal operation (Karlsson & Käck, 2018).

2.2.5 Failure Mode and Effect Analysis (FMEA)

FMEA is a systematic method for identifying possible failures and disturbances of components in a system, to ensure that they will not cause any problem (Davidsson, Haeffler, Ljundman, & Frantzich, 2003). Possible failure modes for equipment could for instance be open, closed, or leaks. A FMEA analysis identifies single failures which could cause direct accidents or significantly contribute to hazards (American Institute of Chemical Engineers, 1992).

The recording is similar to HAZOPs and HAZIDs, but instead of identifying causes of deviations for each node, it records potential equipment failures for each component in the system being reviewed. A FMEA should be performed as early as possible in projects to support the design review concept. However, as the analysis is suitable at a lower level of detail, it requires a more mature design (IEC 60812, 2006).

2.2.6 Layer of Protection Analysis (LOPA)

A LOPA is a type of barrier analysis for defining the Safety Integrity Level (SIL) of safety critical functions (Karlsson & Käck, 2018). For each hazardous scenario with extensive consequences, identified in a HAZOP or similar study, a barrier analysis, e.g., a LOPA, should be performed to evaluate the existing safeguards. Therefore, LOPA is performed when detailed information is available and can be applied both during design phase as well as during normal operation (Karlsson & Käck, 2018).

2.2.7 Risk Graph

The risk graph methodology is a category-based method which aims to determine the SIL of a safety-related system (IEC 61508 , 2010). Hence, the risk graph methodology has the same purpose as LOPA but is in general more simplified and based on a graphical methodology. The analysis is based on consequences of hazardous events, the frequencies of these and probabilities of avoiding the hazard, which generates several outputs. All determined outputs are mapped onto scales based on demand rates and indicates which SIL that must be achieved. A risk graph should, like the LOPA, be performed when detailed information is available, and can be applied both during design phase and operational phase (IEC 61508 , 2010).

2.2.8 Fault Tree Analysis (FTA)

A FTA is both a qualitative and quantitative risk analysis, focusing on one hazardous event and identifying possible causes and probabilities. It uses a graphical method for defining combinations of equipment failures or human errors that could cause a hazardous event, called the top event (American Institute of Chemical Engineers, 1992). As the method focuses on combinations of failures leading to one specific accident, it is suitable for systems with high redundancy. For the identification of single failures causing accidents, FMEA or HAZOP is more suitable. FTA can be performed for specific redundant scenarios identified in earlier risk assessment in the project (American Institute of Chemical Engineers, 1992).

2.2.9 Event Tree

Just like the FTA, an event tree analysis is both a qualitative and quantitative risk analysis focusing on an unwanted scenario. The difference is that the event tree is a bottom-up method meaning it is analysing the course of events following a hazardous scenario, focusing on the consequences (Davidsson, Haeffler, Ljundman, & Frantzich, 2003). However, it is still possible to use both event trees and FTAs in the same risk analysis. Event trees can be used for analysing a complex problem, with several layers of mitigating safeguards (American Institute of Chemical Engineers, 1992). It can further be used to show quantitatively, the background of qualitative evaluations (Karlsson & Käck, 2018).

2.2.10 Bowtie

A bowtie analysis is used to visualize risk, from initiating event to hazardous event and harm. It can be described as a combination of a FTA and an event tree, focusing on initiating events and on the consequence of the hazardous event (Karlsson & Käck, 2018). The method is also used to analyse the barriers in place, both considering preventing and mitigating safeguards. It can be used in different phases, from early design to normal operations due to its simplified methodology and scalability (Karlsson & Käck, 2018).

2.2.11 Checklist

Checklists are a list of common hazards that can be used to evaluate a process in terms of material, equipment, and procedures (American Institute of Chemical Engineers, 1992). It can be applied during different stages of projects, e.g., commissioning, start-up, modifications, and decommissioning (Karlsson & Käck, 2018) and as it is scalable it can be used even for the smallest changes as well as for larger projects. The overall objective of a checklist analysis is to ensure that system being reviewed is acceptable according to standards and regulations (Karlsson & Käck, 2018). The checklist should be based on the system being reviewed and not based on generic hazards (American Institute of Chemical Engineers, 1992).

2.3 How to perform high quality Process Hazard Analysis

How PHAs are performed has significant impact on the results and quality of the PHAs (L Collins, 2010). According to L. Collins a PHA with high quality should be as rigorous and comprehensive as possible to ensure that the likelihood of missing potential initial events is reduced. Baybutt (2013) describes study guidance, available documentation, meeting facilities, team and study leader qualifications as the main human factors which affects the quality of PHAs. In addition, recording of PHAs and follow-up of recommendations is mentioned by Baybutt (2013) as crucial for the quality of PHAs.

Study guidelines are described as essential for performing consistent studies on all processes in a facility. These guidelines should according to Baybutt (2013) contain all possible issues regarding how PHAs should be conducted. If any questions are raised regarding the performance of PHAs, the PHA guideline should be updated reflecting the topic. Both L. Collins (2010) and Baybutt (2013) highlight the importance of having the right information available for successful PHAs. Preferably, operating conditions of an existing plant should form the basis for PHAs (L Collins, 2010). If a study is relying only on knowledge and experience of team members, the quality of the PHAs could be affected as this approach is sensitive for knowledge gaps. In addition, Baybutt (2013) argues that incomplete study documentation may cause distraction in the analysis team which could affect the PHA performance.

The study guidelines should also include how PHAs should be performed in terms of environment and equipment, e.g., considering the meeting facilities, software, paper hand-outs and necessities (2013). By optimizing these aspects, e.g., by performing the PHA in a conference room where all team members can be seen, the study team can focus on what is important and make complete use of the competence and information available (2013). The team members qualifications are thus also important for successful PHAs. However, one should not be too focused on the competence of each the individuals. Baybutt (2015) describes the importance of also taking the group dynamics into account. Having the most experienced employees participating in an analysis may not be beneficial if they are not able to work as a group (Baybutt, 2015). Related to this, L. Collins (2010) argues that one should avoid inviting too many team members to the analyses as it sets high pressure on group dynamics and facilitation of the analysis. Facilitation of PHAs is also described as a key factor for successful PHAs (L Collins, 2010). Baybutt (2013) mentions experience in the PHA method, people skills, and understanding of the process as essential for an analysis leader of a high quality PHA.

To achieve high quality PHAs detailed recording is crucial according to Baybutt (2013). With insufficient recording it is not possible to make complete use of the analysis. To avoid this situation there should be clear guidelines for how the PHAs should be recorded, the scibe should be active and have a technical background (Baybutt, 2013). In addition, the collaboration between the facilitator and the scribe is described as important for effective and successful PHAs (2013). The recorded recommendations should be followed-up closely after the PHA sessions to ensure that the recommendations are not neglected. Baybutt (2013) highlights the importance of proper study management and continue working with the analysis also when the PHA session is ended.

3 Methodology

The study methodology was based on semi-structured in-depth interviews, as well as an analysis based on the answers and literature. Employees from Swedish process industries and safety experts within the Norwegian O&G industry were interviewed. The aim of the Swedish interviews was to identify how Swedish process industries work with PHAs, while the Norwegian interviews intended to identify strengths of how PHAs are performed within the Norwegian O&G industry. The work started with a selection of possible companies to contact. Interviews were scheduled with each of the companies interested to participate and the interviews were prepared by formulating interview questions and giving the participants detailed information of the study. The input from the Swedish interviews was used as a basis for the Norwegian interviews. All answers were then combined and analysed to identify the key topics and applicability of the answers. The following sections aim to describe the execution of each stage of the study.

3.1 Selection

In the initiating phase of the study a screening of possible companies to contact was conducted. The screening was depending on accessible contact information. Consequently, companies known by ORS and IPS were contacted at first. This methodology can be compared to what Guest et al. (2013) refer to as the snowball sampling methodology, as the network of ORS (which is one of the study's participants) were used for recruiting additional study participants. An evaluation of how the selection of companies could affect the result of the study is described in Section 7.2.

As described in Section 1.2, companies classified as upper tier according to the Seveso legislation were selected. In addition, both Swedish owned companies and international owned companies were included as well as facilities of different ages. This was beneficial as the study intended to capture the differences in how the companies are owned, and how the PHAs are performed in different lifecycles. However, due to integrity reasons, no detailed evaluations have been made based on the character of the companies as it would damage the anonymization of the interviews.

During the first interviews, the engineering consultancy companies' role related to risk assessments became clear. As the engineering consultancy companies, working with process industries, often participate in the risk analyses or perform their own risk analyses, they also have valuable experiences of how PHAs are performed in the industry. To cover this perspective, one engineering consultancy company was included, see Table 3-1, and three of the employees were interviewed. As the study was limited in terms of time and participation from companies, only one engineering consultancy company participated in the study. Another reason for including an engineering consultancy company was based on how it works within the Norwegian O&G industry. In general, engineering consultancy companies within the Norwegian O&G industry include all risk assessment when offering a complete design. Hence, they have an important contribution to how PHAs are performed within the Norwegian O&G industry. By including one Swedish engineering consultancy company, this aspect could be observed also in this study.

Gerson and Damaske (2020) explain the importance of selecting the right study participants, rather than aiming for many participants. Hence, extensive effort was put into contacting companies of interest for the study and making it easy for them to understand what the study was about. The 11 companies which participated in the study will not be enough to satisfy statistical significance. But the selection is somewhat representative of how Swedish process industries works with PHAs in general as it includes several sectors and companies of different ages and sizes. The Norwegian O&G part of the study included only one company and four study participants. Thus, this part of the study was more limited, but as the focus of the study was on Swedish process industries, the time was prioritized accordingly. Compared to the other study participants from Swedish process industries, the participants from the Norwegian O&G industry have worked with multiple companies, both within the Norwegian O&G industry and internationally. Hence, they have broad experiences of how several Norwegian O&G companies work with PHAs. Table 3-1 presents the companies that participated in the study and the interviewed representative (s) from each company.

The companies differed not only based on the characteristics of the companies, but on the experiences of the participants. Since all companies have different organizational structures, it was not possible to gather participants with one specific role. However, employees at the respective company with positions related to process safety were selected. In some cases, the employee responsible for process safety could not be interviewed, therefore other employees who had insight into the topic were interviewed instead. These participants may not be as familiar with the work as the process safety representatives, but as stated by Guest et al. (2013) having several perspectives on the research questions is beneficial for the study.

Table 3-1 Study participants

Company	Representative	Comments
Eurenco	Mathias Lethenström, (HSE Engineer, Karlskoga)	
Holmen Paper	Michael Lundqvist (Work Environment Engineer, Norrköping)	Holmen Paper's facility Braviken is no longer classified as an upper tier. Hence, the interview also included information from other Holmen Paper facilities classified as upper tier.
Inovyn	Rikard Widell (Process Safety Engineer, Stenugsund)	
Preem	Charlotte Lind (Safety Manager, Göteborg and Lysekil)	
Processus	Malin Arne (Section Manager and Project Lead, Göteborg)	Processus is an engineering company and thus used in the study to get additional perspectives. However, as Processus is not an operating company in the same way as the others, not all interview questions, see Table 3-2, where applicable.
	Tom Krantz (Project Lead, Malmö)	
	Mikael Roth (Project Lead, Göteborg)	

ProSa Consulting	James Hannah (Consultant, Risk Manager at Company)	The interview focused on Hannah's current project where he works as a risk manager for a newly established company.
SEKAB	Christina Bas (Work Environment and Safety Engineer, Örnsköldsvik)	
SSAB	Daniel Nordmark (Head of fire, Rescue, and Risk Management, Luleå)	
	Joakim Bergman (Risk manager, Luleå)	
SunPine	David Lundman (Production Lead, Piteå)	
St1 Rafinery	Kajsa Thulin Kierkegaard (Process Safety Engineer, Göteborg)	
ORS Consulting	Hans Jørgen Nordstrand (Principal Consultant, Oslo)	ORS Consulting participated in the second part of the thesis regarding lessons learned from the Norwegian O&G industry. The participants have extensive experience within the Norwegian O&G industry and facilitation of PHAs.
	Morten Nilstad Pettersen (Principal Consultant, Oslo)	
	Thomas Solberg Fylking (Principal Consultant, Oslo)	
	Per Ståle Larsen (Principal Consultant, Stavanger)	
	Baris Arslan (Principal Consultant, Malmö)	Participated as additional input to the second part of the study with regards to handling of recommendations.

Handling of recommendations after performed PHAs was identified as an important topic both by the Swedish and Norwegian participants. Since there was limited information found regarding this topic, one additional participant with extensive experience within the Norwegian O&G industry (Baris Arslan, ORS Consulting) was interviewed for the topic. The result of this interview is presented as part of Section 5.5 and in Appendix B.

3.2 Interviews

The reason for conducting interviews for data collection rather than questionnaires or similar methods was to ensure that all questions were covered in a sufficient way e.g., by asking follow-up questions. The follow-up questions made it possible to ensure that the answers were related to the topic and applicable to the thesis. After the first couple of interviews, some topics were trending, e.g., handling of recommendations. Therefore, additional attention was put to this topic by asking more follow-up questions in the subsequent interviews. This made it possible to compare the answers and adjust the questions to what is important for the companies in practice. As described in Section 3.2.1, being flexible and open to unexpected findings throughout the study is important for performing rewarding interviews.

With interviews it is also possible to capture additional perspectives, e.g., how the interviewee speaks and behaves. Thus, it becomes easier to interpret if the interviewee is disappointed, satisfied, or worried, which may not be as clear when using questionnaires. With in-depth interviews the interviewees get to talk about what is important to them (Morris, 2015). This means what was most important to the Swedish process industries could be captured. Further

discussion regarding advantages and disadvantages of using semi-structured in-depth interviews is described in 7.3.

The following Sections 3.2.1 and 3.2.2 describe how the interviews were prepared and executed.

3.2.1 Preparation

To perform successful interviews, research within the field and other experiences were summarized prior to the interviews. The research included information about Swedish legislation, PHA methods and how to perform PHAs, as described in Chapter 2. The author's experiences about the PHA execution chain formed the basis for the interview questions, see Section 3.2.2 According to Gerson and Damaske (2020), it is important to have a flexible mindset when preparing and performing interviews, meaning that the interviewer should be open to unexpected findings throughout the study. Hence, all parts of the execution chain of PHAs were included as a part of the interview questions to counter for this. In addition, the interview questions also included which PHA methods are used, why they are used and how they are used as there is limited Swedish legislation related to this, as described in Section 2.1.

Prior to each interview session the interview questions, see Table 3-2, were sent to each study participant, including definitions and limitations of the study. This gave the study participants a chance to prepare and get familiar with the study, which is beneficial for an interview (Kvale, 2014). Each interview started with an introduction of the background of the thesis, and a repetition of the definitions and limitations which were sent to the participants prior to the interviews.

3.2.2 Interview Execution

The interviews were performed as semi-structured in-depth interviews, which means active participation from both researcher and interviewee. Semi-structured in-depth interviews enable the researcher to follow up the answers from the interviewee to gather as much information as possible (Morris, 2015). The interviews were mainly performed with one interviewee at a time, except for SSAB where two interviewees attended. The reason for performing the interviews one-by-one was based and the trust it establishes and the possibility to adapt the tempo to what suits the interviewee (Gerson & Damaske, 2020). It also enabled the interviewees to discuss problems or ideas that they may not do with their colleges and reduced the risk of one person taking over the interview.

The actual interview started with a short introduction of the participant, followed by eight questions about how the company works with PHAs, see questions 1-8 in Table 3-2. The interview ended with four reasoning questions about how the study participant experience working with PHAs in the company, see questions 9-12 in Table 3-2. Each interview session was 30 to 60 minutes long and was conducted via Microsoft Teams, except for one interview. The reason for starting with fact-based questions was to get an overview of how the company works and to make sure that the main questions for the thesis were covered.

Table 3-2 Interview questions

#	Questions
1	What qualitative risk analysis methods do you use to identify process risks?
2	Why are the chosen methods used instead of other methods? Who decides which method to use?
3	What is the reason for analysing process risks in general?
4	When are the risk analyses perfromed? What is the underlying reason why they are performed at a certain time?
5	How often are the analyses performed?
6	How are the analyses performed? What experience do the participants have?
7	Who facilitates the qualitative risk analyses?
8	How are the results from the process risk analysis used? Are the results used as a basis for other risk assessments (e.g., in health and the environment studies)?
9	How do you experience the analyses? What are the difficulties/shortcomings? What is good?
10	Does it give you anything to work in the way you do today?
11	What potential for improvement are there?
12	How do you perceive the Swedish legislation?

The interview questions for the Norwegian O&G part of the study were based on the same interview questions as for the Swedish process industries. The only difference was on the last reasoning questions, i.e., questions 9-12 presented in Table 3-2. Instead of focusing on how the Norwegian O&G industry could be improved, the focus was on which improvements had been done and whether these could be applicable for Swedish process industries. For each interview question, the results from the Swedish interviews were summarized to identify not only the differences between the industries, but the reason behind the differences. For complete questions and answers, reference is made to Appendix A for the Swedish interviews and Appendix B for the Norwegian interviews.

The interviews were recorded in Microsoft Teams, if the participant allowed for verbal recording, and the answers to each interview question were noted in worksheets after the interview. The interviews were noted in an indexical way of transcription, which means notes were taken in relation to a timeline, but it did not capture every single word that was said. The interviews were thus recorded to ensure that all topics were captured and could be noted after the interview. For the interviews which were not recorded, notes were taken throughout the interviews. An advantage with recording the interviews is that the interviewer can be more present and may be able to ask more relevant follow-up questions. However, one could also argue that by taking notes during the interview it is possible to keep the speed down which could be beneficial for both the interviewer and the interviewee.

3.3 Data Analysis

Based on the recorded worksheets from each interview all answers were gathered in separate documents per interview question. Based on this, the data were interpreted and categorized. As stated by J. Gibson and Brown (2009) the interviewer for semi-structured interviews analyses the answers continuously throughout the interviews to ensure that the concern of the study is covered. Hence, the main part of the analysis was performed during the interviews as the data had to be interpretated in real time. J. Gibson and Brown (2009) also highlight the importance of working with the data in terms of listening, reading, and transcribing, to present the results in a representative way. This aspect has been central for all steps within the data analysis procedure. The main steps for the data analysis part can be described as follows:

- Identification of relevant data for the study;
- Categorization of topics discussed within each interview question;
- The number of participants within each category was counted;
- For the data, which was not possible to categorize in a representative way, the information was summarized to reflect the main points.

During the interviews, the study participants gave examples and further information related to the interview questions. Parts of this information were removed since it was irrelevant to the study or since it could be regarded as classified information.

The data analysis was based on three aspects that are central to thematic analyses, identifying similarities, differences, and relationships (J. Gibson & Brown, 2009). Based on this, the discussed topics were categorized according to a coding methodology. The aim of a coding methodology is to define what the data is about, by linking one thematic data to a particular code (R. Gibbs, 2007). One code could for instance be company-based decision making as described in Section 4.1. The code methodology enables comparison between several data sets (interviews) by dividing the codes into a coding hierarchy where similar codes are within the same level of hierarchy (R. Gibbs, 2007). For example, the two codes company- and personnel-based decision making, were gathered within the same hierarchy level and were thus compared.

3.4 Literature study

A literature study was performed to understand the Swedish legislation within the field, the differences between the PHA methods and factors affecting the quality of PHAs. In addition, the literature study was used as a comparison between the results of the interview study to evaluate the reliability of the results. The main type of sources used for the literature study are shown in Table 3-3.

Table 3-3 Type of sources used for the literature study

Type	Examples of references
Scientific paper	Baybutt (2013) and L.Collins (2010)
International standards	ISO and IEC, e.g., ISO 31000 (2018) and IEC 60812 (2006)
Guidelines from authorities	Swedish emergency agency, e.g., Davidsson et al. (2003)
Guidelines from organisations	IPS, e.g., Karlsson and Käck (2018)
Guidelines from experts within the field	Crawley and Tyler (2015) and Macdonald (2004)

The literature study applied for the background of the thesis, was based on a wide search of literature. Keywords such as Process Hazard Analysis, HAZOP and HAZID was used to find information about the PHA methods. To find more specific information about factors affecting quality of PHAs or information which could be compared with the result of the interview study, additional search words were added. Examples of phrases used for the detailed search are “perform Process Hazard Analyses”, “quality of Process Hazard Analysis”, “Process Hazard Analyses in Swedish process industries” and “handle PHA recommendations”. Google Scholar and LubSearch were mainly used as search engines for scientific papers and guidelines. The Swedish website for international standards (called SIS) and IPS’s website were also used as sources for finding standards and Swedish guidelines within the field. In addition, references from the reviewed articles, guidelines or books were used to find more information within the topic.

Each source was valued based its relevance and reliability. The evaluation was also based on reviewing questions suggested by Höst et al. (2006) which include how the material has been reviewed, who is responsible for the reliability, what methods has been used and confirmation by other authors.

4 Results from Swedish Process Industries

The following sections aim to present the results of interviews of representatives from the Swedish process industries, shown in Section 3.2.1. The answers are summarized for each interview question, either qualitatively or quantitatively. For the results presented quantitatively, the results are shown as number of companies in the category per total number of results for the interview question. For some interview questions, answers from Processus are not included as they may not be comparable with Swedish process industries. This is stated in the table headers were relevant. For complete results to the answers, reference is made to Appendix A. Due to integrity reasons, the answers have been anonymized to ensure that it is not possible to identify which study participant answered what.

4.1 Mapping of Process Hazard Analyses

The most common PHA methods are:

- Preliminary Hazard Analysis;
- What-If;
- HAZOP.

In addition, some participants mention barrier analyses such as LOPA, FMEA, and Bowtie. However, these analyses are not used in the same amounts as the above-mentioned analyses. Table 4-1 presents an overview of the results of **interview question 1**: *What qualitative risk analyses methods do you use to identify process risks?*

Table 4-1 Overview of interview question 1

Analysis method	Result	Comments
Preliminary Hazard Analysis	9/10	
HAZOP	8/10	All companies perform HAZOPs in one way or another. However, two of the companies perform HAZOPs with modifications, see Table 4-2.
What-If	7/10	
LOPA	6/10	
HAZID	5/10	
Company specific analysis	4/10	See examples of analyses in Table 4-2.
FTA	3/10	FTAs are not used as frequently as other more common analyses, such as HAZOP.
Bowtie	3/10	
Checklist	3/10	
Event tree	2/10	Event trees are not used as frequently as other more common analyses, such as HAZOP.
Risk graph	2/10	
FMEA	1/10	

Some participants mention company specific analyses, examples of which are presented in Table 4-2.

Table 4-2 Examples of company specific analyses mentioned in the interview

Examples of company specific analyses	Comments
Deviation analysis	Developed by one company but no additional details were given.
Interruption analysis	The whole production is analysed in a three years-cycle focusing on interruptions risks, e.g., what happens if respectively machine is interrupted. This is used for investment priorities.
HAZOP with modification	A HAZOP with modification is used for changes in the design at one company. It is a list developed by the company which can be compared with HAZOP.
Mix of HAZID and Preliminary Hazard Analysis	One participant stated that they do not attach much importance to which method is used. The term HAZID is used to explain that it is a risk analysis on a higher level, while the method itself is more similar to What-If, without applying What-If questions.

Most of the companies use a preliminary hazard analysis as a basis for the Seveso safety report. The preliminary hazard analysis is for some companies supported by other PHA methods, such as LOPA. The risk assessments could also be mixed, e.g., to make the sessions more effective regarding the extent of the analysis. A HAZOP could for instance be combined with a LOPA or a Preliminary Hazard Analysis.

The reason why some PHA methods are used instead of others varies among the companies. For some companies, the employees working within the process safety discipline are free to choose when and which PHA methods to be performed, while other companies are more controlled by company requirements. An overview of who makes the main decisions regarding PHAs is shown in Table 4-3. The background for these decisions is mainly based on previous experience. Methods that the companies have used before or methods that the employees have experience of are in general chosen above other methods. Except for experiences, the decisions are depending on the available level of detail for the system and time for the analyses. Some of the participants clarify that the decisions are generally made in dialogs with other employees, such as project leaders, production- or maintenance managers.

Some participants describe how methods which the employees has limited experiences with and no history within the company, have been performed or are planned to be performed. For instance, one of the participants mentions that they had started using bowties, supported by an external resource. This was a decision made by the employees at the company with limited experience with the method.

The summarised results of **interview question(s) 2**: *Why are the chosen methods used instead of other methods? Who decides which method to use?* can be summarized as follows:

- The choice depends on the companies' and the employees' experiences with the methods. PHA methods that the company or the employees feel comfortable with are often chosen above methods that are unfamiliar to the company or the employees;
- Who decides which methods to be used varies among the companies. The most common is a personnel approach, where responsible employees decide based on their own judgement which method to use for several occasions. An overview of the main decision makers is presented in Table 4-3.

Table 4-3 Overview of main decision makers related to PHA methods, not including Processus

Choice of PHA study	Result	Classification explanation
Company-based	1/9	The study participant mentions that the choices are based on company guidelines only.
Personnel-based	6/9	The study participant mentions personnel judgement as the main basis for the decisions.
Mixed	2/9	The study participant mentions a combination between company guidelines and personnel judgement as a basis for the decisions.

The main reason why process risks are analysed (**interview question 3**) is in general common for all companies, as all participants mention a safe workplace as the main objective. In addition, most participants mention Swedish legislation, but this is regarded as secondary. Some companies, e.g., the companies classified as company-based or mixed according to Table 4-3, refer to company requirements as an additional reason for analysing process risks. The reasons for analysing process risks are summarized in Table 4-4.

Table 4-4 Reasons for analysing process risks, not including answers from Processus

Reason for analysing process risks	Result	Comments
Safe work environment	9/9	All interviewed companies mention a safe facility as the main objective of PHAs.
Swedish legislation	6/9	Particularly the Seveso legislation and work environment legislation.
Optimization with economic benefits	4/9	PHAs as a basis for investment evaluations or to achieve stable production were regarded as secondary.
Company requirements	3/9	E.g., guidelines or requirements for periodical analyses.
Harmonised standards	1/9	One participant mentions harmonised standards as a basis for performing risk assessments. However, the reason behind this is unclear.

4.2 Performing Process Hazard Analyses

All participants mention the Seveso safety report, which shall be performed each fifth years, as an event which initiates a risk analysis. Some participants also mention company requirements as an initiating factor for PHAs, e.g., to perform HAZOPs of all systems every fifth years. Beyond the Seveso safety report and company requirements, PHAs are performed for new constructions or changes in the design. The PHA methods used for new constructions or changes in the design varies among the companies. The participants also mention incidents or observed risks as initiating factors for performing PHAs.

The results of **interview question(s) 4**: *When are the risk analyses performed? What is the underlying reason why they are performed at a certain time*? are summarized in Table 4-5. The performed PHA methods varies for each initiating factor, e.g., based on the character of the modification, incidents, or the project. Thus, the intention of Table 4-5 is to give examples of PHA methods related to each initiating factor, rather than giving a quantitative overview of the answers.

Table 4-5 Overview of when respective PHA study is initiated, not including answers from Processus

Factors initiating a PHA study	Examples of PHA methods used
Seveso safety report	Preliminary hazard analysis, HAZOP, LOPA.
New constructions or changes to the design	Preliminary hazard analysis, HAZOP, HAZID, LOPA, FMEA, Company methods.
Following another analysis, due to extensive consequences identified.	Bowtie, LOPA, risk graph.
Smaller changes	Checklist, What-If.
Incidents or observed risks	Some interviewed participants mention incidents and observed risks as initiating factors for risk analyses. However, the type of PHA used for this is unclear.
Competitive intelligence	Several analyses can be performed based on accidents from other facilities.
For each phase in a project	HAZOP, HAZID, What-If, LOPA. The type of method is depending on whether it is in the beginning or the end of a study phase and the aim of the analysis.
Company requirements	HAZOP, Preliminary hazard analysis, Company-specific analysis. For instance, some companies perform re-HAZOP each fifth years or interruption analysis each third years, see Table 4-2.

How often PHAs are performed (**interview question 5**) is depending on whether it is initiated by a continuous initiating factor, e.g., company requirements for re-HAZOP or based on new designs or incidents, as shown in Table 4-5. An exact picture of how often each of the companies perform each PHA method is not given as it is depending on several factors. However, some participants mention the following examples of time intervals:

- Preliminary hazard analysis each fifth years (Seveso safety report);
- LOPA each fifth years in connection with the Seveso safety report;
- HAZOP each fifth years;
- Interruption analysis each third years.

How the analyses are performed (**interview question 6**) depend on the scope and extensiveness of the study. In general, five to ten employees participate in the sessions. All companies use a chairman for facilitation of PHAs and usually a scribe who records the findings. Who the other participants are varies slightly between the companies. The following roles are typically present during the analyses:

- Project lead or other responsible leads;
- Production lead and operator(s);
- Maintenance;
- Engineers (e.g., instrumentation, electrical, process, automation, or production);
- HSE;
- Safety delegate;
- Experts or external parties involved in the project.

The experience of PHAs among the analysis team (**interview question 6**) is in general good. However, one study participant mention that the knowledge about risk management could be improved.

Who facilitates the PHAs depends on the scope of the study. In general, both external and internal resources are used for facilitation. A quantitative summary of the results of **interview question 7**: *Who carries out the qualitative risk analyses?* is shown in Table 4-6.

Table 4-6 Overview of type of facilitator (i.e., external, or internal resource), not including Processus

Type of facilitator	Result	Comments
External facilitator for extensive studies and internal facilitator for smaller studies	2/9	
Both external and internal facilitators (not specified on which occasions)	3/9	
Mainly external facilitators	2/9	As one study participant works as a consultant for a project which is led by consultants in general, all resources are naturally external, even if they may be internal to the project.
Mainly internal facilitators	2/9	

The results of PHAs are usually several identified hazardous scenarios and recommendations to reduce risks. All companies mention the recommendations as the main results from PHAs.

Some participants describe the importance of recommendations for further progress in projects or related to changes in the facilities. However, the way the companies work with recommendations and experience the handling of recommendations varies. Some companies use industry specific software for keeping track of the recommendations, while others use manual lists with general software or a mix of both. An overview of the tools for handling recommendations is provided in Table 4-7.

Table 4-7 Overview of supporting tools for handling recommendations

System for managing recommendations	Result	Comments
Industry specific software	5/10	E.g., deviation system, PHA-Pro, document systems.
General software	4/10	E.g., Excel lists, SharePoint
Both	1/10	

The interweaved answers to **interview question(s) 8**: *How are the results from the process risk analysis used? Are the results used as a basis for other risk assessments (e.g., in health and the environment studies)?* can be summarised as follows:

- The main outcome is recommendations which are used as a basis for improvements of the proposed design;
- The recommendations are followed-up, which includes evaluation of the recommendations and current status;
- The analyses are in general not used as a basis for other analyses (except for HAZOP and LOPA, as mentioned in Section 4.1), but the recommendations could be used as a basis for investments.

Some participants mention challenges with handling recommendations, this will be further described in Section 4.3.

4.3 Experience and Improvements

In general, all participants experience the analyses as rewarding. Only two of the participants express dissatisfaction or slight dissatisfaction regarding the PHAs at the company. Thus, the first part of **interview question 9** *How do you experience the analyses?* can be summarised as generally rewarding. The experienced difficulties and strengths among the companies (last part of **interview question 9)** vary amongst some of the companies and are common for others.

The main experienced difficulties and challenges are:

- Long and time-consuming PHA sessions;
- Keeping discussions to the methodology, e.g., not letting the analyses turn into system reviews;
- Follow-up and handling of recommendations;
- Synchronized way of working with PHAs within the company group and all departments;
- Imagination during the PHA sessions.

Several participants mention how resource intensive PHAs could be. Some of the participants mentions the advantages with performing even more analyses, but it would be too time-consuming. Related to this, one mentions the balance between performing PHAs and devoting resources on effective safeguards or developing a better solution. Regarding the same topic, two participants mention problems with PHA sessions being too long. The main reason for this is when discussions go too much into detail regarding solutions rather than identifying hazards. The challenge is hence to facilitate analyses and explain the methodology in a way that minimizes the technical discussions.

One consistent theme throughout the interviews is handling of recommendations. The challenge is however not to identify recommendations and improvements, but rather to follow them up. Some of the participants experience difficulties with ensuring all recommendations are evaluated and closed within a reasonable time, including having a responsible person for each recommendation. In addition, one participant mentions difficulties with evaluating the recommendations both before implementation and after. This topic will be further described related to potential areas of improvements (interview question number 11).

Two of the participants mention challenges with imagination during the PHAs but based on different reasons. One reason is includes exclusively facilitation by internal resources. The imagination is depending on participants who know the facility well and may have limited experience from other facilities. The other reason is based on difficulties with using a worst credible consequence perspective, not crediting safeguards. Meaning that team members struggle with imagining what the ultimate consequences could be if all safeguards fail. Having a worst credible consequence approach is an important to assess PHAs and especially SIL evaluations.

The main strengths are:

- The interest among the employees to contribute to the analyses, as well as the encouraging and permissive culture during the workshops;
- Suitable number of participants during the PHA workshops;
- Increased process and system knowledge during the PHA workshops;
- Synchronized way of working with PHAs within the company group and all departments.

The interest and desire to contribute is a strength of almost all interviewed companies. In addition, the group dynamics and number of participants are experienced as beneficial. Several participants also mention the benefits of PHAs from a knowledge sharing perspective. The PHA workshops are good opportunities for the employees to increase their understanding and learn from other disciplines.

The synchronized and structured way of working with PHAs within both the company group and departments is described as both a challenge and a strength depending on the study participant. This will be further evaluated for interview question 11.

Regarding **interview question 10**: *Does it give you anything to work in the way you do today?* all interviewed participants are positive, however, some interviewees imply that there are still potential for improvements. General areas of improvement (**interview question 11**), according to the study participants, can be summarized based on the following topics:

- Software for handling recommendations and other PHA results;
- Synchronized and structured way of evaluatiung risks and performing PHAs within companies (and the country).

As presented in Section 4.2, tools for handling recommendations vary between general software and industry specific software. Six of ten participants highlight the use of industry specific software for handling recommendations and other results as an area of improvement. These participants believe a more systematic software for handling recommendations and results could help them improve the follow-up and use the results more efficiently. More specifically, the risk of recommendations falling between the chairs could be reduced. However, some participants also mention the disadvantages of using industry specific software for managing results, as implementation of a program requires extensive investments, and introduces dependency on a particular program. One participant highlights that someone still need to put the information in the program, which also takes time.

Working in a synchronised and structured way within the company is mentioned by five of ten participants as an area of improvement. However, the level of structure that these interviewees are referring to varies. Some of the participants highlight working in a synchronised way on a higher level, e.g., guidelines regarding which PHA method to use. While others are referring to a lower level, e.g., related to frequency and consequence criteria for risk ranking, or guidelines for each PHA method. Two of the participants mention the need for extended guidelines or handbooks to ensure that risks are evaluated in the same way and not depending on the person performing the analysis. One other interviewee mentions already improved methodologies and guidelines for PHA methods to ensure standardized performance. The same interviewee also states that this is a topic that could be even further improved.

The less frequently mentioned improvements are:

- Increased use of external companies for facilitation of PHAs to increase the imaginative thinking during PHA workshops;
- Increased use of HAZID as a method for identifying relations between hazardous events and reasonable measures related to it;
- Increased knowledge sharing between several disciplines to perform standardised analyses with higher quality;
- Increased knowledge within several analyses among the employees and capacity to facilitate those;
- Increased use of integrated analyses, including not only systems on a high or low level but the interfaces between the systems.

4.4 Swedish Legislation

As stated in Section 2.1, there is limited legislation related to how and when Swedish process industries should perform PHAs. Therefore, the last interview question aims to identify how the Swedish process industries experience the Swedish legislation.

Most of the participants explain the legislation in terms of requirements for analysing risks as clear, but the support from the regulations as weaker (**interview question 12**). However, whether the system in general is beneficial or not, varies among the participants. The summarized benefits of the Swedish legislation are:

- Each company can adapt the choice of PHA methods and how to work with risk analyses in a way that suits the facility in terms of size, surroundings, and economic resources;
- The legislation is based on goals rather than strict requirements;
- The Seveso legislation is clear, especially with regards to what should be included in the safety report.

The summarized disadvantages of the Swedish legislation are:

- The legislation gives limited support for how it should be achieved as the regulations are perceived as unclear;
- The regulations are detailed within some sectors and less within other fields, this makes it hard to apply them on different industries;
- Regulations and authorities focus on worst-case, rather than including a comparison between frequency and consequence;
- The authorities often focus on risks outside the facilities rather than helping the process industries internally;
- As the legislation mainly applies to the facility owner during operational phase, the safety responsibility becomes distanced from others involved. This could potentially result in stakeholders not taking enough responsibility for process safety. In addition, the delegation of responsibilities within design and construction phase is also mentioned as a problem as the responsibility can be delegated down in the value chain.

Two participants state that it would be beneficial to have more apparent and supportive regulations. At the same time, one other participant explains since the company itself has a desire to analyse risks, it would be more beneficial to have extensive company requirements. In general, the Swedish process industries express a need for additional Swedish guidelines and standards, as well as increased support from authorities rather than stricter legislation.

5 Results from Norwegian Oil and Gas Industry

The following sections present the results from the interviews of consultants working within the Norwegian O&G industry. The interview questions for the Norwegian part of the study are based on the same questions as for the Swedish part. But they are adjusted in a way that suits the research question, i.e., *how can methods and lessons learned from the Norwegian O&G industry be applied in Swedish process industries*. Unlike previous chapter, all results for each interview question are not given, as the intention of this chapter is to provide a background to the last research question (mentioned above). For complete answers to each of the interview questions reference is made to Appendix B.

5.1 Use of HAZID

In Sweden the What-If method is one of the dominating PHA methods while HAZID is more uncommon, see Section 4.1. This is not the case for the Norwegian O&G industry according to the Norwegian participants. All participants from the Norwegian O&G industry agree on the benefits of using HAZID or/and HAZOP instead of What-If. The reasons for this statement can be summarized as follows:

- What-If has a low traceability compared to HAZID and HAZOP as the What-If method does not address guidewords in the same manner;
- With a higher traceability it becomes easier to update an existing HAZID in later phases;
- What-If is unstructured compared to HAZID and HAZOP;
- The facilitator of a What-If has extensive responsibilities as the analysis must be led in a way that covers all concerns, while the HAZID guidewords are more comprehensive;
- What-If generates many answers but no overall picture as it is easy to miss or overlook aspects which would have been caught in a HAZID or HAZOP;
- A HAZID and a HAZOP have a complementary and comprehensive effect compared to What-If.

One study participant mentions the possibility that a HAZID could be implicitly integrated with the preliminary hazard analysis used by the Swedish process industries, i.e., that the preliminary hazard analysis is more like a HAZID. However, the interviewee also mentions the benefits of applying a stand-alone HAZID in addition to the preliminary hazard analysis.

5.2 Barrier Analysis

Barrier management is described by two of the study participants as a topic which have become more important to the Norwegian O&G industry in the last couple of years. The increased use of barrier analyses is due to the increased requirements from authorities as a reaction to the Deepwater Horizon disaster in 2010. Analysing barriers in general and to further do it in an operational manner, by continuous evaluations, is described as a lesson learned from the Norwegian O&G industry which could be applicable to Swedish process industries.

5.3 Company-based Decision Making

As described in Section 4.1 the choice of PHA method is for most of the Swedish process industries based on a personnel-based approach. Meaning that the responsible employees decide which method to use on several occasions. In the Norwegian O&G industry the decision making is rather dominated by a company-based approach. The company requirements are in turn based on the Norwegian petroleum legislation called the Petroleum Safety Authority (PSA). PSA refers to Standards, such as NORSOK or NOROG, which are integrated in company requirements and forms the basis for decision making related to PHAs.

All four participants agree on the advantages of having a company-based approach rather than a personnel-based approach for planning of PHAs. Having a company-based approach is a central aspect for achieving a synchronised and standardized way of working with PHAs. A system that is relying on judgments by employees are described as vulnerable, as the choice of PHA method could be based on subjective decision and not standardized within the company. Hence, Swedish process industries are advised to base their decisions on company requirements rather than on employees' judgements. By having an extensive structure within the company with clear guidelines, companies with fewer resources can make more effective decisions regarding the extensiveness of the analyses.

One of the participants describes the development comprehensive company requirements as demanding. Therefore, the interviewee argues that the most effective solution is if the authorities develop guidelines and standards as support for the companies' own guidelines. This topic will be further discussed in Section 5.6.

5.4 Facilitation

Whether the facilitators are internal, external or a mix of both varies among the Swedish process industries, as shown in Section 4.2. Within the Norwegian O&G industry, most of the facilitators are external. However, engineering companies sometimes use internal resources for smaller analyses. How the analyses are facilitated is described as a main factor for successful analyses. All four participants express having a third party for facilitation as crucial. But that does not necessarily mean that the facilitator needs to be from an external company, most important is to have a facilitator who has not participated in the design as it entails a risk of conflict of interests. One participant explains the difficulties of giving criticism and imagine additional aspects of an own design, and therefore a facilitator who has been involved in the design may not give an objective view.

One participant considers it more effective to invest resources in using external contractors for facilitation of analyses. Alternatively, having one specific internal employee with extensive competence in facilitation of PHAs and who do not participate in projects. Beyond this, the importance of having company guidelines for how different PHA methods shall be performed and how risks shall be evaluated is highlighted. However, even if companies use mainly external resources they are advised not to fully rely on external resources as the companies themselves still need the competence to order the right analyses.

On the other hand, two of the participants highlight the importance of having a facilitator with an extensive understanding of the systems being reviewed. Hence, an internal facilitator could

be an advantage if the internal facilitator has sufficient knowledge about the analysis methodology and has not been involved in the design. One of these participants particularly highlights sung a “cold eye” for ensuring that the risk of having a limited approach is minimized. A “cold eye” is a person with extensive process experience but is not involved in the project and does not facilitate.

Lessons learned from the Norwegian O&G industry related to facilitation of PHAs can be summarised as follows:

- The PHAs should be led by a third party, either an external contractor or an internal employee who has not participated in the design and have extensive knowledge of the analysis methodology;
- It is more effective to have one internal resource with extensive knowledge of facilitation rather than having additional employees with brief knowledge;
- The facilitator should have an extensive understanding of the system being reviewed;
- The company shall have clear guidelines for how each analysis should be conducted;
- “Cold eye” can with advantage be used to support imagination during the analyses.

5.5 Handling of Recommendations

In general, the way recommendations are handled is perceived as good by the participants from the Norwegian O&G industry. Most companies use document management systems, such as PIMS or Synergi, for keeping track of the recommendations. But more manual systems could also be used depending on whether the asset is under design or operation. One of the participants mentions handling of recommendations as a typical finding from audits, e.g., lack of follow-up or insufficient documentation. However, there is no fixed standard for how the closeout should be handled, this is mainly company specific.

Handling of recommendations in terms of software is mentioned as the main area of improvement by the Swedish process industries, see Section 4.3. The study participants from the Norwegian O&G industry are not completely united on whether industry specific software is crucial for successful handling of recommendations or not. Two participants consider the guidelines for how the recommendations should be documented and handled as more important than the type of software. One participant explains how the resources could be used more efficient by implementing synchronised guidelines rather than implementing a specific software. On the other hand, one participant highlights the advantage of having an industry specific software as it puts more pressure on the formulation of the recommendations. His experience is that if industry specific software is used, it requires more follow-up and then only recommendations that are possible to solve is recorded.

The most important aspect for successful handling of recommendations can be summarised as having structured guidelines for handling recommendations. The guidelines should include:

- How the recommendations should be recorded;
- How the follow-up should be documented;
- The responsible for each recommendation and the overall coordination of recommendations related to one analysis.

5.6 Standards and Guidelines

As described in Sections 5.3, 5.4, and 5.5 the company guidelines are according to the study participants from the Norwegian O&G industry, a key for successful PHAs. All participants agree on having a clear structure within the company regarding guidelines as the main lesson learned from the Norwegian O&G industry. Three of the participants highlight the advantages of both general standards and industry specific standards as a basis for company requirements. The standards are for instance described as a security for the companies and something that could support the companies when defining their own guidelines. By having standards developed by authorities or other organizations, each of the companies do not need to develop their own guidelines from scratch, which would be more effective for all companies.

The importance of having a clear structure of how to perform PHAs (and risk management in general) is described by one of the participants as crucial, even at higher levels in companies. By having an extensive structure, companies with limited resources can be supported to make effective boundaries for the PHAs to get appropriate extensiveness of the analyses.

6 Analysis

This chapter aims to analyse the main results of the study and discuss them based on information from other sources such as books, articles, standards, and guidelines.

6.1 Process Hazard Analysis Methods

As shown in Section 4.1, the most common PHA methods within the Swedish process industries are preliminary hazard analysis, HAZOP, and What-if. This statement is also in accordance with what Karlsson and Käck (2018) describe in their Swedish guideline for performing risk assessments. Karlsson och Käck also highlight that HAZOP is often included in companies' own guidelines which is also identified in this study related to re-HAZOP, presented in Section 4.2. The reason why FTAs and event trees are less used in general and not as frequently used as preliminary hazard analyses, HAZOP, or What-If among the study participants could be because they are aimed for specific hazardous events and hence not as general as the mentioned analyses. Karlsson and Käck (2018) mention the required competence and complexity of constructing FTAs as the reason why it is not as common among Swedish process industries.

When comparing with the Norwegian O&G industry, the same PHA methods are used, but with two exceptions. As discussed in Section 5.1, What-If is rarely used in the Norwegian O&G industry. Instead, HAZID is much more common than in the Swedish process industries. This statement is also in accordance with NORSOK S-001 (2021), which refers HAZIDs as the starting point for the technical safety work. The statement can also be supported by the fact that What-If is not mentioned in any Norwegian standard and HAZID is not mentioned in any of the Swedish handbooks for risk management studied for this thesis. All participants working within the Norwegian O&G industry argue that HAZID is a better analysis than What-If since it has higher traceability and is more structured and comprehensive. This opinion is not unique, according to Signoret and Leroy (2021) HAZOP was developed from the What-If methodology in the 60s as the safety engineers experienced it as too unstructured and not rigorous enough. However, the What-If methodology is still used internationally. For instance, What-If is mentioned as a typical analysis while HAZID is not mentioned at all in the American book *Fundamentals of Process Safety Engineering* (Kumar Biswas, Mathur, & Kumar Hazdra, 2021).

What has not been mentioned in the interviews are the human-orientated analyses such as Action Error Analysis (AEA). AEA is often used as a term for defining all analyses which focus on identifying action- or decision errors by operators (Harms-Ringdahl, 1996). For example, Human Reliability Analysis (HRA) estimates the human reliability in terms of probability. According to Karlsson and Käck (2018), AEA is a common risk analysis within the process industry, but it is not as common as preliminary hazard analysis, What-If, or HAZOP. During the research of this thesis, AEA and HRA were mentioned mostly related to the nuclear industry. For instance, 90% of probabilistic risk analyses for the nuclear industry are based on human errors (Swain, 1990). The reason why the study participants did not mention human related analyses can also be due to the limitations of the study or because they are implicitly covered by other analyses. The definition of process safety according to EPSC (2021) includes focus on how operators behave around production and maintenance as part of process safety. This was sent to all participants prior to the interviews, but AEA was not

mentioned as one of the examples to each interview question, which may have affected the results.

Increased use of barrier analyses and to further analyse barriers in an operational manner is presented in Section 5.2 as a lesson learned from the Norwegian O&G industry. This topic was not addressed to any particularly large extent during the Swedish interviews. Therefore, it could be difficult to draw a conclusion that is fully supported by the results from the Swedish interviews. However, as shown in Section 4.1, LOPA is the most common barrier analysis method, and bowtie, FMEA, and risk graphs are only used by a few participants. The fact that LOPA is the most common barrier analysis among the Swedish study participants is also in accordance with IPS's guideline for performing risk assessments (Karlsson & Käck, 2018), which refers to LOPA as the main analysis for this purpose.

In general, the Swedish participants mainly focused on analyses for identifying risks rather than analyses for evaluating the developments of scenarios (e.g., barrier analyses, FTA, and event tree). This could be due to several reasons, e.g., the methodology and limitations of the study or because Swedish process industries analyse barriers to a less extent. As explained in Section 1.2, the thesis focuses on qualitative analyses. Hence, there is a possibility that the study participants mainly focused on the typical qualitative risk assessments. For instance, Mares (2015) refers to LOPA as a quantitative analysis. This means that, even if the limitations were presented prior to the interviews, some participants may have referred barrier analyses to quantitative analyses which could affect the validity of the results. It could also be argued that there is a difference between Swedish process industries and the O&G industry with regards to potential consequences, which sets higher demands on barriers. Even if it is unclear whether there is support for increased use of barrier analyses in Swedish process industries, the importance of analysing barriers is an operational manner is supported by IPS's guideline for barrier management (Mares, 2015).

6.2 Analysis Performance

PHAs are performed in the Swedish process industries for new installations, for modifications to new or existing designs and in yearly cycles. The initiating factors of PHAs for the Norwegian O&G industry are based on the same reasons (see Appendix B), and this is also in accordance with IPS's guideline for performing risk assessments (Karlsson & Käck, 2018) and associated standards such as IEC 61882 (2016).

How the analyses are performed are, according to Section 4.2, is generally similar among the Swedish process industries with regards to number of workshop participants and partcipating disciplines. The team composition is also in accordance with the HAZOP participation proposed by Kumar Biswas et al. (2021). However, who facilitates the analyses varies among the interviewed participants. The importance of using a third party or an internal resource who have not been involved with the design and who is experienced in the methodology is highlighted by the study participants from the Norwegian O&G industry. Having a third party as facilitator is in many cases a legal requirement for the Norwegian O&G companies (see Appendix B), but this is not the case for the Swedish process industries. The importance of having a facilitator who is independent of the project and does not have any responsibilities beyond leading the study is also highlighted in EPSC's guideline (Crawley & Tyler, 2015) as well as in IEC 61882 (2006). The importance of conducting the analyses in an objective way

can be further supported by a statement from Karlsson and Käck (2018) regarding polarity in risk assessments. Karlsson and Käck (2018) highlight the difficulties of conducting risk assessments with participants who have different incentives, e.g., vendors, managers, or other employees who do not want to agree on errors with their products or design.

One of the Norwegian participants also highlights, related to organizational hierarchies (see Appendix B), the importance of having clear guidelines for how the PHA methods should be performed. These guidelines should thus cover all parts, including the procedure, limitations, facilitation, and participation, to ensure that there are no objections during the analyses and ensure an objective risk assessment. As described in Section 2.3, to perform high quality PHAs there should be clear guidelines which should be continuously updated. Baybutt (2013) argues that if any questions are raised regarding the PHA performance, this should be updated and reflected in the PHA guidelines. This gives a hint of how comprehensive the guidelines should be. However, one could argue that having too strict guidelines could also limit the analyses as they may have different scope or team composition. On the other hand, it is easier to make few exceptions for some analyses than trying to perform multiple PHAs in a synchronized way without guidelines. A suggestion could be to have guidelines for each of the PHA methods and one additional guideline for how the employees should handle analyses which are not suitable for the general guidelines, e.g., by requiring one additional employee to review the changes.

One Swedish participant highlights a demand for increased knowledge within several analyses to increase the number of employees who can facilitate PHAs. However, this is not recommended by one of the Norwegian study participants. This participant argues that it is more beneficial to spend resources on external contractors with extensive knowledge in the methodologies, or by devoting resources to educate one internal resource (who does not participate in projects) in the PHA methods. The importance of having a study leader with extensive knowledge and experience is also described as part of IEC 61882 (2006) and by the EPSC guideline (Crawley & Tyler, 2015). In addition, Baybutt (2013) argues that expect from competence in the PHA method and process knowledge, the study leader must also have people skills. As engineers has not been required to show strong people skills historically, companies must ensure that their facilitators have the require qualifications to facilitate high quality PHAs (Baybutt, 2013). One could therefore argue that it could be beneficial to devote additional resources for education of internal resources if these have the required people skill qualifications. But in general, companies should be careful when deciding who should facilitate analyses as people skills are crucial for achieving high quality PHAs. This may recquire more financial resources and consequently companies must evaluate whether they want to perform many PHAs with less quality or fewer PHAs with high quality.

6.3 Handling of Recommendations

As presented in Section 4.3, handling of recommendations is one of the main topics which most Swedish study participants find as an area of improvement. Some of these believe a more industry specific software would help, while others highlight the disadvantages of using such software. Within the Norwegian O&G industry it is common to use document managing software, but according to the study participants working within the industry, the type of software is not the problem. The company's own guidelines are described as the main factor for successful handling of recommendations.

Karlsson and Käck (2018) also highlight the importance of implementing recommendations instead of letting them remain as just documentation. They suggest using an open risk management plan, which is described as an operational preliminary hazard analysis. The intention is to present the information about the recommendation, e.g., evaluation, status, and due date, in the risk management plan in connection to the scenario where the recommendation was identified. As the participants from the Norwegian O&G industry, Karlsson and Käck (2018) further highlight the importance of having a clear structure and tools within the company to enable efficient handling of recommendations (Karlsson & Käck, 2018). Baybutt (2013) also highlights the importance of having a clear structure of how recommendations should be handled to achieve successful PHAs. The keys are described as assigning responsibilities, defining deadlines, devoting additional resources if required, commitment from employees and providing management for follow-up by using a management system. What type of tools Baybutt (2013), Karlsson and Käck (2018) are referring to are however not clear and consequently it is not possible to support the statement regarding industry specific software, as described above. One could anyhow argue that whether industry software for handling of recommendations results in successful PHAs could be dependent on how mature the company is with regards to both risk management and use of software. It is important that the employees are comfortable with the system being used, otherwise an industry specific software may have the opposite effect.

As described in Appendix B, there are no specific standards for how recommendations should be handled, it is rather company specific. However, how risk assessments should be documented and how the improvements should be evaluated are more common in literature. For instance, in Swedish Civil Protection Service's handbook for risk analysis (Davidsson, Haeffler, Ljundman, & Frantzich, 2003), the focus is rather on evaluating risk reducing measures, rather than describing how to ensure that all improvements are evaluated. This may be the answer to why handling recommendations is experienced as a challenge by some of the participants. As there are multiple guidelines for how to evaluate risk reducing measures, handling recommendations in a practical and administrative way may be forgotten.

6.4 Standards and Guidelines

Working in a standardized and synchronized way is the other main area of improvement identified by the Swedish process industries. Having clear company guidelines is mentioned by both Swedish study participants and all the Norwegian study participants as crucial for further improved risk management. The Norwegian study participants mention company guidelines related to both decision making (e.g., how to choose type of PHA), execution of PHAs (e.g., PHA methodology and facilitation), and handling of results as important. This is also mentioned by Mcdonald (2004), who points out the potential for improvement by using PHA guidelines. Due to integrity reasons, it is not possible to present which interview answers are related to what kind of company. But based on the interviews, it is possible to conclude that the amount of PHAs is proportional to the level of structure in the risk management of the company. In general, those study participants who mention that there is a clear structure in the company regarding how to perform PHAs also highlight the importance of not being too personnel-based. As this topic is not mentioned by "unstructured" companies in the same manner, the awareness of the dangers of being personnel-based can be considered

higher in the more structured companies. It is however possible to argue that less guidelines and a personnel-based decision making enables more flexibility which could be seen as an advantage for some companies, especially for those with complex facilities. On the other hand, the guidelines should not be seen as limitations for process safety, rather a support for conducting successful PHAs. As described in Section 2.3, guidelines for successful PHAs should also include how PHAs should be performed with regards to equipment and meeting facilities. The intention of working in a standardized and synchronized way by applying guidelines is ensure that all risks are addressed. If the guidelines are not suitable for one analysis, guidelines could for instance include a statement about expectations and how these expectations should be made, e.g., by an agreement between two employees.

The importance of having a coordinated risk matrix within a company for evaluating risks is described by Davidsson et al. (1997) as crucial. But according to this study, performing PHAs in a coordinated way throughout the analysis execution is just as crucial. If the same system is analysed using different PHA methods, or performed and facilitated in a different way, the outcome of the analysis may vary. As described by Mcdonald (2004), the timing of a HAZOP is important for the results. Hence if there are no guidelines for ensuring that it is performed at the right time, it is not possible to ensure that the results are complete. In the end, the reliability of the results may decrease, and this means that the companies cannot trust the risk analyses. According to ISO 31000 (2018), risk management in terms of identifying and evaluating risks should be structured, iterative, and synchronized. Thus, all parts of the risk management chain should be in accordance with company guidelines, not only the risk evaluation part. By minimizing personal judgement, e.g., by avoiding letting specific employees decide which PHA method to use and rather base the decisions on company guidelines, the analyses can be performed in a more structured, iterative, and synchronized way.

As described in Section 4.4 the Swedish process industries express a need for additional guidelines and standards, as well as increased support from authorities rather than stricter legislation. Having vague legislation and regulations related to PHAs are according to Mcdonald (2004), a problem since it results in a large variation of how PHAs are performed in the industry. This may take out the purpose of the legislation as the companies cannot rely on the results of the PHAs due to the affected reliability of the analyses (Mcdonald, 2004).

When discussing the lessons learned from the Norwegian O&G industry, it is important to keep in mind that the differences compared to the Swedish process industry in terms of potential consequences and capital involved. One Swedish study participant highlights (see Appendix A) the importance of adjusting the analyses to a level that suits the facility. The participant further argues that even if additional and more detailed analyses are performed for the Norwegian O&G industry, it may not be well invested time for Swedish process industries. Related to this, it could be argued that rather than trying to achieve the same amount of risk analyses as within the Norwegian O&G industry the goal should be to achieve the same extensiveness regarding requirements and guidelines.

7 Discussion

This chapter aims to discuss the uncertainties of the study and how different decisions made during the project could affect the results.

7.1 Limitations

The study included process industries classified as upper tier and within several sectors, e.g., chemical industry, steel industry, and fuel industry. What could have been beneficial would be to focus on one sector only, as the different sectors may have different standards and ground rules. For instance, some participants mentioned deviation systems which were sector specific and based on the IA-system. However, this approach could be challenging as the study was depending on participation from multiple companies. In addition, as the study included only upper tier facilities it may not be possible to make an overall conclusion of how PHAs are used in Sweden. However, as upper tier facilities are embossed of extensive risks it could be possible that PHAs are used to a less extent in lower tier facilities. Based on the conclusion in Section 6.4, regarding the relationship between the amount of PHAs and structure of the risk management in companies, it could be argued that the lower tier facilities are less structured regarding PHAs.

7.2 Study Selection

As the study was depending on participation from company representatives it was not possible to include participants with the same role. However, the intention was to interview employees who preferably were responsible for PHAs or employees who are involved in process safety. As shown in Section 3.1, the roles include HSE, work environment, process safety, project- and production lead. In some companies, roles with different names means the same thing and in general, most study participants work with the same tasks. It could however be argued that a project lead or production lead may not be as involved in PHAs as a process safety manager as it is not their primary responsibility. Having study participants with different amounts of knowledge could affect the reliability of the results, as these participants may miss out on certain aspects. On the other hand, it could be beneficial for the thesis to include additional perspectives on the research questions. As responsible employees for process safety may experience that the PHAs work well from their point of view, while others who have different roles may experience the PHAs in another way. Multiple employees from each company would have increased the reliability of the results, as it would be possible to ensure that the data were based on facts rather than individual opinions. But due to the time limitations of the study, this was not possible.

The study also included one engineering consultancy company, in addition to the process industry limitation described in Section 1.2. The intention was to gather additional data regarding which PHA methods are used in Swedish process industries and to get an additional perspective of how the analyses are perceived. The same interview questions were asked, but only results that are applicable to the study, e.g., interview questions 1, 6, 8-10, are included in the report. In addition, the limitations and objectives of the study were described to the participants prior to the interview to ensure validity of the answers. It could however be argued that multiple engineering consultancy companies should have been involved to generate more representative results.

As described in Section 3.1, the selection was based on a screening which was depending on available contact information. Consequently, companies that are members of IPS or have been in contact with ORS were contacted as a starting point. Other companies were also contacted through contact information found on websites, but these were found not as successful as having direct contact. This may have weighted the results as companies involved in IPS may have a larger interest for process safety, and companies who have been in contact with external resources, such as ORS Consulting, may tend to use more external resources.

For the Norwegian O&G part of the study, four consultants from ORS Consulting working within the industry, were interviewed. Compared to the Swedish part of the study, the size of the data was just half as much which may affect the reliability. On the other hand, the focus of the Swedish and Norwegian studies differed. While the Swedish study aimed to perform an extensive survey of how PHAs are performed, the Norwegian study focused on lessons learned and potential improvements. Hence, it could be argued that the extensiveness of the two topics is reflected in the number of sample units. In addition, the roles of the study participants for the Swedish part differed from the Norwegian part as they are consultants working with several companies. The study participants from the Norwegian part of the study have brief knowledge about the industry, while the Swedish study participants have extensive knowledge about a particular company. This approach was thus regarded as suitable for the outline of the study, but additional participants from the Norwegian O&G industry with other roles, e.g., from engineering consultancy companies or facilities, would have increased the reliability.

7.3 Interview Execution

The study method was based on interviews rather than questionnaires, as it is more complicated to use forms for questions regarding opinions and experiences (Höst, Regnell, & Runesson, 2006). Using questionnaires as a basis for data collection adds pressure on the formulation of questions but more people can participate (Höst, Regnell, & Runesson, 2006). The discussion regarding whether questionnaires or interviews as a data collecting method can be seen as an evaluation between reliability and validity. Questionnaires could have generated higher reliability of the results, as it allows for larger sample amounts, while the validity would be lower as it is not possible to ensure that all reasoning interview questions are answered in a suitable way. Interviews on the other hand, do not allow for the same number of samples, while it is easier to ensure higher validity. Since forms still require participation from relevant stakeholders, interviews were considered a more beneficial method.

More specifically the interviews were conducted as semi-structured in-depth interviews. An important limitation with semi-structured in-depth interviews is, that it is not possible to check that the answers are true (Morris, 2015). In addition, conducting interviews were experienced as a challenge during the study as all study participants had different personalities and knowledge. Some participants were more extrovert and answered multiple questions at the same time, while others were more introvert and did not say more than required. This was a challenge since many interesting points came from introvert participants after asking follow-up questions and since the interesting points of the extroverts had to be captured from other information. An observation made during the interview execution was

that, that if the participants struggled with finding out what to answer, some started to talk about other topics outside the interview question. It was thus challenging to conduct the interviews in a way that ensured that the answers were appropriate to the interview questions. In addition, during the reasoning questions, 9-12, new information that were applicable to the first questions, 1-8, was given. This caused confusion as it became unclear whether the interviewee had forgotten the information or did not get the questions right. The importance of having an experienced facilitator, as discussed in Section 5.4, can thus be applicable even for interview facilitation. One strength of in-depth interview is that the interviewees get to talk about what is important to them (Morris, 2015). One example related to this is the handling of recommendations, which was an unexpected common topic. By performing interviews, instead of questionnaires or other methodologies, it was possible to adjust the study in a way that took advantage of the findings. It is however important to keep in mind that the main interview questions should not be changed as it would not make the answers comparable.

The interview technique was developed throughout the project as each interview gained additional experience. Hence, the interviews at the end of the study were led in a more confident way than the first interviews. This may have affected the results, but it is unclear in which manner. In addition, as the four study participants from ORS Consulting were colleagues it may have affected the interview execution, but most probably in a positive way. These interviews were easier to conduct, as their personalities were known before and since it was possible to refer to common experiences.

7.4 Analysis

The interviews were recorded in an indexical way of transcription which means notes were taken based on the timeline of the interview, but every single word that was said was not captured. Höst et al. (2006) highlight the risk of losing precision of the analysis by not applying full transcription. This aspect has been considered, as most of the interviews were recorded in Microsoft Teams to enable full transcription if required. However, as discussed in Section 7.3, the participants sometimes struggled with keeping the discussions to the interview questions, and limitations of the study, or they told sensitive information about the company which could not be used. Therefore, to ensure nothing unnecessary or sensitive information would be included in the report, and to save time, indexical transcription was applied.

The study identified which PHA methods are performed by the Swedish process industries participating in the study. This finding was also in accordance with other literature such as IPS's guideline for performing risk assessments (Karlsson & Käck, 2018). However, it is not possible to make a conclusion which includes other industries than process industries as these have not been included in the study. As described in Section 5.1, some companies may perform PHA methods in different ways, e.g., that a preliminary hazard analysis for one company could be defined as a HAZID by another company. The extensiveness of the analyses could also vary, for examples a company that perform HAZOPs often may also perform less extensive HAZOPs. As there are no national guidelines defining how each PHA method should be performed, it is not possible to ensure that the interviewed companies perform and experience the analyses in the same way relative to each other.

As the reasons for performing PHAs were shared for all companies in the study, it could be argued that having a safe facility is the main reason for analysing risks for all Swedish process industries. Multiple study participants mentioned the self-preservation as important, thus facilities that are embossed of similar risks may experience the same. However, for facilities which are exposed to slighter risks, it could be possible that self-preservation may be less present. In addition, it is also important to highlight that risk perception may vary between the interviewed participants. The objective to achieve safe facilities may be interpreted different by different companies and what is perceived as safe to one company may not be perceived as safe by another company. Thus, even if the reason for performing PHAs are the same for the interviewed companies, the practical application may vary.

All companies in the study mentioned recommendations as the main results of PHAs, therefore it could be argued that this is also applicable for other Swedish process industries. However, how recommendations are handled vary among the companies in the study. As described for the Norwegian O&G part of the study, handling of recommendations is rather company specific. Thus, it is not possible to make a conclusion of how Swedish process industries handle the results, i.e., the recommendations. What can be concluded is that multiple companies find handling of recommendations difficult. It is also important to keep in mind that these experiences are subjective. While some companies find it difficult to follow-up the recommendations within a certain time, others may find it difficult to ensure that all recommendations are follow-up at all.

Working in a structured and synchronised way was mentioned by multiple study participants, both from the Swedish- and Norwegian study. The possible disadvantages of applying guidelines for PHAs was discussed in Section 6.4. However, as the structured and synchronised way of working with PHAs was mentioned by the majority of the study participants, one could argue that these disadvantages are not seen as a concern. This study shows that there is an aspiration of working in a structured and synchronized way within the Swedish process industry. But the level of structure the companies are seeking may vary and the guidelines should preferably be adjusted to each of the companies. Based on the aspiration of Swedish process industries to work in a structured and synchronized way it could be argued that the identified lesson learned from the Norwegian O&G industry is applicable for other Swedish process industries. Having structured risk management is also mentioned in multiple standards. However, what is important with the lesson learned identified in this study is to work synchronized not only when evaluating risks, but for all stages and decisions. This includes choosing PHA method, performing the analysis and follow-up the analysis. If one part differ this may affect the successfulness of the PHA, and this vulnerability should always be avoided to ensure reliable analyses.

8 Conclusions

The study intended to identify how Swedish process industries work with PHAs, and which lessons learned from the Norwegian O&G industry could be applied to Swedish process industries. This includes identifying which PHA methods are used by Swedish process industries, as well as why and how they are performed. By identifying how Swedish process industries work with risk management in practice, companies can get inspiration which may improve how they work with PHAs. The intention of identifying lessons learned from the Norwegian O&G industry was to add additional perspectives on how risk management with regards to performing PHAs can be improved, as it is an industry characterized by mature risk management.

8.1 Main Study Results

The study identified preliminary hazard analysis, HAZOP, and What-If as the most common PHA methods. Related to this topic, the difference between Swedish process industries and the Norwegian O&G industry in terms of using What-If or HAZID was discussed. Among the Swedish participants, only five of ten used HAZID, while within the Norwegian O&G industry HAZID is always used as a starting point and What-If is barely used at all. The Norwegian participants argued that HAZID is a more structured and extensive method, and thus considered more beneficial than What-If. As this finding was made after the Swedish interviews, it was not possible to collect their thoughts regarding this statement.

The PHAs are mainly performed for modifications in existing facilities, for new designs, or as part of the Seveso safety report. Some of the Swedish companies perform certain PHA methods in cycles in addition to the Seveso safety report, e.g., re-HAZOP every fifth years, but this was not common for all. The main reason for performing PHAs was to have a safe facility and to meet the legislation was regarded as secondary.

The results of the PHAs are in general used to identify improvements with regards to safety of the proposed or existing design, by identifying recommendations. In some cases, the results are further used for other analyses, e.g., HAZOP as input for LOPA. But in general, results of PHAs are not used for other fields such as health or environment.

The main lesson learned from the Norwegian O&G industry, identified as applicable to the Swedish process industries, is to work in a standardized and synchronized way within companies. This includes having clear company guidelines, especially for how to choose PHA method, performing (and facilitation) of PHAs, and handling recommendations.

8.2 Further Work

This study identified a need for additional company guidelines as well as increased support from authorities in terms of national standards and guidelines. As described as part of the limitations in Section 1.2, the focus of the study was to identify how PHAs are performed in practice in Swedish process industries rather than making a gap-analysis to the Swedish legislation, regulations, and standards. Thus, further work could include mapping of Swedish regulations and standards and identify how these could be improved to support what have been discussed in this study. The Swedish legislation could also be considered vague in other areas, for example in connection to QRA or permit to work. IPS have guidelines both for QRAs (Nassiri, Bergstrand, & Lindblom, 2021) and permit to work (Danielsson, et al., 2019) which describes how QRA and permit to work should be performed in practice. Hence, further work could include a mapping of how Swedish process industries work with for instance QRA and permit to work as this has not been included in this study. This study identified barrier management as a topic which is growing within the Norwegian O&G industry, but it was only mentioned in a limited extent by the Swedish participants. As the reason behind this finding was considered unclear, further work regarding details of barrier management within Swedish process industries could be beneficial.

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Appendix A – Summary of Swedish Interviews

The following tables summarize the answers from the study participants working within the Swedish process industry. The answers are presented without any order for each interview question, e.g., the first answer for interview question 1 is not related to the same company as the first answer to interview question 2. Thus, it is not possible to identify who of the study participants answered what.

Interview question 1

What qualitative risk analysis methods do you use to identify process risks?
▪ HAZOP (mainly used); ▪ What-if; ▪ LOPA; ▪ Risk graph methodology.
▪ What-if (used at all facilities); ▪ Preliminary hazard analysis (used at all facilities); ▪ HAZOP (used at some facilities); ▪ Company standards – deviation analysis.
▪ What-if (for smaller changes, performed frequently); ▪ HAZOP (typical for large projects or large process changes); ▪ Preliminary hazard analysis (performed in conjunction with the Seveso safety report); ▪ LOPA (for scenarios identified in a preliminary hazard analysis with major consequences or for SIL classification after completed HAZOP); ▪ FTA (not frequently used); ▪ Event tree (not frequently used); ▪ HAZID (not frequently used); ▪ Checklist (for smaller changes).
▪ HAZID (mainly used as an overall analysis of changes implemented by projects); ▪ HAZOP (used for detailed phases of the projects, after a HAZID and in yearly cycles); ▪ LOPA (partly used related to HAZOP); ▪ What-if (mostly used related to personal risks): ▪ Preliminary hazard analysis (used for overall analyzes and as a basis for Seveso safety report). In general, FTAs, event trees, FMEA are not used. There are examples of occasions when variants of FTAs have been used to study specific risks.
▪ Preliminary hazard analysis (often linked to the Seveso safety report when identifying the plant's greatest risks, so-called “Seveso risks”) ▪ Bowtie (a more in-depth analysis of the risks with higher magnitudes, this analysis has been used more in recent years); ▪ HAZOP (typical for new installations); ▪ HAZID (typical for new installations); ▪ FMEA (typical for new installations, but is not as systematically used as HAZOP and HAZIDs); ▪ Interruption analyses where the entire production is analysed in a three-years cycle with a focus on interruption risks. In this analysis, the team goes through the system and analyse the consequences of each machine having an interruption. This analysis forms the basis for investment priorities.

- HAZOP;
- LOPA;
- FTA (not as frequently used as HAZOP och LOPA);
- Event tree (not as frequently used as HAZOP och LOPA);
- Preliminary hazard analysis (depending on the phase, usually this is already done when entering the projects);
- HAZID (mainly for project risks);
- FMEA.

Confirms that HAZIDs are used much less in Sweden and What-If is more common.

- Preliminary hazard analysis;
- HAZID;
- HAZOP;
- LOPA;
- SIL-classifications;
- JSA (Jobb Säkerhetsanalys) for special work which is not carried out regularly and for which there are no work instructions or routines;
- What-if;
- Checklist (see below).

Highlights the small difference between HAZID and preliminary hazard analysis.

Explains how requests for small changes include routines for smaller risk assessments. This is a light variant of a risk analysis. For these analyses, the team is smaller than for other analyses, e.g., HAZOP, and the level of detail is lower. Checklists are typically used.

- What-if;
- HAZID/Preliminary hazard analysis (see comment below);
- HAZOP (both preliminary and final HAZOP);
- LOPA or risk graph method (usually performed together with the final HAZOP to streamline);
- Bow-tie.

Does not attach much importance to the method, for example, the term HAZID is used to explain that it is a risk analysis on a higher level. The HAZIDs on the company is more like a What-if without applying What-if questions. The type of analysis is often depending on what it is about and how much time is available.

Risk ranking is not performed for early stages, this is done in later phases.

- What-if;
- Preliminary hazard analysis (for all risks at the site);
- HAZOP (with modification). For changes, a list produced by the company which could be compared to a HAZOP is used. The list includes various aspects that can affect the system being analysed;
- Bowtie.

The risk analyses are often a mix of What-If, Preliminary hazard analysis, and HAZOP. After these risk analyses, bowties are sometimes performed to further study a typical risk and defining barriers.

- Preliminary hazard analysis;
- HAZOP (see comment below).

Preliminary hazard analysis is mainly used (regardless of whether it is linked to process risks or work environment risks). This preliminary hazard analysis is based on a HAZOP methodology. Today, preliminary hazard analysis is performed on already existing HAZOPs, based on the changes since the previous analysis. HAZOP was used more before, but this disappeared in connection with the company losing competence within the method.

Interview question 2

Why are the chosen methods used instead of other methods? Who decides which method to use?
The PHAs are chosen mainly based on the experience of the employees at the company, the knowledge available, and what is considered reasonable for the facility. The interviewee experience that there is a lot of knowledge at the facility, but the challenge is to get this down on paper. The company is not considered to be particularly company-controlled regarding risk analyses. There is a risk matrix from the company which includes frequency, consequence, and probability which intend to support risk evaluations.
The security department recommends which analysis should be performed based on the background to the analysis. The company strives to make synchronized choices of analyses and follow a standard to ensure that there is a history of how to work. There is also a desire to not use too many different methods, as there should be a continuity in the analyses. The analyses should be known by the employees and executed in a standardized way. The interviewee also highlights that the choice of PHA is not written in stone. In summary, the main goal is that the choice of PHA should be as appropriate as possible and that the number of different methods used at the company should be limited to what is stated in the company requirements.
The responsible engineer for process safety usually decides which PHA method to be performed. The choice depends on how accurate the analysis needs to be. Usually, the responsible engineer for process safety asks the group of involved employees. This group consists of the production manager, maintenance manager, operators (safety representative or other), process engineer, and production engineer.
Preliminary hazard analyses have historically been used as a basis for the Seveso report in the company. The preliminary hazard analysis is described as a good analysis for assessing the risks at a higher level and is thus used frequently. The decision to start using bowties at the company was made by the employees working in the security department and it was not controlled by the central management. The bowtie methodology is described as a good methodology to illustrate risk and easier to understand compared to, for example, HAZOP that can be more confusing. The interruption analyses have been used since the 1990s and were a collaboration between the business community authorities. Thus, the interruption analyses are used as they have a long history in the company. The reasons for why some methods are used instead of others are mixed, some have been in the company for a long time and other have been introduced by employees. The company management is not described as controlling regarding which PHA to be used.
It is the employees working with the risk management at each facility who decide which methods to use. The company does not require all facilities to use the same, even if it is a request from the interviewee. The importance of choosing analyses that are feasible for the level of complexity of the plant and the knowledge of the employees is highlighted. It would be possible to perform more detailed analyses, but the organization is not considered mature enough since it requires a lot of knowledge, time, and resources to perform these analyses. Therefore, they do the best of what they have, and thus it is depending on the people who work at the facilities.

There is a certain degree of freedom linked to which analyses to be performed and when. The company has established a group of process risk analysis leaders as part of the management system. This group consists of five people who can facilitate the risk analyses and decide which PHA method to use with responsible project manager. There is thus a degree of freedom for to choosing different methods for several purposes. The company has decided that re-HAZOP should be performed every fifth years, which should be separate from the preliminary hazard analysis performed in connection with the Seveso safety report. This is described as strongly recommended by the company, while the preliminary hazard analysis is described as recommended in connection to the Seveso safety report. The reason why HAZID has not been used instead of, for example, preliminary hazard analysis, is because the preliminary hazard analysis has been used for a long time in the company and because the interviewee feels like there is not have enough experience of HAZIDs to perform it more often or instead of other analyses.
The type of PHAs used are described as experience-based. Together with an external company. HAZOP was used during the start-up of the facility and has since then continued to be used as a central analysis within the company. The company has fixed guidelines, e.g., HAZOP must be performed in each project. But it is the employees who to the greatest extent decide which methods to use. As the company have limited resources, it takes EPCM (Engineering, Procurement, Construction) contracts. The choice of risk analysis method is thus influenced by the company participating in the project and what experience they have. The interviewee describes that the company generally bases its risk management work on how facilities in similar industries nearby work with risk management.
In general, the risk manager decides which analyses to be performed, but it can also depend on the sub-project manager. The project managers' experience and how risk-conscious they are can affect how many and which analyses are performed. In practice, the choice of risk analyses is thus person dependent but there are basic requirements and principles to be followed when choosing type PHA, as well as a timeline for this. Experiences that subcontractors and other stakeholders are more risk-aware nowadays than before. Risk is now discussed at the beginning of the meetings, unlike before (not specifically for the company) when risk was discussed at the end. The subcontractors are not negative, but they see PHAs as a tool for developing and improving their systems. The sub-project managers often request to perform different analyses, for example, a HAZID, to solve different problems. This is because the method is perceived to work very well.
There are company standards which describes how the risk management should be performed, for example how a HAZOP is performed. The methods used are standard and well-established analyses, which the interviewee believes is the reasons for why they are used at the company.

Interview question 3

What is the reason for analysing process risks in general?
The legislative requirements are not perceived as a reason, it is rather based on self-preservation operations. The company has a policy that says that health and safety should always come first. The risk analyses focus mostly on safety. Sometimes investigations are made to see how to optimize the process (management of change), but this is not linked to the risk analyses as such.
The analyses are partly performed because the Swedish Work Environment Authority sets requirements, but also because it protects the employees. The company has the ambition to have a very high level of personnel safety. Expresses that the analyses are not used as documentation only, they should also have a practical function.
The reason behind the risk analysis depends on the stage of the project. In the early demonstration phase, there are financial underlying reasons, such as dimensioning of equipment. Legal requirements are obviously an important point, but there is a goal picture (not fully stated) that the company should be better than the legal requirements as the company itself want a safe facility.
The most important and main purpose of analysing process risks is described as having a safe facility. There is a zero vision, meaning that no one should be harmed at the facility, and this is central in the risk management within the company. Having a safe facility is thus the highest purpose, after which legislation can be considered as a reason but at a lower level. Optimizing the process is included as a parameter in the risk analyses (property is evaluated in the risk matrix), but this is secondary in relation to personnel and environmental risks.
The main reason is to have a safe workplace. There are projects with the aim to optimize the process, and when these projects arrive at improvements to be implemented, they are assessed by several risk analyses. But the risk analyses are not used as a first step to identify optimization potentials.
The reason why process risks are analysed is partly linked to legal requirements (e.g., Seveso legislation and the Work Environment legislation) and company requirements (e.g., re-HAZOPs every fifth years), but also to optimize the process. The main purpose is to have a safe facility. The demand for this is described to increase over time, both from the society and through legislation. The interviewee describes that the legislation is mandatory, but it also helps the company to work towards what they want, i.e., to become safer. The interviewee emphasizes both the importance of no one being harmed and the financial benefits that can be achieved in the long term. The legal requirements are described as helpful in obtaining mandate internally to perform various risk analyses, in this way the legal requirements are described as a good basis.
The main reason is to have a safe facility and the interviewee highlights the self-preservation operations. Legislation is also described as part of the reason, but this is mainly due to the responsibility to inform municipalities and authorities about the risks of the facility. Optimization of the process is not regarded as a central part, but the site itself has added property as part of template for risk assessment evaluations.

The main reason is based on the company's desire to have a safe facility, with regards to health, environment, and safety. The interviewee describes the great advantages with performing risk analyses, for example identifying errors from the outset. The company has also focused on availability, maintenance, and access in the latest analyses to include parameters that can optimize the process and thus also get the financial benefits of risk analyses. The interviewee believes that the company has regained the work that was put into the risk analysis by spending additional time on the mentioned aspects.

The company works towards harmonized standards. The interviewee experience that there may be questions of interpretation which could be challenging, but the company has representatives from all departments who work with interpreting these.

The company have internal requirements on interruption analyses, as part of "loss control guidelines" which are preventive guidelines.

The company aims to have the world's safest facility in the in the sector, which is described to characterize the security work. Highlights the importance of avoiding incidents which affects people, environment, or assets and if this is fulfilled, there will be a more stable production that the company can profit more from.

Regulatory requirements are described as an important part in principle, but the ambition is to have a stable production and a high level of process safety, hence the regulatory requirements are not the only incentive.

Interview question 4

When are the risk analyses performed? What is the underlying reason why they are performed at a certain time?

Risk analyses are performed in all phases of the projects, some methods more often than others. The interviewee refers to the book *Guidelines for Integrating Process Safety into Engineering Projects* regarding which methods are used for several occasions. The intention is to work in accordance with the book at the company.

There are three categories of process risk analyses:

- In the event of changes, both small and large changes which are implemented though projects;
- Periodic analyses, in connection with the Seveso safety report (preliminary hazard analysis and LOPA) every fifth years or re-HAZOP every fifth years;
- Spontaneous, for example after an incident. Sometimes there are legal requirements linked to certain incidents that require a risk analysis to be performed before the process can be started again;

To perform PHAs in projects related to changes in the process is described as a part of the project process and is a legal requirement from the Work Environment Act. But the PHAs are also important for ensuring that the design being developed is good.

The interviewee experience that the preliminary hazard analysis performed for the Seveso safety report and the re-HAZOPs (performed each fifth years) complement each other very well. But at the same time, the interviewee experiences that these periodic analyses require a lot of resources and take a lot of time from other work. The advantage of performing both the preliminary hazard analysis and HAZOP periodically is because they have different focus, as the preliminary hazard analysis focuses on large-scale chemical accidents while the HAZOP focuses on details and helps to optimize the process.

HAZOPs are performed for all projects performed at the facility.

Different analyses are performed at different occasions:

- In the case of major renovations or new systems, the external actor who perform the projects usually also do the risk analyses. When the project is to be implemented in reality, an analysis is made by the facility owner (the company);
- Special hazards are identified and assessed continuously with reporting systems (IA-system).

HAZOPs are used for renovations or new designs. HAZOPs are thus not performed continuously, but when existing systems are changed.

A Preliminary hazard analysis is performed each fifth years in connection with the Seveso safety report where an updated risk picture should be presented.

Risk analyses are performed in the following occasions:

- Continuous audit, each fifth years;
- In the case of incidents, which require further investigations;
- Reconstruction or change (difficult to define what is a small or large change according to the interviewee);
- New substances are introduced to the plant or reclassification of substances.

About 230 risk analyses are revised at an interval of five years.

The company performs risk analyses every fifth years for each process at the facility. The various processes are usually divided during these years, meaning that every process is not assessed in the same year. This means every year there is at least one process which is analysed. This is because there are other analyses, e.g., related to changes in the facility, that need to be performed in parallel.

PHAs are always performed in connection to renovations or major modifications.

The following qualitative risk analysis are used at different occasions:

- Preliminary hazard analysis performed related to the Seveso safety report (each fifth year) to identify the plant's greatest risks, so-called “Seveso risks”;
- For new installations HAZOP, HAZID and FMEA (not as systematically used as HAZOPs and HAZIDs) are performed;
- Interruption analyses are performed periodically, each third year.

Incidents or risk observations can trigger a risk analysis. How often risk analyses are performed is based on incidents or risk observations and the extent of these. The interviewee points out that the frequency of incidents or risk observations may be depending on the risk awareness and hence it is not completely proportionate to how often risk analyses are performed. The company uses a reporting system, which includes environmental, work environment, and process risks. Since 2018, process-related incidents have been compiled to the responsible departments every month with the help this system. The reason behind this is to sort out which incidents and risk observations have been identified in the system and should be analysed further. Both actual consequences and potential consequences are reported to highlight if the incidents could have been even worse.

Surveillance of the outside world can also be an underlying reason for performing a risk analysis.

Risk analyses are performed for daily work in connection with work permits. They are also performed in connection with rebuilding and changes of the facility (mainly HAZID and HAZOP).

The analyses are described as having a certain validity period, usually 5 years, after which the respective analysis should be updated.

Interview question 5

How often are the analyses performed?
A HAZOP is performed at the end of every basic design or at the beginning of a detailed design (preferably at the end of a basic design to ensure that everything is captured before moving on to the next phase). Based on how the extent of the changes made in the design after the HAZOP, additional risk analyses may be performed. Continuous risk evaluations are performed when working with the 3D model.
Different analyses are performed with various frequencies: ▪ Simpler risk analyses of hazards identified with the deviation reporting systems are performed continuously; ▪ New designs, often requires larger analyses; ▪ Management documents state that every third years, a comprehensive risk assessment must be perfromed based on hygiene, behavioural factors and technical factors.
PHAs are performed in connection with renovations, changes to the facility, or certain incidents or risk observations. Hence how often the risk analyses are performed varies depending on several factors. In addition, some risk assessments are performed periodically, e.g., every fifth year for the Seveso safety report (preliminary hazard analysis) and every third years by the interruption analysis.
At least every fifth year for the Seveso safety report and related to new rebuilding or changes in the existing system. Consequently, the frequency of the risk analyses varies depending on several factors.
About 230 risk analyses are revised at an interval of five years. For systems that are particularly exposed / characterized by high risks, audit analyses are performed more often. In addition to the continuous audit, risk analyses are performed in case of incidents, renovations, or changes to the design, or when new substances are introduced.
PHAs are performed for each new design. Hence it is not possible to give an exact number of how often the analyses are performed. But the more comprehensive design the more analyses.
The company performs risk analyses every fifth year for each process at the facility. The various processes are usually divided during these years, thus not everything is performed for one year. This means that every year there is at least one process to be analysed. In addition to the periodic analyses, PHAs are performed for rebuilding and major modifications.
PHAs are performed as analyses, e.g., every fifth year. In addition to this, risk analyses are performed on daily basis related to permit to work and in conjunction with new designs, renovations, and modifications in the process.
HAZOPs are performed for each project, as well as What-if and LOPA if necessary. The analyses are performed mainly for the projects and less often for the existing facility. It has been discussed whether there should be a retake with HAZOP on the entire facility, but today there are no schedule for this.
Periodic analyses are performed every fifth year (Seveso safety report and re-HAZOP). Re-HAZOPs usually take 100 full days in five years, for example re-HAZOP is performed every Tuesday for 40 weeks this year. The latest preliminary hazard analysis and LOPA which was performed for the Seveso safety report required 30 full working days, but for this analysis, they started all over again. Minor analyses (such as a checklist) are performed for all small changes, which is about 100 per year. These analyses usually take one hour and about three to five people usually participate.

Interview question 6

How are the analyses performed? What experience do the participants have?
In general, the following positions participate during the PHAs: ▪ Operations manager / department manager; ▪ HSE; ▪ Safety representative; ▪ Operator with extensive knowledge; ▪ Technology/development (mainly in the event of changes); ▪ Eventually an external contractor who is involved in the system. Approximately five people participate during the analyses in general. The interviewee highlights the importance of not being too many during the analysis. Usually, they take the questions as follow-up outside the analysis meeting instead of inviting too many.
The company performs both internal analyses and analyses with the help of consultants. The purpose company has an internal group of facilitators who can conduct the smaller analyses, e.g., the checklists. But for larger analyses, for example HAZOPs, an external facilitator is usually contracted but the scribe is usually an internal resource. Consultants are hired to reduce the burden on the internal employees but also to gain more knowledge and see the facility with new eyes. About five people participate in re-HAZOPs, but for HAZOPs in connection with projects, more people usually participate as more disciplines are involved in the projects. Instrument engineers, for example, are always involved in HAZOPs linked to projects, but it is not possible for them to participate in re-HAZOPs since it takes too much time. The interviewee believes that process engineers should be able to answer questions for the instrument engineers at re-HAZOPs since the design is not new. Operations and process always participate in re-HAZOPs (and project HAZOPs). Safety representatives always participate, they are also from the operations, which means that they have operator knowledge. For larger analyses (not internally facilitated), both an analysis leader and a scribe participate. But for the smaller analyses, the facilitator and the scribe are the same persons. A total of three to seven people participate in analyses of minor changes (performed internally). The facilitator must decide which disciplines are needed for the analysis and how many should participate. The interviewee describes the trade-off between getting the right knowledge (the number of participants) without inviting the entire company. It is important to get as much out as possible with as few people as possible for the analysis to be effective. Risk awareness is described as high, there is an established culture of doing risk analyses. Most employees have participated in several analyses, are used to the methods, and has a generally good understanding of the purpose.
In general, for systematic and larger analyses there are approximately five to ten participants. The participants are usually operators, responsible managers, and safety representatives. The interviewee expresses that there must be a wide range of skills to capture the whole perspective. The risk awareness is described as good. The interviewee describes that if process safety would be highlighted even more it would be possible to bring in more risk observations related to process safety.

At least five to six people always participate in the analyses, including the following people:

- Chairman (typically a sub-consultant or customer representative);
- Scribe;
- Automation engineer;
- Instrument engineer
- Process engineer;
- Process safety engineer;
- Project lead;
- Eventually a specialist within a subject.

Operations always needs to be involved as they know the process best and know how they intend to run the facility. Highlights the importance of having the right competence and a suitable number of participants. Internal resources from the facility are the most common resource for the facilitation of PHAs.

Experienced that the participants in general have good understanding for the PHAs.

The risk analyses are performed by a facilitator, scribe and participants from four to five different disciplines, e.g., operator, safety representative (working in the process), electrical and instrument manager, engineering manager, mechanics, maintenance, fire protection, project manager. There are standard lists for which people should participate.

For participants who have not participated in risk analyses at the company, a short training is performed prior to the analysis. The challenge is to keep the participants in place and follow the methodology for the analysis. The interviewee describes the importance of presenting the agenda, the risk criteria, and how to evaluate barriers already at the beginning of the analysis.

The interviewee has made a document for process safety that shall be used at the company. It will be a requirement that those who work with process safety issues at the company to use it. The idea is that the project managers should use the document as a background when they perform their analyses. The interviewee experience that the process safety document is often sufficient for those who perform the analyses to be familiar with the risk analysis method.

The analyses are usually performed internally with those who are employed by the company, but it happens that consultants are hired, e.g., when more knowledge is required.

The interviewee experiences that those who usually participate in the risk analysis (typically production manager, maintenance managers, operators, process engineers, production engineers) are interested and have good knowledge of the processes and risks. The company have arranged training for all operators at the site which is described as beneficial for the risk awareness.

How the analyses are performed is described as depending on the type of PHA. How many and who participate in a HAZOP is governed by the competencies required for the system to be analysed. An approximate number is about ten people, but this number may vary. In addition to those who participate in the analysis, a call-list is used, which is a list of people who can be contacted if additional competence in a subject is required. The interviewee explains the importance of having the right number of participants in the analysis, and the risks of being too many participants. This is described as a responsibility for the facilitator.

In general, eight to ten people participate in the analyses, both internally from the company but also externally. The company uses the PHA-Pro program to perform the analyses.

Consultants are often hired as facilitators and scribes for analyses. The same facilitator has been used at the company for a long time, this person knows the systems and the facility well. The participants are internal employees of the company who have knowledge of the system to be analysed. If an engineering company has been involved in the design, they also participate in the risk analysis. Many participants have participated in several risk analyses before and are familiar with how the risk analysis methods work. The method is always presented at the beginning of the analysis to ensure that everyone who participates has the knowledge required for the analysis.
The company puts pressure on those who perform the analyses to have the knowledge required to be able to facilitate the analyses. It is the manager who delegates the analysis assignments to engineers, who then must decide how many should participate in the analysis. Different people from the company who participate, such as engineers, operators and always at least one safety representative. The company attaches great importance to the participants' planning and preparedness for the workshops. The interviewee expresses that the knowledge about risk management would need to be improved.

Interview question 7

Who facilitates the qualitative risk analyses?
Consultants are often hired as facilitators and scribes for most analyses. The same facilitator has been used at the company for a long time, who knows the systems and the facility well.
External resources perform the analyses in teams.
Smaller analyses such as checklists are performed internally, while larger analyses are (in general) performed with the help of an external facilitator.
The type of facilitator for the risk analyses varies, there is internal competence to facilitate all analyses, but sometimes external actors are used instead. The background behind why internal resources is used instead of external resources, and vice versa, varies from time to time.
The PHAs are in general facilitated by the company's own employees but sometimes consultants facilitates.
The analyses can be facilitated by both external actors and internal employees, depending on the scope of the analysis and who participates in the projects. In some cases, the company takes help from suppliers, or experts such as burner experts who participate in the risk analyses.
In general, the company hires external consultants to ensure that someone can see the system with new eyes. For example, for the Seveso safety report where the entire facility is audited, an external consultant is hired. If there are minor revisions, these are usually made with internal resources only.
So far, it has mainly been internal resources that perform the analyses as there is knowledge internally to conduct analyses.
Who performs the analyses may depend on the project. For renovations or new designs where external actors are involved, they also conduct the risk analyses. In these cases, representatives from the company (and always a safety representative) also participate. Sometimes consultants are hired for facilitation of other analyses. The internal risk analyses are typically led by engineers and managers.

Interview question 8

How are the results from the process risk analysis used? Are the results used as a basis for other risk assessments (e.g., in health and the environment studies)?
Works with the identified recommendations after the analyses, which form the basis for implementation of changes to ensure a design with as low risk as possible. The recommendations are always followed up and handled carefully. Deviation systems are sometimes used to coordinate the recommendations, but other follow-up methods can be used for recommendations.
The results are used as a basis for other assessments and to identify areas that need to be addressed. The interviewee experiences that the company do not value the measures before they are implemented. If something is classified as red or yellow according to the company's risk matrix, they try to fix the problem, but today they do not really give feedback on whether it was good or not. The interviewee highlights this as something the company should get better at.
For all HAZOPs in project phases the recommendations play a major role in the work ahead. The HAZOP is a self-evident part of every project phase, and it is always performed before locking the design for each project phase. Thus, the recommendations are applied in the design, and some scenarios may lead to a LOPA. Hence, the results are used as a basis for the other analyses but not for health or environment in that manner. The interviewee experience that the results from HAZOPs in projects are used to the greatest extent. PHA-Pro is used for documentation and management of the results of HAZOPs (and other analyses).
The recommendations are handled, either by being implemented or rejected with a comment or argument. In the event of changes, the previous analyses are included as appendices until start-up. The company has a system for recommendations that are based on a list in SharePoint, which is more like a database or archive. This list follows if and when the analyses are closed. An analysis can only be closed if all recommendations are handled. The work process includes that the responsible for the risk analysis and the project manager agree that recommendations are handled, and then the analysis can be closed. Every month they try to check that as many analyses are closed and opened, but this mainly applies to smaller analyses in connection with small changes (checklist method). For larger analyses and recurring analyses such as the Seveso safety report and re-HAZOPs, everything is transferred to action plans (which are created in Excel). These risks are then followed up during a year before the risk analysis can be closed. The recommendations are then moved to other action plans where it is possible to keep them open instead of having the whole risk analysis open. In the action plans, it is possible to use different types of dashboards to get an overview of the risks and recommendations. There is a system for incident reporting, which for example sends reminders, but similar systems are not used for risk analyses. The system for handling results of risk analyses are more manual.

The results of the analyses are based on the risk evaluation template, i.e., whether it was low, medium, and high risk. For scenarios classified as intermediate, measures to reduce the risk are always described. If the risk is described as high and it is an existing system, the production must stop, or alternatively temporary measures that reduce the risk until other solutions can be implemented. Recommendations are collected manually in action lists which are the results of the risk analysis. The recommendation responsible should always show how far each recommendation has come in the work and whether the measure had the desired effect. The company has a desire to summarize the overall risks in a good way so that the employees at the facility can easier take part of it.
The company uses and investigates the analyses, and then implements the recommendations that are deemed appropriate. Currently, the company is building a system for collecting recommendations, which can also be used for, among other things, deviation reporting. The purpose of this is to be able to work with the recommendations and get a traceability in what has been done. For example, if a recommendation is not implemented, it should be possible to trace why it was not implemented. The interviewee explained that they want it to be more system-controlled than individual-controlled. With this new system it may be possible to receive system reminders. Previously, there was only a list of open recommendations.
The company always follow up the analyses, all recommendations are followed up carefully and should always be closed. The recommendations are used to ensure that all safety equipment needed is implemented in the design. The results are for instance used as a basis for SIL classifications. The recommendations are usually handled in Excel without any help from action management system. There is various software for documenting HAZOPs and these can usually be exported to Excel. The follow-up is perceived to work well. If all recommendations are not closed, it is not possible to close the project.
The results from the risk analyses are used as a basis for future risk analyses, e.g., preliminary, and final HAZOP and LOPA. The results are also used as a basis for financial decisions and to find potential for improvements. The company use the program PHA-pro for handling of recommendations and results.
The company follows up the recommendations from the analyses. They make an action plan of what measures are to be taken immediately after the risk analysis. Then the measures are followed up after six months to see if they have been implemented or why they have not been implemented. The recommendations that have not been implemented are in the longer-term included in the company's case management system, for future follow-up. When the next risk analysis is performed, it is not based on previous analyses but focuses on the updated process drawings that are available at the time. When a risk analysis is completed and the measures have been implemented, that risk analysis is archived. Hence, when the next risk analysis starts, they start from the beginning, but there is usually focus on what has changed since the last time a risk analysis for the system was performed.

After the risk analyses have generated a result, it is usually presented to the top management locally at the facility but also at the responsible departments. Hopefully there are also recommendations that can make the facility better.

The interviewee describes that they try to keep the analyses alive as long as possible to ensure that they do not become material that only lies on the shelves. But keeping the analysis alive involves a lot of work. The interviewee's role has no direct responsibility for the follow-up, but rather a support function that will help others by providing competence about risk management. The interviewee experiences that it is a challenge, not because there is a lack of commitment but because those who are responsible for the different areas have a lot to do with their other tasks.

A reporting system is used which requires that each recommendation is investigated and there is an automatic reminder.

For the interruption analysis, the results are entered in the investment plan, and they are prioritized relative to everything else. The responsibility thus goes on, but they try to follow it up when the next interruption analyses continue.

Interview question 9

How do you experience the analyses? What are the difficulties/shortcomings? What is good?
In general, the analyses are experienced to work well since those who participate are motivated and knowledgeable, and there is a permissive environment. The interviewee highlights that the facilitators (both internal and external) have a responsibility to create the right conditions for achieving a successful risk analysis. This includes encouraging creativity, not allowing anyone to ridicule someone else, letting all participants speak, etc. The interviewee experience this a strength of the company. Much has happened in the last two years which has improved the work, the internal group with facilitators did not exist a couple of years ago and the work process for risk analyses were not described in the management system either. The interviewee experience that everything is still quite manual which makes the work depending on the facilitator group, but since there are five people in the group, the system should be able to cope with eventual changes in the group, but the system is not completely waterproof. The interviewee does not feel like the work becomes person-dependent but points out that the more manual a system is, the more person-dependent it becomes. The company has become better at closing the analyses since they started to focus more on it, which has started to give results. In the past, recommendations could slip through and not be implemented even though they should have been implemented. This never happen today as there is a greater focus on follow-up and signatures along the way. The action plans for the larger analyses are described as being relatively new and a challenge in connection with this is how it should be linked to the budget and goal process. Many recommendations are about something being investigated further to produce a cost, and then evaluating whether it should be implemented or not. This requires a lot of work to coordinate, and it could be possible that a more automatic software could be used to improve the work. There is today a management system, but the weak link is that it requires some manual work.

The interviewee feels like the company does not evaluate the measures that are introduced. If something is classified as red or yellow according to the company's risk matrix, they try to fix the problem, but today they do not give feedback on whether it was an improvement or not.

The interviewee describes thinking in the same throughout the company group as a challenge. This is something the company is trying to improve by having an employee with a coordinator role for this. In addition, the interviewee states that there should be more clear guidelines from company's central management, which is described as crucial.

There are many operators showing strong interest in risk management.

It is important to make the right conditions for good discussions. The interviewee experiences that with larger groups there is a risk of becoming more of an information meeting. One difficulty is described as having the right competence in the analysis, but the company tries to work with this by hiring consultants who are experts in different areas. Experiences that it is easier to perform analyses on new systems, than for existing systems because it requires that more aspects are taken into account.

In general, the interviewee experiences that the analyses are performed systematically and work well.

In 2020, a calibrated risk matrix was implemented, which is used throughout the company in all disciplines. In this way, it is ensured that each project assess risks in the same way.

The interviewee explains that the company has started to focus more on the education of the employees.

A challenge is described as linked to SIL classifications and their service life.

The difficulties are described related long and time-consuming analyses. If the facilitator does not have full control, the discussions can be more technical discussions that do not belong in that risk analysis and thus make the analyses too long. There is a challenge to keep the workshops short and concise and refer technical discussions to other sessions outside the risk analysis. The purpose of a risk analysis is not to solve problems, that is done in a design review. This requires that the participants are aware of what is to be discussed in the workshop. The interviewee experiences that it works well when it is an experienced facilitator. When there is no clear structure for how the analysis should be performed, the analysis does not yield as much and does not become comprehensive. If internal facilitators are used, there is a risk of becoming home blind.

What works well is that risk analyses often provide an expanded understanding and an eye-opener between the different disciplines. The interviewee points out that this should already be understood when the design has been worked out, but different perspectives between the disciplines give increased understanding.

The interviewee describes the benefits of someone who has not worked so much with a facility or project previously participating in risk analysis. This means that new risks which have not been considered before can be identified. The interviewee describes an example where a company saved a lot of money because someone new to the project mentioned an aspect which had not been thought about.

The interviewee experiences that when preliminary hazard analyses are performed on old HAZOPs, risks could be forgotten. This is something the company will develop, and HAZOPs will instead start to be performed separately.

The risk analyses for different systems can have different quality, and this is mainly because different departments work in several ways. As there is no clear support for how the analyses should be performed, the risk assessments can become subjective. Some departments are good at one part, while others are better at another. The interviewee wished they had collaborated more, using a clear structure as a basis.

Overall, there are no problems with the risk analyses, they work well. How well an analysis goes is described as depending on the participants. The group composition must include the experts, and there should be at least one person responsible for each system. This has worked very well as there is usually a small group where everyone are experts. The small group of competent participants makes it easy to make decisions and get the right information.

The interviewee explained how some of the employees have difficulties in drawing a connection between an event and what measures are reasonable to implement. In this case it is important to understand the risk criteria being used at the company. The interviewee suggests that when such topics are discussed it is more beneficial to perform a HAZID where the scenario can be discussed in a structured way.

How the risk analyses are facilitated plays a major role for the results. For example, discussing consequences without barriers was mentioned as a topic. The interviewee describes how the participants typically have difficulties describing the consequences, not including safeguards. The participants often start discussing the barriers immediately, which is not correct.

The weakness is how the company works with the follow-up. This includes using action lists, closing actions, and finding a responsible person for all recommendations. The interviewee experiences that many believe someone else will do the job and that the analysis is over when the workshop is over. Therefore, it is important to go through all the recommendations at the end of the workshop and identify a person in charge. There are systems for recommendations in PHA Pro, generating lists of actions in different formats. The company will develop a centralized system for follow-up but today it is not entirely clear how it will be.

The company use only one risk matrix, which includes consequences that affect personnel, property, and environment. Adds a breakpoint to the frequency scale to get a scale lower than 1/1000 years, 1/10000 years, and 1/100000 years. This allows more serious events to be illustrated in a simpler way, e.g., by reducing risks in two steps and further explaining the need for SIL classification. This is explained as beneficial for the risk analyses. Availability, production downtime, and cost of measures can also be included in the matrix. It is important that everyone agrees on the criteria and that the company stands by them.

Based on the interviewee's short experience of the company, the analyses have worked well. The interviewee points out the importance of having a good balance in the group, for example not to be too few or too many and that people with knowledge of the system participate.

The interviewee experience that the company take the risk analyses one step further, for example, the SIL classifications are done directly in the HAZOP.

The interviewee experience that it is sometimes difficult for the participants to imagine that different scenarios with a certain dignity can occur, e.g., serious events. It could be difficult to analyse from a perspective that includes the worst consequences. This has become better as the interviewee has started to talk more with the employees about it. One strength is that safety responsible disciplines are often out talking about this and are present in the organisation. One challenge is that the facility has looked very similar since the 70s, and therefore it is not always easy to get hold of all drawings and functional descriptions.
The interviewee experiences that the company works with risk analyses in a rigorous way.
The interviewee experience that the imagination during the risk analyses are the weaknesses. It would sometimes be an advantage if the company took the help of someone external to get new perspectives and contribute with other experiences. As it is now, the participants may be limited in terms of knowledge and experience as they do not have as much experience from other facilities. The advantage of conducting risk analyses with internally is that it is more simple, more flexible and enables risk analyses to be performed frequently. What works extra well is that the risk analyses can be done in a smooth way internally and that everyone is committed and interested in a safe working environment.

Interview question 10

Does it they give you anything to work in the way you do today?
It gives a lot. However, sometimes there should be a balance between doing analyses and investing resources in developing systems and implementing measures. The interviewee wants to see security in practice, not just in the analysis. The importance of questioning whether the resources could have been used in another way, e.g., to be able to buy a barrier that increases security, is described. The challenge is to prioritize and focus on the right recommendations to make the right decision, for which the action plans must provide a basis.
Yes, as it gives more knowledge and identifies improvements to the design. The interviewee wishes that the company could be even better and establishing a mindset where risk analyses are a part of the projects already from the beginning.
Yes. The interviewee experiences that the work helps the company to fulfil its main purpose of having a safe facility. In addition, by working in the way they are doing today linked to qualitative risk analyses, knowledge can be spread within the company. The analyses are described as a good opportunity for the employees to learn about the facility.
In general, the analyses works well as they are today and fulfils their purpose.
Yes, but there are clear areas of improvements.
Absolutely. The company always identifies improvements in every analyses.
The interviewee experiences that it gives something to work in the way the company does today, but they could of course be even better.

The interviewee experiences that it gives a lot to work as they do today. The interviewee explains that during the recent projects, it felt like the time the company spent on risk analyses really gave results when the projects continued to the implementation phase. HAZOP is described as a special analysis that is central in the improvement work of the projects.
The interviewee indicated that they do the best of what they have, to achieve a safe workspace.
Yes, especially since it is an old facility. The interviewee explains that the risk analyses are important for improving the facility to ensure it meets the current standards.

Interview question 11

What potential for improvement are there?
The interviewee experiences that even if the most experienced and competent efforts are staffed from the company to the risk analyses, the group often gets stuck on evaluation questions, mainly linked to probability assessments. The interviewee would have like to have a handbook or table that could provide evaluation support. The intention is to minimize the number of judgments of frequencies or probabilities related to scenarios and thus not only rely on the competence of the participants.
The interviewee believes that the company is behind technically, especially related to systems for keeping track of ongoing actions and when different systems need to be controlled. More technical solutions could be a way for the company to get better at keeping track of the actions. The interviewee also highlights the risk of having everything gathered in one program since the company becomes very dependent on that program and may have difficulties changing. Using a program to coordinate risk management requires large investments and it is currently uncertain whether it is practically possible. As there are no clear guidelines from the central management, the employees are doing what they think is the best. Consequently, everyone is working differently with PHAs within the company. This is described as a problem, especially when some employees are doing less than they should. The interviewee highlights the importance of having a standard for how to work in Sweden and in the company. However, the interviewee also highlights that the proposed methods should not be too detailed. They need to be scalable for each facility. Working coordinated with risk management within the company is described as something the company should be better at and something that they are currently working on.
The interviewee expresses the follow-up of recommendations as an area of improvement. This includes using action lists in a proper way, closing actions, and finding a responsible person for all recommendations. Hence, the general structure for the handling of recommendations is an area of improvement.

A potential area for improvement could be to further systematize the work around the risk analysis, as the current system is relatively manual and vulnerable for changes in the organization. At the same time, someone still needs to enter the results or other input data into the systems. The interviewee believes that it is possible to make the current system more automated but that it is not regarded as a considerable improvement as such. The benefit of the current system is that it involves many employees who then need to think more about the analyses, which is perceived as good.

One potential improvement is described as increased number of employees with competence in facilitating several PHA methods. As the company works mainly manually, it could be easier if more people could handle different analyses.

The interviewee also describes that the company tries to stay up to date on the subject, for example via IPS or master degree projects to identify if there are any improvement potentials that could be applied in the company.

During the recent preliminary hazard analyses and HAZOPs, the interviewee tried to develop a set of rules for how they should assess risk, for example how they view frequency, causes, and barriers. It is important to calibrate the risk assessments to ensure the right priorities in the end. Before, there were many different facilitators, and the risk assessments could be somewhat scattered. In addition, it is always possible to make guidelines even better and structured.

It is hard for the company to have someone who can work with risk analyses full time. An potential improvement could be that a process engineer from the company has enough knowledge to be a facilitator.

LOPA is often performed by electrical and instrument engineers. A process engineer may need to understand more about what a LOPA is about. Between electrical, instrument and process, there would need to be more cooperation to increase the understanding between the disciplines. Knowledge of ATEX and how it is handled is also an area that lies between process engineers, electrical and instrument engineers. There are parts within ATEX, SIL and LOPA that the process engineers need to know.

The interviewee experiences that risk analyses are performed too late in the projects and believes that it should be an important part of the projects right from the start.

The interviewee wish they had a system for collecting recommendations but also entire analyses to make it easier to get an overview of what is available and to ensure no important information disappears. Today, this is done manually with excel or similar, but it possible to buy or develop a system that gathers information about the project and risk studies.

Express a need for more resources that can work with risk analyses and possibly facilitate more analyses. At the same time, increased use of external facilitators is mentioned as an area of improvement as there are advantages of having someone who can see the system with new eyes.

The interviewee mentions how improvements are captured at regular basis and that the improvement work is an important part. For example, the company has studied how to further describe the methods and standardize the work linked to risk analyses. Clarifying routines is described as something which could always be improved. Discusses the importance of having a structured and standardized way of handling PHAs. This is described as important for how the company succeeds with the security work.
The interviewee believes that it would be possible to get more out of the risk analyses if an external actor was hired more regularly, to improve the imagination during the analyses.
Systematic handling of recommendations is described as an area of improvement, which is something the company works with by developing a program for collecting recommendations. The purpose of this is to get traceability in what is done. For example, if a recommendation is not implemented, it should be possible to trace why it was not implemented. The interviewee wants it to be more system-controlled than individual-controlled.
Getting a more holistic view is described as a potential for improvement. The interviewee describes that it is a large facility and there are all sorts of different risk analyses performed but these are not done for the same system or stored in the same place. The interviewee wants to get a holistic view, so that relevant analyses can follow in later projects and not be forgotten. On a detailed level there are extensive analyses of the systems and also for the entire plant, but sometimes there may be no analyses that cover the interface between different systems at a higher level. Tools for this, e.g., software, is also described as is missing. The interviewee would like to have a system that can coordinate the integrated designs. One problem is that the experts who know the systems and need to participate in the analyses are usually fully occupied with their usual tasks. Believes that if the interviewee and other responsible for risk management would become even better at showing that the safety work makes a difference and visualize, e.g., with a bowtie, this may be improved.
The safety culture at the company is at a high level, but the documentation and structure of the risk management is described as an area of improvement. Limited resources are a part of the reason why the documentation and structure are perceived as inferior to the actual safety culture at the company. A program for managing actions would make it easier to follow up actions and move away from the manual work. At the same time, the interviewee emphasizes the importance of using similar systems for both risk analyses and in other parts of the company to keep it structured. A potential for improvement is described as having more transparency between departments to ensure that the analyses are performed and assessed in a similar way.

Interview question 12

How to you perceive the Swedish legislation?
The interviewee considers Swedish legislation as unclear and believes it would have been better if it was more specific and had more guidelines. The interviewee experiences that there are very few guidelines from the Swedish Work Environment Authority, they do not value what is good or bad. At the same time, the interviewee highlights the importance of having a standard for how to work not only in Sweden but in the company. The proposed methods from national standards must not be too detailed, rather scalable to each facility.
The company mainly works with the legislation in connection with pressurized devices and sometimes related to counselling. Explains problems with who is responsible and delegation of responsibility. The legislation is aimed at the industrial owner, which makes the safety responsibility is distanced. At the same time, the interviewee explains how legislation related to construction or design often can be delegated to sub-consultants, which means that the safety responsibility becomes distanced in the other direction. The interviewee experiences that this problem is special for Sweden.
The legislation is clear regarding that the company should analyse risks, but there is no clarity in how it should be performed. There are no overall criteria for risk analyses, as for QRA in Norway. However, Swedish legislation could also be beneficial as it gives a certain freedom. If there had been stricter criteria, for example, the surroundings could not have been considered in the same way. The legislation does not describe how the risk analyses are to be performed, but the interviewee points out that, for example, the authorities usually describe after the audit how it should have been done. The interviewee is not sure if it would have been better to have stricter legislation, but more clear guidance from authorities would have been positive. IPS is a good organization for guidance.
The interviewee experiences that the legislation works well as it is today when it is not too governed. Instead of having too strict legislation it is more beneficial for the companies to have more extensive internal requirements since it is easier to adjust it to the facility. In addition, the interviewee experiences that the Swedish Work Environment Authority's support has become increasingly diffuse and is more limited than MSB, who is providing good support and answer many questions. It is possible that the support from the authorities could be improved. To sum up, there is no need for stricter legislation, the interviewee believes increased support from authorities would be sufficient.

The interviewee believes that it is possible to see the Swedish legislation in different ways. The law says that the companies must analyse risks, but it is unclear at what level and how often. It however, more clear for the Seveso safety report. The facility is classified as a Seveso facility, which means they get Seveso audits, but it is very rare that the authorities ask about risk analyses and what risks have been identified. The interviewee experiences that those who do the audits do not dare to ask. It is extremely rare that someone asks about the Seveso reports, which the interviewee finds strange. The interviewee does not perceive that they get any support from the legislation. It is company's own will that drives the risk analysis work. It is good that the legislation is not stricter, if it would not adapt to different kinds of facilities, as facilities in different sizes have different resources.
The interviewee considers the legislation to be relevant but regardless of whether the legislation was there or not, the company would analyse risks anyway. The legislation is clear and provides support for how the risk analyses should be handled to meet the regulatory requirements.
The interviewee has no special opinion linked to the legislation, but regarding harmonized standards the interviewee wish there would be more support for frequency evaluations. The assessments of frequency and probability are often person-dependent and subjective. If there had been more support for this in the form of legislation or other manuals, it would have improved the analyses.
The Seveso legislation is clear, for example with regards to what should be included in the safety report. The interviewee has no negative opinion regarding the legislation.
The Seveso legislation is based on the worst case, which is perceived as a problem in practice. The interviewee experiences that the Swedish legislation itself is good but that it is the authorities' interpretations that are unclear. Refers to an example from MSB that says that distance should be "reassuring", which is perceived as unclear. The interviewee experience that MSB simplifies the regulations too much, which makes them unclear while some authorities focus too much outside the facility, which does not help the process industries internally. More focus on process safety in the UK and internationally, as the place greater demands on employers and plant owners. Swedish legislation is regarded as weaker on that side. How responsibilities have been divided between different agencies is described as a weakness. The interviewee experiences that different authorities sometimes do not have reasonable proposals relative to the frequency of the event being discussed and lacks a cost/benefit perspective. Points out that the Swedish approach is deterministic, which is not good for the projects.
Since it is such a complex system/facility, it is not always possible to apply the regulations directly to the facility. The interviewee experiences that the regulations are in general made for smaller facilities and therefore own guidelines are required to find corresponding protection. It is perceived as good to have legislation that is based on goals rather than requirements as it is today, because it is possible for each of the companies to adapt to it. The interviewee experiences that the legislation does not take into account the type of facility and that certain regulations are too detailed while others are floating. At the same time, the interviewee points out the advantage of not being too controlled.

Appendix B – Summary of Norwegian Interviews

The answers from the interviews of the study participants working within the Norwegian O&G industry are summarized in the following tables. The answers are presented without any order for each interview question, e.g., the first answer of interview question 1 is not related to the same person as the first answer to interview question 2. Hence, it is not possible to identify which of the study participants who answered what. The interview questions are based on the same questions as for the Swedish process industries, shown in Table 3-2. But some are adjusted in a way that suits the research question, i.e., how can methods and lessons learned from Norwegian O&G industry be applied to Swedish process industries.

Interview question 1

What qualitative risk analysis methods are used to identify process risks? o In Sweden HAZID is not very common, and What-If is used more frequently. Do you see any advantages/disadvantages? o Do you think barrier analyses should be used more in Sweden?
What-if is not very common in Norwegian O&G industry. However, it is used in the O&G industry in the United States. HAZID is described as a more structured method than What-if. For a What-If, a lot of responsibility lies with the facilitator and that is the person who can control the focus of the analysis. HAZID is considered a better method because it is well structured and there is a high traceability. The reason why What-If is used instead of HAZID could be because a HAZID is more difficult to facilitate. What-If is often perceived as simpler and a method that many feel like they can facilitate. The problem with What-If is that the method gives many answers but not an overall picture, it is easy to miss or overlook aspects that would have been captured in a HAZID. The most common methods for the Norwegian O&G industry are HAZID, HAZOP, LOPA, FMECA (especially for subsea).
The industry uses the complete range of analyses. The interviewee believes that the reason why HAZID is not used in the same way in Sweden is because it already exists as part of the preliminary hazard analysis, meaning that the preliminary hazard analysis is very similar to a HAZID. In the Norwegian O&G industry, HAZID is an important part, especially for analyses performed in later stages. The interviewee describes the advantages of performing a stand-alone HAZID since there is higher traceability in using that method. With the high traceability, it becomes easier to update already executed HAZIDs in later phases. For example, if a flammable substance is introduced into a plant, it is easier to update relevant scenarios based on this. Barrier analyses are probably used to a greater extent in the Norwegian O&G industry, but at the same time, the hazards are different compared to the Swedish process industries. A facility that is generally not exposed to as many hazards does not need to perform as many barrier analyses. However, the interviewee still believes that barrier analyses are an important part of the PHAs which should be performed to some extent. In connection to discussions around barrier analyses, the importance of having clear acceptance criteria for defining acceptable risks is highlighted.

It is mainly the regulations, i.e., the PSA, that decides which analyses should be performed. This is not done explicitly by the PSA, but it refers to industry standards such as NORSOK, which describes more in detail which methods should be used to analyse risks.

According to NORSOK, HAZID must always be implemented as a starting point for new facilities/installations. This HAZID forms the basis for the quantitative analysis performed in the projects. According to NOPRSOK P001, a HAZOP must always be performed for processes that include process medium, this also in accordance with IEC 61882.

LOPA is performed if there are instrumented functions, this is described in NOROG 070. Sometimes standards for the minimum SIL requirement are used for general functions. Risk graphs could also be used instead of LOPA or as a compliment. Other barrier analyses such as FTA, FMEA, and bowtie are used but not to the same extent as LOPA. The interviewee describes that barrier management has become increasingly important in recent years and it is a focus area in projects right from the start. In connection with the initiating HAZID, MAs and the main barriers (both preventive and mitigating) are identified. This is done with, for example, a bowtie or similar barrier analyses. These forms the basis for the performance standards which describe how reliable the barriers should be and which. This is used as a basis for the barrier strategy developed in later phases of projects.

Barrier analyses are performed to a large extent. This has been a trend since 2010 (after the Deepwater Horizon accident). The reason why companies have started to use barrier analyses more is mainly because the authorities' requirements have become increasingly extensive related to barriers. These barrier analyses include everything from LOPA to bowtie analyses.

In addition to barrier analyses, HAZID and HAZOP are also performed to a large extent. All companies in the Norwegian O&G industry use a HAZID as a starting point for risk management work in projects. What-If is not used in the Norwegian O&G industry. It is described as a light variant of HAZOP but not as structured as a HAZOP. The reason why What-If is not used is that the companies need to make sure that everything is covered in the risk analysis and the interviewee believes that HAZOP is a more structured way to do this. The interviewee also considers HAZID as a better method in comparison with What-If because, in the same way as a HAZOP, it is well structured and identifies risks that are not linked to process risks. It is therefore important to use both HAZID and HAZOP to analyse risks as they are complementary and comprehensive in comparison with What-If.

Interview questions 2

Who decides which method to use? o How has it been historically? o Are there any advantages/disadvantages when the company/employees decide?
The companies decide which analyses are performed and when. The companies have clear guidelines for how it should be done, and which analyses should be used for various issues. The guidelines are in turn based on standards and regulatory requirements. According to government requirements, the risk for a facility must be low enough (10^{-4} for MAs), but the law does not describe which analysis should be used to determine this. The interviewee believes the reason why companies are so controlling regarding which analyses are performed at which time is because the authorities have stricter requirements for the Norwegian O&G industry. It can be vulnerable for companies to make decisions that are based on the employees' own judgements. The risk is that the choice of risk analysis will be subjective and not structured within the company.
How to work with PHAs is governed by the regulations of the authorities (PSA). These regulations state that the facilities must be safe, and the frequency of MAs must not be estimated above 10^{-4}. The regulations also refer to standards, such as NORSOK. These standards provide more detailed information of how the risks should be analysed and with which methods. The operators and engineering companies usually include the standards in their own guidelines to ensure that they work according to the law. The routines at the companies are well established, and they have been around for a long time. The established process has matured over the years. This has resulted in very good understanding of the methods both among facilitators and participants. Thus, they can focus on what is important, which makes the analyses more successful. The employees do not have much influence on which analyses are to be performed and when. The interviewee considers that it is an advantage for companies to have clear guidelines for when and how the analyses are to be performed.
The decisions are based on regulations, which in turn refers to standards. Thus, the companies have several guidelines to ensure that the regulations and the standards (e.g., NORSOK) are complied. The interviewee experiences it positive that there are clear regulations and that the companies have clear guidelines. The structure within both authorities and companies means that there is a high level of competence in the area. The interviewee explains how the differences between the Norwegian O&G industry and Swedish process industries may have to do with the fact that the legislation is aimed at a specific industry, compared the Swedish legislation which is general for several sectors. It is easier to formulate regulations and standards that are applicable for one industry only. The interviewee elaborates in connection with this that the land-based industry in Norway is more similar to the land-based industry in Sweden. By having more clear guidelines from authorities each individual company does not have to devote large resources on developing its own guidelines from scratch. The companies can use these guidelines and make them suitable for their own facility. The authorities should have general standards, e.g., referring to systems with process medium, and in addition, there should be industry standards for certain industries.

For the large oil companies, it is mainly company guidelines that dominate rather than individual judgements. For smaller companies (especially land-based industries), it can vary as the engineers at the companies have a greater influence. Historically, it has also been very controlled, after the major chemical accidents which occurred in the 70s and 80s, companies have become increasingly controlled by their own guidelines. The interviewee emphasizes the benefits of having clear company standards, this is described as central for having a standardized way of working.

Interview question 3

What is the reason for analysing process risks in general? Is optimization an important part?
The interviewee experiences the optimization aspect as not very common. Safety is the main reason, but also to meet the requirements of the authorities.
In addition to having a safe facility and complying with legal requirements, the optimization aspect is an important part. This is especially applicable for HAZOP. In general, company requirements are stricter than the legislation.
The facilities themselves consider having a safe facility as the main reason for analysing risks. But the interviewee argues that the legal requirements are an important part as well. Historically, the authorities have had a great impact on the safety of the facilities. The interviewee describes that the objectives of the risk analyses have increased and includes today the environment, optimization, and other aspects more.
Today, the main focus is to comply with legal requirements and have a safe facility. The optimization aspect with regards to availability and production loss is not described as common. RAM studies are used for this. Believes that companies have a lot to gain with regards to optimization and sees great benefits in including this aspect.

Interview question 4-5

When are the risk analyses performed? How often? What is the underlying reason why they are performed at a certain time?
For plant owners, there is usually no clear rules for how often several PHA methods shall be performed. For engineering companies, there may be more guidelines related to when each analysis should be performed in each phase. From the authorities' side, there are only requirements linked to FSA. It is relatively common to perform HAZOP every five years. International companies operating on the NCS usually have stricter rules than Norwegian-owned companies. The interviewee describes that the background to why some companies have more guidelines than others, it is because they are larger (have more capital) but they have also have more experience as they have been operating for a long time.

The risk analyses are performed in all project phases, exactly to what extent are defined by the companies. Main HAZOP is performed in a detailed design, if changes are made to this design, a new HAZOP must be performed according to the regulations. In principle, all oil companies in Norway perform HAZOP every five years, this is described as a good opportunity to capture very small changes (e.g., operational procedures), but also to take advantage of the experiences from the operational phase.
The analyses are in general performed based on the same background as in Sweden, i.e., periodic analyses, for projects and modifications. Most companies have internal requirements to update HAZOPs (and some other analyses) every five years. The modifications leading to risk analyses are usually referred to as "Major modifications". For minor modifications, the safety manager usually assesses whether a risk analysis is needed or not. The interviewee describes that the barrier analyses must have an operational perspective, i.e., the barrier control must be alive in the operational phase and thus provide a current picture of the facility. The barrier analyses should therefore be performed continuously to identify deficiencies in barrier management. This is described as important since the barriers are used to ensure that the is not exposed to an unacceptable risk. Assumptions made in the other risk analyses are based on the barriers, therefore, it is essential that these are updated and based on what the facility's' current conditions.
The risk analyses are performed in each design phase and in cycles, such as re-HAZOP. Most often, companies have governing documents stating that a re-HAZOP should be performed every fifth to tenth years. Risk analyses are also performed for changes in the process. How extensive the modifications must be to trigger a PHA is different from company to company. Some companies are very careful and perform analyses even for very small changes. Companies generally have clear guidelines for when risk analyses are to be performed, typically when there is a project linked to the change. For small companies, it can be difficult to analyse exactly everything due to resource limitations. The interviewee believes that it is important to evaluate which risks are analysed. To make the assessment as effective as possible, the organization's own structure is described as essential, the more guidelines there are, the more effective the scope of the analyses.

Interview question 6

How are the analyses performed? What experience do the participants have?
The interviewee experiences that the problem with participants discussing solutions instead of potential scenarios also exists in the Norwegian O&G industry. This is mainly because those who participate have different expectations. But in general, the competence and the execution of the PHAs works well. In the O&G industry, more people are participating in the analyses, e.g., 30 people. This is described as a disadvantage and something that needs to be improved. The interviewee thinks it may be due to the pandemic that led to many analyses performed digitally, hence more people can participate.

During the risk analyses, the following disciplines usually participate:

- Process;
- Instrumentation;
- Technical safety;
- Operators;
- Safety representative;
- Mechanical;
- Material.

Usually, 20-30 people participate in the analyses, which is described as a just some of them are active. Those who participate usually think it is a good opportunity to get information about the design and therefore more people want to participate. This is a trend from the latest years, before there were only small groups participating.

The interviewee participated at the first HAZOP in Norway, when the participants had no experience with the methodology. The interviewee experiences that when the participants do not fully understand the method, it becomes less effective. Having constructive cooperation between the facilitator and the participants is described as important. The interviewee also describes the importance of having a permissive safety culture. The interviewee has participated in risk analyses in other parts of the world where the culture looks different and where there is a strong hierarchy. During these analyses, it is mainly the managers who talk, sometimes it also happens that the managers' managers have become angry when they have seen the results of the risk analyses. Often because they have a limited budget to implement the changes. There could also be focus on who made the mistake in the design, but this has become increasingly rare in recent times.

The interviewee experiences that as long as it is a good facilitator and scribe, the analyses work well, and the discussions are relevant to what is to be discussed. If this works, the participants usually find the analyses useful. The risk analyses are well established in all parts of the project and general work.

In a bowtie, about five to ten people participate, but for other risk analyses, it can be significantly more.

During the risk analyses, there are usually many participants (up to 50), which is described as a disadvantage. This is described as something that the Norwegian O&G industry could learn from Swedish industry. There is always a safety representative involved, as well as process and other relevant disciplines. Most often a "cold eye" participates, this is a person with a lot of process experience but who has not been involved in the project and who does not facilitate.

Interview question 7

Who facilitates the qualitative risk analyses?
In general, there are many different people who facilitate risk analyses, both linked to projects and reoccurring analyses. Larger operators always use external actors, while engineering companies sometimes use internal resources for smaller risk analyses. There may be advantages with having fewer different facilitators since it is beneficial if the facilitator is more familiar with the systems and the companies' guidelines. To reduce the risk of having a limited approach with a limited number of different facilitators, cold eyes can be used.

The facilitator can be both an external and an internal resource, but what is important is that the facilitator does not participate in the project. If the facilitator has a preconceived notion, it can be difficult to have an objective view of the design, this is because it can be difficult to give criticism or come up with more aspects to an own design. The risks with internal resources are that they can be biased. For example, if both the operator and the engineering company participate in the analysis and the facilitator is from the operator, the risk analysis can be weighted, as that person can make the engineering company have more responsibility, unlike if someone from the engineering company facilitated the analysis. Having an external party as a facilitator can thus be advantageous. The interviewee experiences that the analyses work well since the companies have clear guidelines, and the participants are well acquainted with how the analyses are performed.
In general, it is most external resources facilitating the analyses. The intention is to get a third-party perspective but also to get additional resources. When there is a lot to do in the industry, external resources are especially used. For smaller scopes, it may be internal resources that facilitates the analyses. This can allow the analyses to be performed more ad hook or on-demand, which can be beneficial. If the internal facilitator behaves like a third party, it can be advantageous to have internal facilitators. But in practice it can be difficult to fully function as a third party. Therefore, external actors are described as the best alternative, as they are not involved in the projects and can contribute with new experiences. In addition, the interviewee considers it more effective to invest resources in external actors for the facilitation of risk analyses or to have only one internal person who is very competent and is not involved in the projects. The interviewee emphasizes that it is important to have guidelines for how the analyses should be performed and how the company values risk. It is important that the company not only relies on external resources, competence must also be available within the company to order the correct analyses from external actors. It has often been too long before companies ask for help.
In general, it is most external resources that facilitate the risk analyses. The reason for this is that companies need more capacity and/or because they need more competence. For HAZOP, there is often a requirement that it must be an external facilitator. It must be a third party who has not been involved in the design and thus limit the risk for conflict of interests. For HAZID and bowtie, it is also common to have external facilitators, but this is not a requirement. The interviewee experiences that it can sometimes be better to have internal facilitators, as they know the facility better and thus get more relevant discussions. But the internal facilitator must have sufficient knowledge of the analysis methodology and shall not be involved in the project or system being reviewed as it would generate a risk for a conflict of interest.

Interview question 8

How are the results from the process risk analysis used? o Are the results used as a basis for other risk assessments (e.g., in health and the environment)? o How are recommendations handled?
It is relatively unusual to have a system for the recommendations. Engineering companies usually use interphase management programs that link the recommendations to the project. For existing facilities, the recommendations are in general handled in manual systems. Scenarios identified in previous analyses are used in later analyses and are followed up as appropriate. In case of changes, it is possible can go back to an analysis and update individual scenarios. The risk analyses are also used as input for FSAs. There are examples of companies that have implemented software to handle worksheets and recommendations, but these are not so developed yet and are not used to a greater extent. The interviewee believes that the important thing is not to have a program for handling recommendations, but that the work is done in a systematic way. Even if a software is implemented, there is a lot of work involved and not least when it is implemented. The interviewee believes that these resources can be spent in a better way by developing clear guidelines for how the recommendations should be recorded and followed up.
Action tracking systems are most often used to handle recommendations, mainly for engineering companies. Everything from excel to other, more industry specific systems can be used for this. All information about a recommendation ends up in the same system, this information includes the person who is responsible for the recommendation, the due date, and what the action close-out is. Before a project can be completed, all recommendations must be closed. There are good routines for how the recommendations should be handled. The same applies to recommendations identified for facilities in operation. The interviewee describes that they also have guidelines linked to the handling of recommendations. In connection with FSAs, it is discovered that there is no traceability for certain analyses. But in general, handling of recommendations work very well for HAZIDs and HAZOPs. For successful handling of recommendations, it is important that each recommendation is followed up and that there is a high level of traceability. The interviewee considers that each analysis should have an internal coordinator who is primarily responsible for follow-up. The interviewee does not believe that the main problem is the software, rather the structure in the organisation.

The handling of the recommendations works well. There are clear guidelines for how the recommendations should be handled. Each recommendation must be followed up with a written comment that must be approved. The handling of the recommendations must be traceable and well documented. The process for handling recommendations is in itself manual and some people are responsible for this, at the same time all recommendations are always followed up in a document system. This means if someone does not do as they should, this will be captured in the document system. It is important to have a close-out report where it is possible to get an overview of how each recommendation has been handled. The traceability and structure are essential for handling of recommendations, this is something that the industry has improved historically.
The interviewee experiences that similar problems with handling recommendations also exist for the Norwegian O&G industry. This is a typical audit finding, e.g., that recommendations are not followed up or that they are not documented in a sufficiently detailed manner. All operators have a recommendation system and guidelines for how they should be handled. Without a recommendation system, the work becomes more demanding, and the risk of missing recommendations is described as greater. Having a manual system is more demanding. The interviewee describes, if there is a system and clear guidelines, only relevant recommendations are entered. Writing recommendations in a good way is also something that is described as important for successful handling of recommendations. It is important to have clear recommendations that are not already a natural part of the work process, these only create unnecessary work. It is important that the facilitator has control over which recommendations are noted and that that they are clear and applicable.
Handling of recommendations is one of the most central aspects with regards to implementation of process hazard analyses outcome for the assets in design stage and operations. The handling of recommendations would, however, differ depending on whether the asset is under design och operational phase. For assets under design, the key focus is that the recommendations are available to the design team as soon as possible. This is to allow the timely implementation of the recommendations which would have design-, cost- and operability impact for the asset operators. In this case, the arrangement could be as simple as that the Lead Process Engineer, typically the study responsible for the PHA, receives an excel database with the complete set of the recommendations where it is indicated which systems the recommendations belong to, if they are safety- or operability related and which P&ID it is related to. The handling and close-out of the recommendations would then be a dynamic process during the project execution. When the project finishes, the remaining recommendations are handed over to the asset team for close-out process as a part of the operational readiness / asset operations team. To summarize, typically, no industry specific software is used for handling of recommendations. However, for assets in operational phase, most integrated companies with high-risk assets in operations, use a cloud-based database system for handling the recommendations from different PHAs. Some examples are PIMS, Synergi (Risk management for operational excellence and sustainability - DNV) etc. These tools are typically cloud-based and allow assigning each action to an individual who is responsible for close-out. In this regard, the close-out typically also goes to another stakeholder (typically a subject matter expert) for approval. Even for the close-out process, there is no fixed standard about how it should be handled. It is very company specific.

Most companies who operate a safety-critical asset have a safety management system. Normally, the safety management system is a part of the overall management of change system. Usually, when there is a change in some documentation, such as P&IDs, it triggers arrangement of a HAZOP or similar. Likewise, the outcome from the HAZOP would be a treated as part of the MOC procedure. The follow-up and the closure of the actions would look differently from company to company, but the essence is that all the actions are closed-out with supporting evidence and references. The complexity of the close-out handling would also depend on the complexity of the business and the size of the asset. For some assets (or development projects) there could be more than 1000 actions, while for some other assets there are only three to four actions to close-out. The greater the complexity, the higher the need for deployment of a software to handle the action close-out process.

Interview question 9-10

How are the analyses experienced?

- What are the difficulties/shortcomings? What is good?
- What have become better?

In general, the analyses work well, and the Norwegian O&G industry is at the forefront when it comes to risk analyses. This is also reasonable because it is an industry that is characterized by great dangers if something goes wrong.

The interviewee describes getting the right number of participants for the analyses as a challenge for the Norwegian O&G industry. This is something the industry could learn from Swedish process industries.

Working with PHAs in a structured has been improved over the years and is described as a strength in how they work today.

The interviewee highlights the importance of having participants with a clear picture of their role in the analysis. The difficulty of keeping the discussions to the methodology and not discussing solutions is described as also applicable to the Norwegian O&G industry, but this has improved recently since there is a better routine now. The interviewee also highlights that those who facilitate are better today than before, which is of great importance for the result.

Regarding imagination, an external party or an internal resource that is not involved in the project should facilitate the analysis.

Having a structured way of working is something that has worked well for the Norwegian O&G industry, and this is described as a key for conducting successful analyses.

The interviewee experiences that it can sometimes be difficult for the external facilitator if that person is not familiar with the design being reviewed, this will also affect the result of the analysis. It is thus important that the external facilitator understands the facility and does not just have general knowledge.

There is a clear ambition that those who perform the analyses should be experts in the methods and the implementation of it.

One weakness is the companies' own guidelines for how the methods should be performed, they would need to be clarified in such a way that the participants understand what is identified as the cause, consequence, and barrier. The interviewee describes that some find it difficult to understand that the consequence should be described without safeguards, they tend to describe how the barriers will respond to an event rather than describing the consequences without safeguards (overpressure, fire, explosion, etc.).

For the design phase, the engineering companies always makes sure all recommendations are closed before the plant is put into operation. For operators, it may look different. The interviewee experiences that they may have recommendations that are only on lists and never closed. Linked to this, the design of the recommendations should be reviewed. One problem is described as how the recommendations are recorded. The interviewee believes that one should avoid recommendations such as "clarify" or "verify" as well as general recommendations that are impossible to solve. For this to be implemented in practice, it is important to have guidelines for how recommendations should be written to make them as effective as possible.

Interview question 11

What improvement measures have been taken in recent years?

Can you think of any lessons learned that could be applicable for Swedish process industries based the summary from the Swedish study?

The importance of analysing the integrated design is highlighted by the interviewee. This is something that is described as a problem also in the Norwegian O&G industry. A facility is divided into several different systems and for each system, there can be different vendors. This means that, there are sometimes no analyses that cover the interface between different scopes and vendors. The interviewee emphasizes the importance of having integrated analyses that enable different vendors and disciplines to discuss with each other.

The main lessons learned from the Norwegian O&G industry is summarized as follows:

- Guidelines and standards from the authorities;
- Clear and structured company requirements throughout the management of PHAs.
- Understanding the importance of risk assessments from a high level, i.e., up in the management.

Other aspects that may be relevant to the Swedish process industry are to evaluate how, in particular, HAZOPs and HAZIDs can be good for other aspects, such as optimization.

The improvements made are mainly linked to structure, with regards to the companies' own guidelines for performing risk analyses and follow-up of these. How the analyses are performed is also something that has been developed, today both the facilitators and the participants are more familiar with the methods. Highlights the importance of the facilitator's role. The facilitator not only needs to read out guidewords, but the person also needs a good understanding for the system being reviewed to ask challenging questions to the participants. The interviewee believes that, as far as possible, one should avoid having internal facilitators. Instead of having more internal resources with basic knowledge of various analyses, these resources should be invested an external party. Using HAZID instead of What-if is a possible improvement for the Swedish process industry, which works well in the Norwegian O&G industry.
An improvement that has been implemented in the Norwegian O&G industry (and which can be further developed) is to work with the barrier analysis in an operational way, i.e., through continuous evaluation. The risk of a plant is the sum of the operating parameters and barriers, therefore an overall understanding of what affects the systems and barriers is required. Using barrier analyses to a greater extent is a lesson learned from the Norwegian O&G industry, which has become increasingly important in recent times. Using the combination of HAZID and HAZOP rather than What-If is described as a potential for improvement in the Swedish industry. This would help the companies to analyse the risks in a more structured and comprehensive way. Having a facilitator who is well acquainted with the facility without being involved in the design is described as an important aspect. If this is achieved with an external or internal facilitator is not described as important, but rather that the facilitator has sufficient competence in the analysis, the facility, and that the facilitator does not risk having a conflict of interest linked to the scope.
Having a standardized way of working is described as an improvement that has become increasingly central in recent years. This applies both to how the documentation is structured, how the respective analysis is performed, what they are to be based on, and how they are followed up. This needs to be implemented at a higher level in companies. The interviewee points out that there are also mismatches between the level of details in different analyses in Norway. Some analyses are performed at a higher level and others are performed at a detailed level and only focus on a certain piece of equipment. Sees great advantages in working with analyses that connects different systems, through integrated analyses. The companies need to have a clear picture of which risks they accept and start from this during the risk analyses.

Interview question 12

How do you perceive the Norwegian legislation related to PHAs within the O&G industry?
There is generally more legislation for the O&G industry, but it is not very specific. There are several Norwegian standards for the O&G industry, for example, NORSOK which are more comprehensive. These standards are usually used by the companies. The interviewee believes that there are advantages of having more comprehensive legislation, for example with legislation referring to standards.
The interviewee considers that the legislation for the Norwegian O&G industry works well but points out that there are major differences between the O&G industry and land-based industry. For example, PSA has requirements for safety functions for those who work onboard but it also refers to standards such as NOROG and NORSOK. The legislation is described as more functional, while the standards describe how the analyses should be used. The interviewee considers that it would be advantageous if there were more standards in Sweden, for example, more general standards or based on industry. The standards are providing a security for companies. The interviewee also highlights navigation in standards which can be a challenge. Navigation in standards is something to keep in mind when developing and using standards. The standards must not only be there, but it must also be possible to use them in a good way. Inspections are performed frequently, and the inspection reports are made public. The deviations identified in the audit reports often provide a representative picture of how the companies are doing.
Experiences the Norwegian law and the authorities' standards as good and believes that it is beneficial to have clear guidelines.
When the O&G industry started in Norway, the law was more descriptive, more like a cookbook. How the systems were to be designed was clearly described in the regulations. Then the law was changed to become more functional. Today, the legislation is about doing it safe enough and refers to a frequency criterion of 10^{-4} for MAs. The legislation mentions that HAZID and HAZOP should be performed but not how the systems should be designed as it was before. The interviewee believes that it is good that the legislation is more functional today and refers to standards regarding how the design should look.