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TESTING AND EVALUATING THE NEW SAFETY JOB ANALYSIS (SJA) GUIDELINES

Master Thesis by

Seyed Ali Shariatpanahi

Thesis submitted in partial fulfillment of

the requirements for the Degree of

Master of Engineering

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PREFACE

This master thesis is submitted in partial fulfillment of the requirements for the Master of Science degree in Risk Management at the University of Stavanger (UiS), Norway.

I wish to express my sincere thanks to my supervisor Professor Terje Aven for his support, guidance and help throughout my research. Only through his support and invaluable advice have I been able to complete this task.

I also wish to express my appreciation to those who contributed to this work.

I would also like to thank all my family, especially my brother, my wife and my daughter, as well as my friends, for their support.

University of Stavanger, 07.06.2018

Seyed Ali Shariatpanahi

ABSTRACT

Safe Job Analysis (SJA) is a systematic approach to conducting risk assessment for work operations and is used when planning critical work. It is a systematic, step by step review of risk prior to a work activity or operation. SJA is conducted to identify risks and eliminate or control identified risks.

A new version of the Safe Job Analysis has recently been introduced by Norwegian Oil and Gas. Traditional risk matrices have been replaced in the new version by enhanced risk matrices. Strength of knowledge is included in the enhanced risk matrix.

The aim of this thesis is to test and evaluate the new version of the SJA guidelines and to clarify to what extend the SJA is in-line with the current perspective on risk. The thesis also intends to show how both the current and new version of the SJA work in a practical example from the Norwegian oil industry. Strengths and weaknesses of the new version in risk analysis are identified. The final goal of this study is to present suggestions of how the guidelines can be improved.

- **Keywords**: *SJA guideline, enhanced risk matrices, black swan, strength on knowledge, HSE, probability, risk assessment, uncertainties, and risk analysis*

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LIST OF ABBREVIATIONS

SJA	Safe Job Analysis
NCS	Failure Modes and Effects Analysis
WP	Work Permit
FMEA	Failure Modes and Effects Analysis
HAZOP	Hazards and Operations Analysis
FTA	Fault Tree Analysis
ETA	Event Tree Analysis
AFD	Anticipatory Failure Determination
QRA	Quantitative Risk Analysis
SoK	Strong of Knowledge
HSE	Health Safety Environment

1. INTRODUCTION

1.1 Background

Oil and gas industry activities are always associated with uncertainty and risk. Risk needs to be understood and managed. The "Black swans - an enhanced risk perspective [15]" approach is used to identify uncertainty and risk before the threat of an incident or accident becomes reality.

Safe job analysis (SJA) is a method for conducting a risk assessment of work operations. SJA is a systematic, step by step review of risk that is carried out prior to a work activity or operation is begun. SJA is conducted to identify risks and eliminate or control identified risks.

Norwegian Oil and Gas has recommended, in a guideline, how and when to use SJA. The guideline applies to the implementation of SJA to fixed and floating facilities on the Norwegian continental shelf (NCS).

It is recommended, in the new version of the SJA, that the risk matrix is enhanced by including the factor 'strength of the underlying knowledge' for identified risks. This enhancement is based on a new clarification of the risk concept. The enhanced risk matrix with the new clarification of risk and unexpected/unforeseen events is addressed in the new version of the SJA.

A risk matrix alone gives a confusing picture of risk. One must therefore see beyond probabilities. It is recommended that an enhanced risk perspective is used to provide a broader basis for understanding risk. Our knowledge of the phenomena is held to be as important as the probabilities of events in the enhanced risk matrix.

The enhanced perspective on risk covers concepts and instruments related to understanding and assessing two new risk components, knowledge dimension and surprise/unforeseen events. An enhanced risk perspective is relevant in all phases of a project or activity from planning to operation.

1.2 Objectives

The main objective of the thesis is to test and evaluate the new version of the SJA guidelines. This thesis aims to clarify to what extent the SJA is in line with the current perspectives on risks, and how it will work in practice. Will it lead to improved risk understanding, assessments and management? This work also aims to present suggestions of how the guidelines can be improved.

1.2.1 Evaluation of New SJA Process

To evaluate the new version of the SJA, a practical example from the Norwegian oil industry has been selected for risk assessment using the current and new versions of SJA. A comparison analysis of the two is performed to examine how Norwegian oil companies perform safe operation.

All probabilities and consequences are, in the new SJA procedure, based on background knowledge. An important step in the new procedure is therefore to collect as much information as possible, ideally strong knowledge. Information is usually gathered through an individual's knowledge. It is therefore sometimes challenging to collect valuable information when participating in meetings with many people.

The new SJA is a qualitative method. Its purpose is to identify all hazards and operability problems in a project based on available knowledge (SJA checklists - see Appendix 3). Enhanced risk matrices are captured by the dimensions: Consequence (C), Probability (P) and SoK.

SJA is used to first find out how big the risk level is, ranging from high to low depending on its SoK, and to then reduce the risk level to an acceptable level. Figure 1-2 shows how this thesis is structured. Firstly, the new version of the SJA procedure is evaluated. The available methods for performing SJA are then analyzed and finally an improvement approach is suggested.

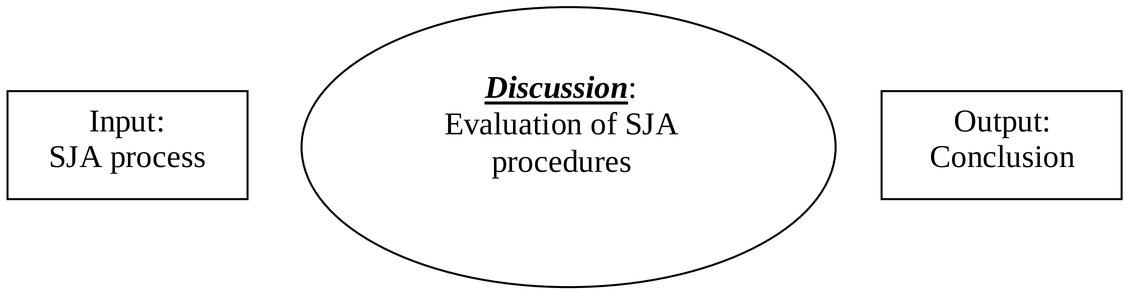


Figure 1: Evaluation structure of SJA in the present study

1.3 Content

The first part of this thesis is Chapter 1 and it contains the background knowledge, aims of the thesis and the outline of the thesis. Chapter 2 contains a review of the current version of the SJA guideline for the common model. Chapter 3 contains a review of the new version of the recommended guideline for the common model for SJA with respect to surprises. It introduces the concept of this guideline. In this chapter, the new version of the SJA guideline will be assessed using a practical example of a SJA for an offshore platform to identify its strengths and weaknesses. Chapter 4 contains an evaluation of the SJA guideline. The results of the evaluation of this procedure will be presented and discussed and recommendations for improvements will be made. Chapter 5 presents a summary and conclusion and the last chapter, chapter 6, contains a reference list.

1.4 What the thesis is built on

Activities in the oil and gas industry are always associated with uncertainty and risk. Risk needs to be understood and managed. Risk in a work activity or operation and how this risk can be eliminated is dealt with in a SJA. When and where a SJA should be carried out is discussed in the guideline. Risk is, however, not fully described by just probabilities. A risk matrix only associated with probabilities and consequences gives a misleading picture of risk.

It is therefore important to see beyond probabilities. A broader understanding of risk is required, one that can be provided by an enhanced risk perspective. The knowledge and uncertainties relating to a phenomena and activity are as important as the probabilities.

This study is based on the new version of SJA. Knowledge and uncertainty are, in this version, important aspects of risk and make it possible to read signals better and to see when a hazard is developing into a black swan. This enhanced risk matrix is proposed to improve risk understanding, assessment and management.

1.5 Terminology

Initials:	**Definitions:**
ALARP	As low as is reasonable practicable
Risk	Consequences of activities and associated uncertainty.
Risk Analysis	RA is a systematic analysis of risk. An estimation of risk for the basic activity
Risk Assessment	The process of analyzing level of risk, by reviewing those in danger. It is then evaluated whether hazards are adequately/can be controlled by putting measures in place
Risk Management	The process of selecting the appropriate risk reduction measures and implementing these in the activity.
Safety Management	Safety management is understood to be all systematic measures that are assumed to achieve and maintain a safety level that conforms with goals and acceptance criteria.
HAZID	Hazard identification
HAZOP	Hazard identification and operability study
HAZARD	Hazard is anything that has the potential to cause injury. This can be a dangerous substance, part of a device, a form of energy or a way of carrying out work.
Lessons leaned	A database that contains experience from previous jobs. Project engineers use this before implementing a project to obtain information from similar operations.

2. CURRENT SAFETY JOB ANALYSIS (SJA)

2.1 Introduction

Job related injuries and fatalities can occur in day-to-day operations in work places. These injuries often occur because workers have not been properly trained for the work they are to perform. One approach that is used to prevent injuries in the workplace is to establish suitable job procedures and to train employees for the work they are to carry out. A suitable job procedure (Safe Job Analysis) is developed by recording each step of the job, by determining the best way to carry out the job or a way that can reduce or eliminate hazards. The SJA can reduce costs arising from worker compensation and increase productivity. SJAs are often carried out for major and complex works and jobs which are not covered by existing procedures.

The assessment of whether an SJA is required consists of several phases: planning, approval and execution. SJA is required for any work that involves risk factors which have not been checked in prior procedures or approved work permits (Figure 2).

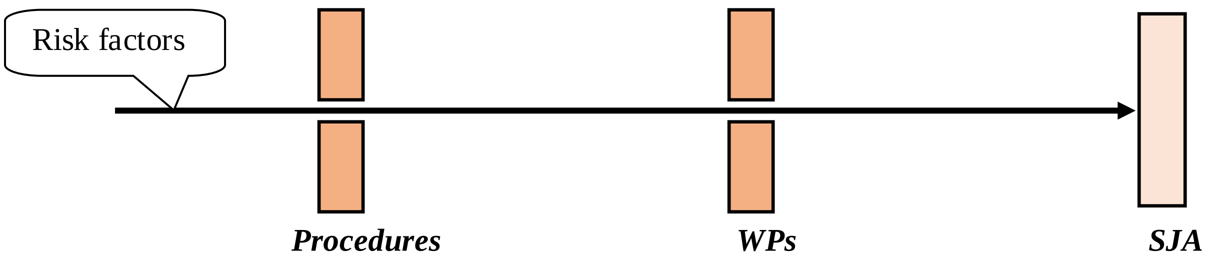


Figure 2: Requirement for using SJA [13]

2.2 Risk Matrix

SJA uses a risk matrix in the assessment of hazards, i.e. evaluates the likelihood of an undesired event occurring and the consequences. Such an assessment can help clarify the need for and prioritization of risk or of consequence reduction measures. This is a rough and qualitative approach. High risk hazards can be subjected to a more detailed assessment in the subsequent round.

A risk matrix assesses or estimates risk by plotting the probability of an undesired event along one axis and the degree of consequences along a second axis. This is carried out for each assignment (Table 1). Each block in the risk matrix describes a level of risk. Blocks with the same risk level are usually grouped together into one risk area [14]. The size of the risk matrix can differ with risk ranking grades. Some use a 3x3, 4x4 or 5x5 matrix, others not. A 5x5 matrix for example gives 25 blocks, the blocks presenting risk grades. More blocks gives more risk ranking grades. This allows organizations to assign the low, medium, high and extreme risk to the acceptance level of the organization. The greater number of probability and consequence options in the risk matrix gives greater scope for different levels of responsibility to the risk group.

Measures will be necessary where the combination of probability and consequence becomes medium or high. Each company has its own risk assessment matrixes. A simplified version such as that shown below, with three levels of probability and three degrees of consequences, may be beneficial to the implementation of SJA.

Table 1: Risk matrix - old version [13]

	Probability		
Consequence	Low	Medium	High
Low	L	L	M
Medium	L	M	H
High	M	H	H

Grade of consequences:

High	Death, serious injury or illness, significant pollution, significant damage to equipment or materials, significant production delay, gas/oil leakage, weakening of whole or large parts of a device's security integrity.
Medium	No injury or minor injury, low level of pollution, low level damage to equipment or materials, low production delay, low level gas/oil leakage, weakening of parts of the device's security integrity (for example, one module)
Low	No personal injury, minor/insignificant pollution, minor/insignificant damage to equipment or materials, negligible production delay, insignificant gas/oil leakage, local/negligible weakening of the device's security integrity

Grade of probability:

High	Probable, may occur several times in a year
Medium	Possible, may occur occasionally, has occurred on the installation
Low	Little realistic, but imaginable, has occurred in the industry

2.3 Example of Using Current SJA

In this chapter, an example of a safe job analysis using the current version of SJA is presented. Let's assume that a construction company is going to transport a heavy steel structure by wagon from/to a workshop. The job of lifting and transporting steel is firstly required to be broken down into several steps, the three steps of the job.

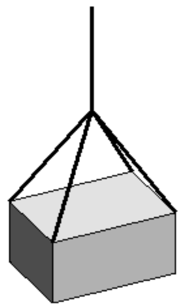
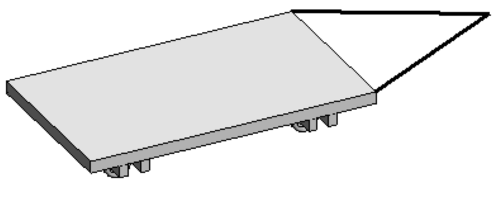
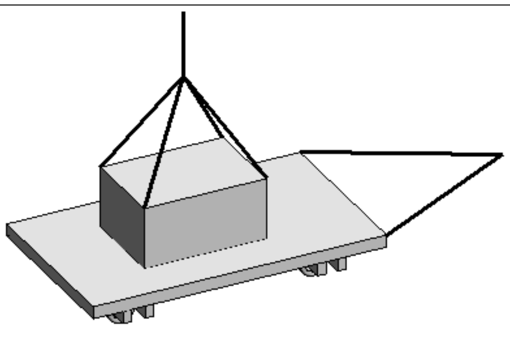
	***1. Lifting heavy steel structure***
	***2. Using wagon for transporting***
	***3. Placement of steel structure on the wagon and transporting***

Figure 3: Lifting and transporting steel – job steps

After a job has been broken down into steps, each step should be examined to identify the hazards which exist or might occur, i.e. potential incidents that can result in dangerous situations for people, the environment and assets. The hazards identified during the lifting and transporting of the steel structure are listed in Table 2. Each hazard or potential hazard should then be reviewed by those who are to carry out the job, to determine whether the job can be carried out in another way that can eliminate the hazards or whether safety equipment is required to control the hazards. The consequences and probabilities of each hazard are then analyzed to find the probable risk, i.e. a risk matrix of evaluated consequences and probabilities.

Table 2: SJA table - Lifting and transporting steel deck [20]

SJA Tittel (Title)**: Lifting of steel deck and transporting to Hall 2C**	**SJA ansvarlig** (Person responsible for SJA)**: Ali Shariatpanahi**	**SJA #:**
Beskrivelse av arbeidet (Job description)**: Lifting of steel deck and transport from workshop to Hall 2C**		
Dato (Date): 09.03.2018	**Områdeansvarlig** (Person responsible for the area) (sign.): *Ali Shariatpanahi*	**Verneombud** (Safety officer) (sign): *Neda Sedghi*
Orginal skal henges opp ved arbeidsstedet (Original to be visible at the place of work)	**Formann** (Foreman) (sign):*Christian Hana*	**Ved behov: HMS representant** (HSE representative) (sign):
	Involvert operatør (Operator) (stilling/ position, navn/ name, sign.):	**Andre involverte** (Other personnel involved) (stilling/ position, navn/ name, sign.):
	Er den totale risikoen akseptabel: (Ja/ Nei) Is the total risk acceptable: (Yes/ NO) **Yes**	**Konklusjon/ Kommentar** (Conclusion/ Comments): If events occur, work will stop and timeout will be instigated.

Arbeidsoperasjon Work operation (level)	**Faremoment** (Hazard)**:**	**Konsekvens (**Consequence)*****	**Sannsynlighet** (Probability)*****	**Rating***	**Tiltak** (Action)	**Ansvar** (Personnel responsible)
Rig and connect lifting equipment according to lift sketch/procedure	**Work at a high height. Falling objects. Risk of trapping. Fault on lifting equipment. Heavy equipment. Communication.**	**H**	**L**	**M**	**Barriers. Fall Protection Experienced personnel. Protection of equipment. Certified equipment. Certified personnel. Radio.**	**ASH/CH**
Perform lifting (2x90T and 90T crane)	**Risk of trapping. Loose objects. Uncontrolled crane. Unwanted personnel. Communication. Personnel under hanging load**	**H**	**L**	**M**	**Experienced personnel. Check section for loose items. Certified personnel. Barring. Radio**	**ASH/CH**
Placing section on the 200T Wagon	**Risk of trapping. Uncontrolled crane. Unwanted personnel. Communication. Personnel under hanging load Wrong load on the wagon**	**M**	**L**	**L**	**No Action**	**ASH/CH**
Disconnect lifting equipment	**Work at a high height. Loose objects. Risk of trapping. Communication.**	**M**	**L**	**L**	**No Action**	**ASH/CH**
Transport to Hall 2C	**Obstacle in the transport route. Collision.**	**M**	**L**	**L**	**No Action**	**ASH/CH**
Transport to the Hall Mounting (out side of Hall 2C)	**Obstacle in the transport route. Collision.**	**M**	**L**	**L**	**No Action**	**ASH/CH**

	Communicates , Falling object					
Explanation: * Low (acceptable)- Medium – High						

Table 3 is an example of a risk matrix prepared for this case. This shows that, based on probabilities and consequences of each task, risks are ranked as small, medium or large, identifying whether measures are required implemented to reduce risk. Measures are often required where consequences are medium or large.

Table 3: Risk matrix - current version

	Probability		
Consequence	Low	Medium	High
Low	L	L	M
Medium	L	M	H
High	M	H	H

H: high risk, L: low risk, M: medium risk

This SJA describes and ranks the risks associated with each step of the job through events, consequences and probabilities. A risk matrix is appropriate for the SJA group's risk assessment. A risk matrix is a simple approach for describing and characterizing risks associated with a job. Consequence and probability (P) and the product of these two give the so called expected value (E). Risk is therefore described as (P(A), E(C|A)), where "A" is, for example, a major accident.

The main issue relating to this approach is the lack of 'background knowledge' and the effect of this on expected consequences. Strength of knowledge (SoK) is not incorporated into the current risk matrix. SoK could be strong or weak for the probabilities and consequences given in the above table. It is therefore very important to know and distinguish events with weak background knowledge and include its possible effect on the risk matrix. The expected consequence of E(C|A) could therefore be a poor prediction of the real consequences of C if such an event occurred.

The variation in P(A) and E(C|A) in the above table can also be considered to be another weakness of the current SJA. The expected values of low P(A) and high E(C|A) or high P(A) and low E(C|A) are the same. But they should not be. The risk matrix can also benefit from SoK through avoiding such circumstances.

3. THE NEW VERSION OF SAFETY JOB ANALYSIS

3.1 Introduction

Norwegian Oil and Gas' HSE Forum has recommended a modified guideline for the use of SJA on the Norwegian continental shelf [4]. It is recommended, in the new version of the SJA guideline, that an enhanced risk matrix is used for assessing hazards. This assessment is based on the probability of an undesirable incident occurring, its consequences and strength of knowledge. The main steps for implementing an SJA are presented in Figure 4.

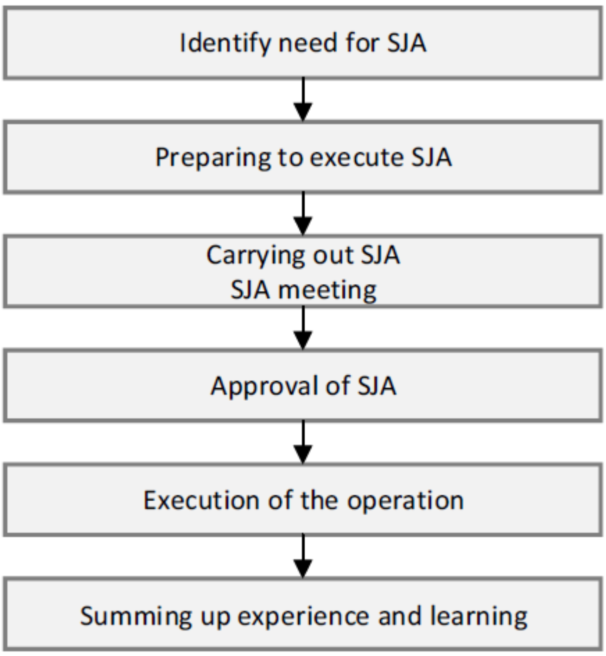


Figure 4: Main steps for executing SJA [4]

3.2 Identify the Need for SJA

The first step is to identify whether there is a need for SJA implementation in each phase of the project, from planning to execution. All involved in planning, authorizing and executing the work and work permits (WPs) are required to evaluate the need for an SJA.

SJA is required for a task or operation when they contain risk elements which have not been adequately identified and controlled by relevant procedures. Hazards should be identified and control of these must be documented. An SJA is not required if the risk has been clarified and controlled in other suitable procedures or an approved WP. The following should be considered when identifying the need for an SJA [4]:

Need for an SJA	**Yes**	**No**
Is the work reported in procedures or routines ,or are exemptions from these required?		
Have hazards in each sub-task been identified?		
Have unforeseen incidents occurred previously?		
Does the work operation include several disciplines or units?		
Is new equipment/methods not covered by procedures being used?		
Do the personnel involved have enough experience with the work operation?		

3.3 Preparation for an SJA

SJA is carried out by a small group of people who are familiar with the project and who are to carry out the job being analyzed. When a need for an SJA has been identified, the area responsible is to nominate a person who is to be responsible for the SJA. The person responsible for the SJA must ensure that required preparations have been completed prior to the SJA meeting. A new safe job analysis is recommended carried out for each new job, even if a SJA has been previously prepared for the same type of work [4]. Previous SJAs are used for experience transfer and lessons learnt. The person responsible for preparation of the SJA meeting is to:

- Collect data, drawings, previous experience and any risk assessments for the work in question.
- Prepare a draft of the breakdown of the job into sub-tasks that shows the sequence of work execution
- Preconditions for the job need to be considered
- Define SJA participants
- Call SJA meeting

The SJA meeting should be held as close to the beginning of the job as possible.

The following persons should always participate in the carrying out of a SJA:

- Supervisor
- Safety officer
- Operator involved

The HSE representative can be involved to provide professional assistance in the planning and/or execution of the analysis. Other technical personnel may also be involved.

3.4 Carrying out an SJA

The safe job analysis is carried out by the SJA group. Good communication and dialogue in the meeting always helps ensure that all aspects are covered. The work must be broken down into sub-tasks so that the personnel involved understand the work. Hazards in each step should be identified, the checklist in Appendix 3 being used to identify hazards. Probability and consequence (risk) should then be assessed. This is shown in Table 5 for the example case of lifting and transporting heavy steel. Measures that eliminate or control hazards should be identified [(4)].

3.4.1 Identify Hazards

Potential incidents and conditions that can cause hazards for personnel, the environment or financial assets must be identified for each sub-task. The following must be assessed [(4)]:

1. Which incidents and conditions create hazards during the work? (e.g. dropped object)
2. Which incidents and conditions create hazards later? (e.g. forgetting tools at the work site)
3. Could an error be made when carrying out the job which can lead to a major accident, immediately or later? (e.g. wrong type of gasket)

There are a number of different identifying processes for hazards. Theses include HAZID (Hazard Identification) and HAZOP (Hazard identification and operability study).

3.4.1.1 HAZID – Hazard Identification

HAZID is a method for evaluating hazards early in projects [(11)]. The method is a practical technique for revealing weaknesses in the design and in the detailed procedures. A group of experts with different skills normally carry out a HAZID. Hazard identification should involve personnel who are relevant to this hazard, such as shift supervisors, engineers and leaders responsible for operational and technical aspects. The HAZID leader should be a person who is skilled in both operation and engineering. The HAZID process begins with a visiting of the work area. Then follows the identification of all potential undesirable consequences that can occur and the identification of hazards that would cause consequences. All hazards that cause a significant hazard to the activity should therefore be included in this process. A list of hazards is therefore prepared and reviewed. It is helpful to use a check-list, “lessons learned” from similar activities and previous HAZIDs when identifying hazards.

3.4.1.2 HAZOP – Hazard Identification and Operability study

The purpose of HAZOP is to ensure adequate functionality and project back up if operability problems occur [(12)]. It is a systematic approach for identifying problems with facilities, equipment and processes and analyzing systems from multiple perspectives. The approach assesses the potential risk of a possible deviation from design specification. Unforeseen events can be divided into the three different perspectives; (1) design, (2) physical and operational environment, (3) operational and procedural controls. It is important that a contingency plan for critical parts of the project has been prepared and is available. Timing of the HAZOP is also important, as it is important that there is enough time to correct a discovered fault in a project. A HAZOP is carried out by a team of experts with different skills. HAZOP starts with the presentation of work scope, the breaking down of tasks into sub-tasks and then the identification of hazards that can affect operation. The three HAZOP perspectives are presented in Table 4 [13].

Table 4: Categories of HAZOP perspectives [13]

Design	Assessment of system design capability required to meet user specifications and safety standards. Identify weaknesses in systems
Physical and operational environments	Assessment of environment to ensure system is appropriately situated, supported, serviced, contained, etc.
Operational and procedural controls	Assessment of engineered controls, sequences of operations, procedural controls, etc. Assessment of different operational modes, start-up, standby, normal operation, steady & unsteady states, normal shutdown, emergency shutdown, etc.

3.4.2 Risk Assessment

The next step in an SJA is risk analysis. This step consists of a cause and a consequence analysis (Bow-Tie). Different root causes for the initial event are analyzed in the cause analysis., an event trees (ET) might be used. Different consequences of the initial event are analyzed in the consequence analysis, a fault tree (FT) may be being used. A Bayesian network (BN), where both the cause and the consequence are analyzed, can be used. The new version of SJA guideline is based on a new clarification of risk (enhanced risk perspective) that focuses on the unforeseen and unexpected.

These risk assessment methods are not a good solution for identifying black swan type events and undesired events. Hazard identification methods must therefore be improved to solve for unforeseen problems.

Aven [7] has introduced a new version of a risk matrix for risk analysis, called the enhanced risk matrix. SoK is in this linked to the traditional risk matrix.

3.4.2.1 Enhanced Risk Matrix

A risk matrix is a qualitative risk evaluation tool captured by two dimensions, consequence (C) and probability (P) of the occurrence of an accident. The product of these dimensions is the expected value (E). This is used to determine the risk level, which can be negligible, manageable or difficult. The risk matrix is used to define the ALARP principle and to define where risk-reducing measures are required before an operation begins. The risk matrix is simple to use, but at the same time sufficiently informative for manager and decision maker use. This is most probably the reason why many organizations prefer to use a risk matrix.

Risk matrices are used extensively. They have, however, been heavily criticized. Influencing factors or sources such as cost-efficiency factors in an organization are not covered in the risk matrix. Strength of knowledge is also not included in the risk matrix. We therefore need to look beyond the traditional risk matrix. Using a risk matrix, the highest risk is determined and the risk level is visualized based on reviewing a number of constituent people. Risk matrices can be improved by them better reflecting the knowledge dimension.

Aven [7] believes that traditional risk matrices with two dimensions probability and consequence should not use. He has recommended that a strength of knowledge dimension should always be included in the risk matrix. The consequence dimension also requires the inclusion of the spectrum of consequences, not only the expected value given the initiating event. A prediction interval can be used for this. It might also be useful to fix the consequence dimension to a specific type of outcome (for example, events with some minimum damages).

An enhanced risk matrix is used to assess or specify risk. Probability of an event is along one axis, the consequences related to the probabilities along the other axis and the SoK linked to events.

Each company has their own risk matrices for risk assessment. A simplified version of the enhanced risk matrix is presented in the following table. The matrix consists of three levels of probability, consequences and strength of knowledge.

In the new version, measures often need to be implemented to reduce risk when the risk associated with probability, consequence and strength of knowledge is ranked as high.

Table 5 : Risk Matrix - New version [4]

		Probability		
Consequence	**Strength of knowledge**	**Low**	**Medium**	**High**
Low	**Weak**	M	M	H
	Medium	L	M	H
	Strong	L	L	M
Medium	**Weak**	M	H	H
	Medium	M	H	H
	Strong	L	M	H
High	**Weak**	H	H	H
	Medium	H	H	H
	Strong	M	H	H

H: high risk, L: low risk, M: medium risk

Knowledge included: data, information and justified beliefs.

Strength of knowledge; SoK:

Strength of knowledge expresses how good the background information is in the assessment of risk and in the estimation of consequences and associated probability. Assessments of probabilities and consequences are supported by strength of knowledge. Aven [6] has recommended the following table for assessing strength of knowledge:

i. Knowledge K is judged to be WEAK if one or more of the below conditions are true:

Knowledge is weak if:	**True**	**False**
The assumptions represent strong simplifications?		
Data/information is non-existent or highly unreliable/irrelevant?		
Strong disagreement among experts?		
The phenomena involved are poorly understood; models are non-existent or known/believed to give poor predictions?		
Knowledge K has not been examined (for example with respect to unknown knowns)		

ii. Knowledge K is judged to be STRONG if all below conditions are met:

Knowledge is strong if:	**True**	**False**
Assumptions made are seen as being very reasonable?		
Large amounts of reliable and relevant data/information are available?		
There is broad agreement among experts?		
The phenomena involved are well understood; models used are known to give predictions with the required accuracy?		
Knowledge K has been thoroughly examined.		

Strength of knowledge is classified as medium where between these two.

3.4.3 Identified Measures

All measures that can prevent an incident are identified and prioritized in this step. Measures are implemented to strengthen knowledge and reduce uncertainty for black swan and unforeseen events with very serious consequences.

Other experts should be brought in to the analysis where the knowledge used is weak. Attention should also be given to measures that can strengthen robustness if an unforeseen event should occur [(4)].

3.4.4 Using a Checklist

The checklist presented in Appendix 3 is used to assess hazards, consequences and measures [(4)].

3.4.5 Assess Residual Risk and Conclude the Analysis

The SJA concludes with an overall assessment of whether the job can be carried out. This assessment specifies whether the remaining risk associated with the job or operation is acceptable [(4)].

3.4.6 Documentation and Signature

The SJA is documented on the SJA form given in Appendix 4. It is signed by the person responsible for the SJA [(4)]. A standard list of participants is presented in Appendix 5.

3.5 Approval of SJA

The person responsible for the implementation of the work in this step reviews the SJA form and recommends whether it should be approved to the area supervisor [(4)].

3.6 Execution of Operation

- The work is broken down into sub-tasks so that the personnel involved understand the work.
- Hazards in each step are identified. The checklist in Appendix 3 is used to identify hazards.
- Probability and consequence (risk) is assessed according to the classification shown in Table 5 for the lifting and transporting of heavy steel.
- Measures that eliminate or control hazards are identified.
- Residual risk is assessed and accepted.
- The results of the SJA are to be documented, including identified measures, defined responsibilities for carrying out the measures and the participants in the analysis in the form of Table 5.
- A new review of SJA is required when new personnel are included in the work.

3.7 Summing up Experience and Learning Lessons

The person responsible for the SJA must, when the work has been completed, sum up the experiences gained and register them on the SJA form. This documentation must then be archived [(4)].

Experience from a job for which a SJA is required should be used in the preparation and improvement of future work procedures.

3.8 Example of Using New Version of SJA when Transporting and Lifting a Heavy Steel

3.8.1 Scope

This chapter presents an example of a safe job analysis using the new version of the SJA. The example illustrates how a company carries out an SJA using an example case. Some preparation is required before carrying out an SJA. The company that is to carry out the task nominates a person responsible for the task or area/operation supervisor. This person should designate a team for carrying out the SJA and must ensure that the team has the experience required.

This job is performed in different stages; lifting the heavy steel, lowering down onto the wagon and transporting - as described below.

- Phase 1: connect lifting equipment according to lift sketch/procedure, and perform lifting using 90 tonne crane.
- Phase 2: place the object (heavy steel) on the 200T wagon, disconnect the lifting equipment.
- Phase 3: transport to Hall Mounting (outside of Hall 2C).

The tasks are described step-by-step in Figure 5.

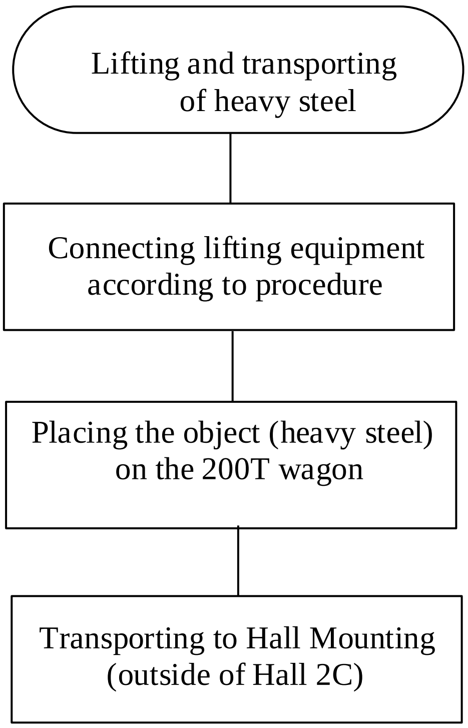


Figure 5: Scope of work in the example

3.8.2 Step 1 – Identify Need for SJA

A SJA is required for tasks or operations that can lead to risk elements that have not been adequately identified and controlled in relevant procedures or area risk assessments. The area that is responsible for this task (lifting and transporting of heavy steel) should always consider carrying out a SJA for the following tasks/operations:

- New and unknown work tasks
- Work on pressurized systems
- Complicated lifting operations
- Entering tanks and confined spaces
- Complicated operations at height
- Use/handling of dangerous chemicals

3.8.3 Step 2 – Participation in the Execution of an SJA

A SJA is carried out by a small group of persons familiar with the job and persons who are to carry out the job. The area responsible is to appoint a person responsible for the SJA where there is a proven need for a SJA. The following persons are to always participate in the SJA:

- Foreman
- Safety officer
- Operator involved

3.8.4 Step 3 – Execution of SJA

The steps below present how a SJA is executed for lifting and transporting heavy steel.

- The work is broken down into sub-tasks so that the personnel involved understand the work.
- Hazards in each step are identified. The checklist in Appendix 3 is used to identify hazards.
- Probability and consequence (risk) is assessed according to the classification provided in Table 6 of risk consequence and likelihood.
- Identify measures that eliminate or control hazards.
- Residual risk is assessed and accepted.
- The results of the SJA are to be documented, including identified measures, defined responsibilities for carrying out the measures and the participants in the analysis in the form of Table 6.
- A new review of SJA is required when new personnel are included in the work.

Table 6: SJA table - Lifting and transporting steel deck [20]

SJA Tittel (Title)**: Lifting of steel deck and transporting to Hall 2C**	**SJA ansvarlig** (Responsible for SJA)**:Ali Shariatpanahi**	**SJA #:**
Beskrivelse av arbeidet (Job description)**: Lifting of steel deck and transport from workshop to Hall 2C**		

Dato (Date): 09.03.2018	**Områdeansvarlig** (Person responsible for the area) (sign.): *Ali Shariatpanahi*	**Verneombud** (Safety officer) (sign): *Neda Sedghi*
Orginal skal henges opp ved arbeidsstedet (Original to be visible at the place of work)	**Formann** (Foreman) (sign):*Christian Hana*	**Ved behov: HMS representant** (HSE representative) (sign):
	Involvert operatør (Operator) (stilling/ position, navn/ name, sign.):	**Andre involverte** (Other involved personnel) (stilling/ position, navn/ name, sign.):
	Er den totale risikoen akseptabel: (Ja/ Nei) Is the total risk acceptable: (Yes/ NO) **Yes**	**Konklusjon/ Kommentar** (Conclusion/ Comments): If events occur, work will stop and timeout will be instigated.

Arbeidsoperasjon Work operation (level)	**Faremoment** (Hazard)**:**	**Strength of Knowledge***	**Konsekvens (**Consequence)*	**Sannsynlighet** (Probability)*	**Rating***	**Tiltak** (Action)	**Ansvar** (Person responsible)
Rig and connect lifting equipment according to lift sketch/procedure	**Work at a high height. Falling objects. Risk of trapping. Fault on lifting equipment. Heavy equipment. Communication.**	**H**	**H**	**L**	**M**	**Barriers. Fall Protection Experienced personnel. Protection of equipment. Certified equipment. Certified personnel. Radio.**	**ASH/CH**
Perform lifting (2x90T and 90T crane)	**Risk of trapping. Loose objects. Uncontrolled crane. Unwanted personnel. Communication. Personnel under hanging load**	**H**	**H**	**L**	**M**	**Experienced personnel. Check section for loose items. Certified personnel. Barring. Radio**	**ASH/CH**
Placing section on the 200T Wagon	**Risk of trapping. Uncontrolled crane. Unwanted personnel. Communication. Personnel under hanging load Wrong load on the wagon**	**M**	**M**	**L**	**M**	**Experienced personnel. Check section for loose items. Certified personnel. Barring. Radio. Placement. Sketch/verify weight of 200T Wagon. Section secured at the end with load straps.**	**ASH/CH**
Disconnect lifting equipment	**Work at a high height. Loose objects. Risk of trapping. Communication.**	**M**	**M**	**L**	**M**	**Barriers. Fall protection. Certified personnel. Protection of equipment.**	**ASH/CH**

						Radio.	
Transport to Hall 2C	Obstacle in the transport route. Collision.	H	M	L	L	No Action	ASH/CH
Transport to the Hall Mounting (out side of Hall 2C)	Obstacle in the transport route. Collision. Communicates hugs. Falling object	H	M	L	L	No Action	ASH/CH

Explanation: * Low (acceptable) - Medium - High

A risk matrix is a method for characterizing risks based on approaches that reflect threats, their consequences and probability, risk factors and risk sources. There are, as shown previously, many challenges related to the characterization of risk and there is a potential for improving how characterizations are conducted. Reflecting the knowledge aspect of risk is of great importance. An enhanced risk matrix includes strength of knowledge judgments and the rankings of risk factors and assumptions. These support the analysis. Special attention also needs to be paid to potential surprises in relation to current knowledge.

The new SJA uses an enhanced risk matrix, which is applied to the assessment of hazards for the job of lifting and transporting a steel structure. As shown in the risk table, the strength of knowledge is now reflected in the risk matrix. When assessing the probability and consequences of an incident, it is important to know the strength of the knowledge on which these assessments are based. Assessments are based on weak, medium or strong knowledge. The ability to predict, measure and learn from an accident is essential in the assessment of hazards. Models are based on assumptions and data. It is therefore important to ensure the availability of valid, updated and relevant data and assumptions. Low quality data or lack of data does not prevent activities, but reduces the validity of the output of a model. The competence of experts in the activity area and a high level of agreement between experts can definitely lead to a better design and low uncertainties.

It is recommended, based on the enhanced risk matrix, to implement measures if the risk assessed in terms of probability, consequence and SoK is judged to be high or medium.

Table 5 is an example of an enhanced risk matrix prepared for this case. Risks are ranked and whether measures are required to reduce the risks are identified based on the probabilities and consequences of each task and on strength of knowledge. Measures are often required where risk is ranked medium or large.

3.9 How Knowledge and Lack of Knowledge Play a Key Role in a Risk Matrix

Risk assessment is based on knowledge including data, models and expert judgments. SoK should therefore always be considered to support decision-making. Imagine evaluating a risk of an event. A probability that express the degree of belief is used in this case. The probability of occurrence of the event is based on specific background knowledge, which could be strong or weak. When assessing the probability of an event, it is important to know the strength of knowledge to describe the risk better and arrive at the correct decision.

Oil and gas companies in Norway have been trying to include SoK in their risk matrices. It is still, however, not clear to them how risks where knowledge is medium and weak should be treated. That is why they focus on strong strength of knowledge cases, because they know how to deal with a traditional risk matrix, the modified SJA for strong knowledge giving the same picture as the traditional SJA.

Table 7: Traditional risk matrix [21]

	Probability		
Consequence	**Low**	**Medium**	**High**
Low	**L**	**L**	**M**
Medium	**L**	**M**	**H**
High	**M**	**H**	**H**

Table 8: New risk matrix based on the modified SJA for strong knowledge [4]

		Probability		
Consequence	**SoK**	**Low**	**Medium**	**High**
Low	**Strong**	**L**	**L**	**M**
Medium	**Strong**	**L**	**M**	**H**
High	**Strong**	**M**	**H**	**H**

There is therefore no difference between the modified and the old SJA where knowledge is strong and the areas for defining measures are identical.

It is, however, interesting to compare the new SJA for strong knowledge with that for medium and weak knowledge and to compare these two with the old risk matrix. It can easily be concluded that the area for measure implementation becomes systematically larger when moving from strong knowledge to medium and then to weak.

Table 9: New risk matrix based on the modified SJA for Medium knowledge [(4)]

		Probability		
Consequence	**SoK**	**Low**	**Medium**	**High**
Low	**Medium**	**L**	**M**	**H**
Medium	**Medium**	**M**	**H**	**H**
High	**Medium**	**H**	**H**	**H**

Table 10: New risk matrix based on the modified SJA for weak knowledge [(4)]

		Probability		
Consequence	**SoK**	**Low**	**Medium**	**High**
Low	**Weak**	**M**	**M**	**H**
Medium	**Weak**	**M**	**H**	**H**
High	**Weak**	**H**	**H**	**H**

4. EVALUATION OF NEW SJA

The opportunities for improving the new SJA procedure are discussed in this chapter. One way of assessing this is to compare different risk analysis methods which identify and respond to hazards. Norwegian Oil and Gas companies use a SJA to determine risk prior to a work activity or operation and to eliminate and control identified risks.

There are many different methods for describing risk. The most common are qualitative, semi-quantitative and quantitative methods. Qualitative approaches are the easiest to apply, as they require least resources and least additional skill sets. The approach, however, gives the lowest level of detection. Quantitative approaches require resources and skill sets. They are based on the preparation of a detailed understanding and provide the best decision foundation. The semi-quantitative approaches are between the two other methods.

Project teams decide which methods to use. All methods are, however, in principle equivalent. When the approach has been selected, the method that fits the approach must be selected. The strengths and weakness of the methods are discussed, to determine which method best fits the SJA.

4.1 Hazard Identification Tools

The first step in risk assessment is risk identification. This is perhaps the most important step in risk assessment as project hazards are identified at this stage. Only identified hazards can be managed. There are several methods that can be used to identify hazards.

Important factors for identifying hazards are included in the conclusion. They include: gathering information, identifying hazards, teams of experts, work in every operation. The following are the methods evaluated in this thesis.

4.1.1 HAZID Analysis

Hazard identification in a SJA is a qualitative exercise based on expert judgment. A group of experts working as a team and with different background knowledge normally carry out a HAZID early in the project. The objective of a HAZID analysis is to systematically identify hazards in operation, to map risks and existing barriers and establish new actions for identified hazards that are not in accordance with acceptable risk.

HAZID form

Each identified hazard relating to a specific guideword is marked with a sequential ID-number. The guideword and hazard/observation used is described. Consequences are described and existing barriers are stipulated. The group estimates the risk for a hazard/observation in accordance with the risk matrix (ref. Appendix 6 as sample [20]). If the risk for an area of the matrix is above an acceptable level, then the group is to evaluate new actions/barriers. A new estimated risk level is then stated. If new actions are established, a person responsible and due date is to be decided. A risk matrix is used to estimate level of risk.

Hazard guidewords are an important tool in HAZID analysis. They ensure consideration of a complete range of safety questions. Every company has its own guidewords. A sample of guidewords used in Rosenberg Worleyparsons for HAZID and HAZOP analysis is given below.

Table 11: Guidewords [20]

Guideword	Description
Much/little/no quantity	Possibility for to much/little or no fluid in the system?
High/low level	Possibility for high/low level in tank?
Wrong direction (Reverse)	Possibility for process/fluid to move in other directions than intended?
Wrong content	Possibility for wrong fluid composition?
High/low pressure (More/less)	Possibility for high/low pressure to arise in the system?
High/low temperature	Possibility for high/low temperature to arise in the system?
Starting up/blackout	Possibility for start-up/blackout causing problems?

4.1.2 HAZOP Analysis

The objective of a HAZOP analysis is to systematically identify any possible operational errors/design errors that may cause hazards for personnel, environment and equipment in new installations or process equipment modifications (test equipment, chemical handling equipment, storage system etc.)

Working sessions are held with the relevant personnel to identify any potential operational errors/design errors that can cause hazards for personnel, environment and equipment. The HAZOP leader leads the working session and the HAZOP secretary records the hazards identified using the HAZOP form (ref. Appendix 7 as a sample [20]). The HAZOP leader, during the working session, creates a dialog between participants for each guideword and node. When all guidewords are reviewed for one node, the discussion moves on to the next node.

4.1.3 FMECA

FMECA (Failure Mode, Effects and Criticality Analysis) is based on DNV 2002 [16] and describes a systematic method for identifying the failure modes of mechanical or electrical systems and for the evaluation of consequences. FMECA is a qualitative analysis technique, which is normally carried out in the design phase.

The FMECA process begins with identifying potential “single point failures”, risks to the system and the cost of loss associated with such failures. The next step is (if possible) to eliminate “single point failures” and if this is not possible, to reduce risk. Finally, probability plans for “single point failures” that cannot be reduced or eliminated are identified.

FMECA is a systematic technique that helps identify all hazards associated with the electrical and mechanical parts of a system. FMECA can be performed by one expert. FMECA identifies critical equipment failures that can be vital to the entire system. FMECA could be very uncertain if experts do not have enough experience with the system. The expert therefore needs to have enough information about the system that is analyzed. For example, drawings of systems need to be prepared before system analysis is begun. FMECA is suitable for mechanical and electrical equipment, but it is not suitable for process equipment and multiple human errors. FMECA should, in these cases, be used with other risk analysis such as HAZID or HAZOP. Figure 6 shows an example of how a FMECA is conducted.

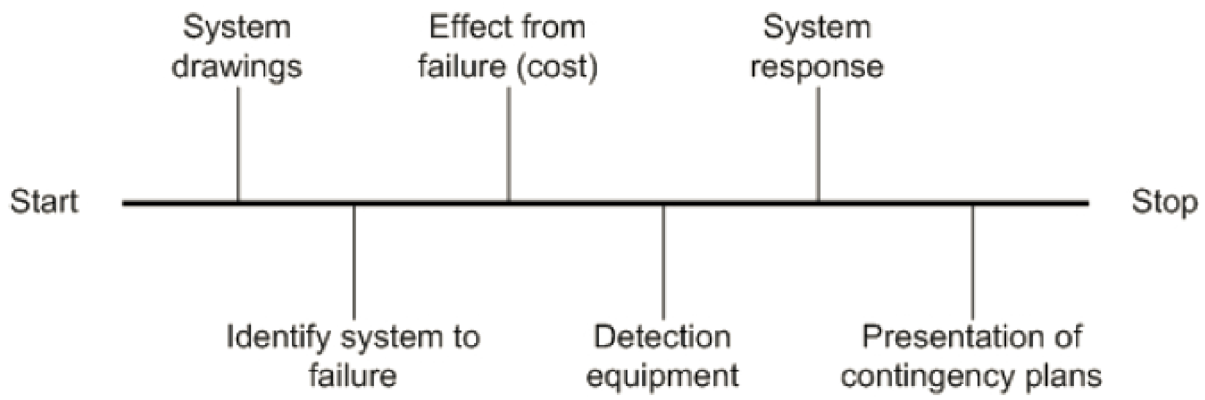


Figure 6: Failure Mode, Effect and Critically Process [23]

4.1.4 Structured “What-If” Technique (SWIFT)

SWIFT is a method for identifying hazards and has been developed as a simpler alternative to HAZOP. SWIFT is a systematic team-based study. It starts with a team of experts who use standard “what-if” phrases and prompts to study how a system, procedures and organization will be affected by deviation from normal works.

The experts who perform the analysis must be familiar with the system. SWIFT is designed for petroleum plant and chemical plant hazard studies and applies to systems, procedures and organizations. The SWIFT method is a very flexible method of studying any type of installation and operation at any step in the lifecycle of the project.

SWIFT relies on brainstorming and checklists for finding hazards in a system. The correct preparation of a checklist is therefore very important. The method also uses the experience of experts in meetings. The experts and their experience is therefore important. Figure 7 shows how a SWIFT can be conducted.

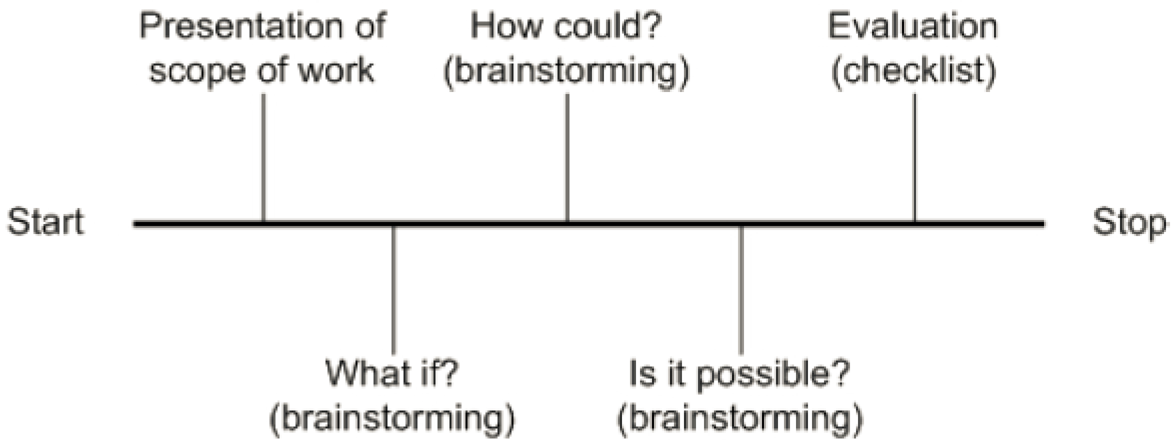


Figure 7: Structure What-If Checklist Technique Process [23]

4.1.5 Anticipatory Failure Determination (AFD)

The methods of risk assessment described above do not provide the opportunity to identify black swan type events and surprises. Hazard/threat identification methods therefore need to be improved to solve the problem of the unforeseen.

A new approach to identifying hazards/threats and to failure and risk analysis is Anticipatory Failure Determination (AFD). It was introduced to analyze black swan and unforeseen events. It is based on the theory of inventive problem solving, which has two broad applications. AFD-1 and AFD-2. AFD-1 used for discovering the causes of a failure that has already occurred and is called failure analysis. AFD-2 is called failure prediction and is used to identify potential failures that have not been yet occurred (Kaplan et al., 1999).

The strength of AFD is that it makes a significant contribution to revealing category B and C black swan type events through the process of failure inversion and failure amplification. Failure inversion and failure amplification are, however, steps that are the most important parts of the AFD-2 template and follow the successful identification of failure modes [5].

4.1.6 Conclusion

We can, in a SJA, use methods such as HAZID and HAZOP to identify project hazards. Identified hazards are entered into a risk register database and are therefore easy to trace when evaluating risk level. The methods contain parts of different methods of risk identification and are important in the obtaining of a more suitable risk picture for an operation. The techniques used are guidewords and task analysis. It is, however, suggested that parts of SWIFT such as “what if analysis” which questions the procedures in more detail should also be implemented. FMECA can also be used for critical equipment, as this does not risk the whole operation stopping. This is expected to give better information on where hazards are hidden. A combination of all methods is therefore thought to be a better way of preparing the procedures.

4.2 Risk Assessment Method

When all hazards have been found, the risk level should then be evaluated to determine whether it is acceptable. There are many ways of evaluating risk level including BowTie, fault tree and event tree. The most common approach in oil and gas operation and in SJA is the risk matrix.

4.2.1 Risk Matrix

The results of a risk analysis have traditionally been presented using risk matrices.

Once hazards and consequences have been recorded, the risk of how likely a hazard will occur and the degree of severity should be calculated. The goal of the risk matrix is to prepare a basis for determining whether an event is safe or not. The risk matrix also considers the reduction of risk through implementing measures. Project management and the project owner decide whether the risk is ALARP or not, which is a major responsibility.

The evaluation of risk in this way has both positive and negative aspects. A positive aspect of the risk matrix is that it is easy to use providing there are clear guidelines on how to evaluate the level of risk. Other methods are more complex and require more detailed calculations. The risk matrix, however, only requires basic expert experience and just a few experts who know how to evaluate risk level. Risk matrices cover risks to people, assets and the environment and making more correct risk decisions.

The risk matrix does, however, have some negative aspects. Most decisions require probabilities and consequences. Decisions that are not correctly recorded will result in the basis for risk decision being lost. Because of this, Norwegian Oil and Gas always recommend that the results are recorded in a SJA database. If a hazard occurs that causes major damage to a vessel, then the SJA for the project can be traced in the database. All predictions in traditional risk matrices are based on just two dimensions, probabilities (P) and consequences (C). Risk influencing factors and sources are not covered. We need to see beyond traditional risk matrices if we are to arrive at good judgments. It is recommended by Norwegian Oil and Gas that traditional risk matrices are therefore replaced with enhanced risk matrices, which include strength of knowledge. Surprises can always occur. This new procedure, however, accepts that risk is more than a number and gives sufficient weight to basic safety principles such as robustness and resilience, so that uncertainties and potential surprises are met.

4.2.2 Bow Tie Analysis

BowTie analysis is another risk assessment. BowTie is a fast and easy-to-use assessment tool. It is a technically advanced tool which simplifies the carrying out of risk assessments. A BowTie diagram is a strong visual presentation of the risk assessment process. One that can easily be understood by the non-specialist.

BowTie is a cause-consequence analysis that highlights the causes of a problem and describes the potential consequences. This is a structured approach to risk analysis which highlights the barriers that prevent hazards occurring. BowTie is a single diagram which combines cause and consequence analysis. Fault tree analysis (cause analysis - FTA) is plotted on the left side of the diagram and event tree analysis (consequence analysis - ETA) is plotted on the right side of the diagram.

FTA

Fault tree analysis is a common tool which uses graphics and statistics to analyze an event and predicts how and how often a failure will occur. FTA is used in engineering and business arenas to aid process and system development. It is a graphical presentation of the events and component failures which can combine to cause a critical incident (system failure).

FTA uses "logic gates" (mainly "AND or OR") to show how "basic events" can combine to cause the critical "top event". Qualitative identification is used to find the combinations of basic events that can lead to a top event occurring. The FTA begins with a top event, and then works towards intermediate events and then the basic events at the bottom.

The conditions required to produce each event are considered and are represented in terms of the events that must occur at the level below. Each event or multiple events that can cause a higher event are connected with an "OR" gate. If two or more events can occur together, then they can be connected with an "AND" gate. A fault tree analysis is shown in Figure 8.

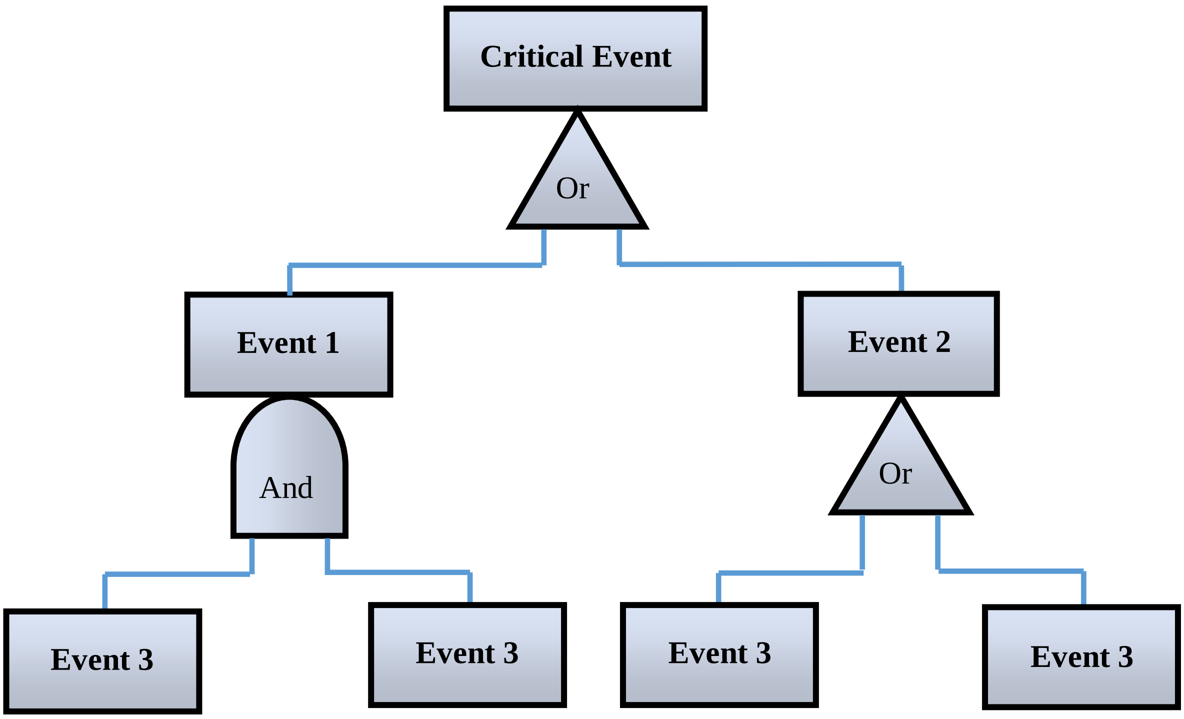


Figure 8: Fault Tree diagram

ETA

Event tree analysis (ETA) is a logical representation of events starting from an initiating event (component failure). As shown in the figure below, ETA uses branches to show the possible outcomes that can occur at each step. The tree connects a failure event to different consequence models, and can also be used to quantify the probabilities of system failure where there are several causes that only can occur at the same time.

ETA begins with the initiating event such as component failure and works towards the final result. This method provides information on how a failure can occur and the probability of its occurrence. A branch is defined in terms of a question (Experienced people?). The answer can be either “Yes” or “No”. Each branch is conditional based on the answers to the previous branches in the tree. ETA is a structured and methodical approach and can be effectively performed at different levels of design detail. The ETA method is a simple method and can be carried out by hand or using a computer. The decision can be based on probability, start or stop. The event tree diagram for the lift of a heavy structure is presented in Figure 9 and the decision is based on start or stops.

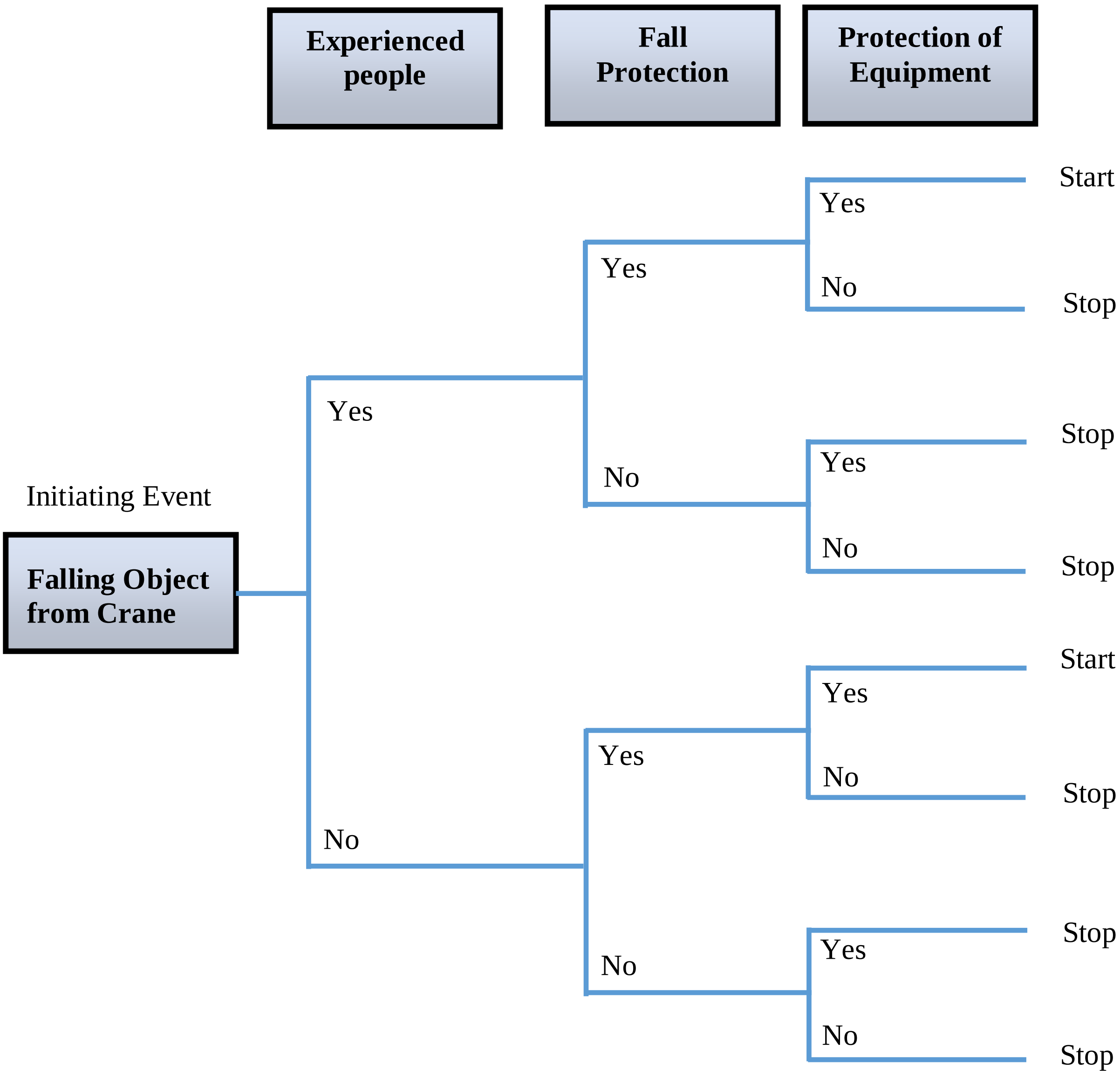


Figure 9: Event Tree diagram

4.2.3 Conclusion

Risk assessment techniques for decisions in safety investment have been developed in many fields in recent decades. Increasing responsibilities and limited resources force decision makers to make decisions on risk reduction measures and safety.

Risk matrices are very effective tools and a common approach in risk assessment. A risk matrix can be an effective tool for showing the outcomes of risk analysis and for helping people to obtain an overview of the relative risk of different scenarios that might be faced in a system.

There are some disadvantages of using risk matrices. These include the difficulty in handling multiple consequences of a single hazard. The BowTie diagram can, however, be used as an alternative. This method is not complex and can be understood by even non-specialists. BowTie also clearly shows how causes and consequences affect each other, causes being shown in the FTA and consequences in the ETA. Executing a BowTie however takes more time than risk matrices and so costs more to carry out.

Previously, traditional risk matrices which are based on consequences and probabilities were used in SJA for risk assessment. The lack of background knowledge is, however, a major issue associated with this approach. SoK is not reflected in traditional risk matrices. A risk matrix alone, based on probability and consequence, can therefore provide a weak picture of risk. Norwegian Oil and Gas has recommended the use instead of the enhanced risk matrix, which includes strength of knowledge. Oil and gas plants are complex systems. A dynamic understanding of risk is therefore required. The enhanced risk matrix is therefore an improved risk management tool that can make safety more efficient.

5. SUMMARY AND CONCLUSIONS

The safe job analysis is a method that is used in Norwegian offshore and onshore facilities for carrying out risk assessment for work operation. It is used to identify, eliminate or control risks. The enhanced risk matrix, the new version of SJA which has been recommended by Norwegian Oil and Gas, replaces the traditional risk matrix in risk assessment. Strength of knowledge is included in the enhanced risk matrix. A SJA shows how activities in a work area should be conducted and managed such that they are in accordance with approved practices.

The goals of this thesis were to test and evaluate the new version of the SJA in a real case and present improvement suggestions for the new SJA procedure.

The example used was the lifting and transporting of a heavy steel structure by wagon from/to the workshop, the new SJA being compared with the previous SJA.

METHODS USED TO IDENTIFY MEASURE AND COMMUNICATE RISK

An important part of a SJA is risk identification. Different risk identifications are recommended used to achieve a better risk picture of an operation. Guidewords and task analysis are the techniques used. However, some parts of SWIFT should also be implemented. SWIFT is a checklist method which questions the procedures in more detail. It is also suggested that FMECA is used for critical equipment. This is expected to give better information on where hazards are hidden. Black swan type events and surprises can be identified using AFD. Therefore, combining all hazard identification tools could be the best way of preparing procedures. This is, however, time consuming.

Risk matrices are a very effective tool and common approach in risk assessment. The BowTie diagram, which is not complex and can be understood by even non-specialists, is a good tool for risk assessment. BowTie execution however requires more time than risk matrices and time means money.

As suggested by Aven [(6)], traditional risk matrices with only two dimensional probability and consequence should not be used. Strength of knowledge as a third dimension should also be included. It is recommended by Norwegian Oil and Gas in the new version of SJA, that the enhanced risk matrix is used, strength of knowledge being reflected in the risk matrix. In oil and gas plants, which are complex systems, a dynamic understanding of risk is required and enhance risk matrices are a better risk management tool for more effective safety.

IMPROVING RISK MATRIX

Risk is evaluated in a SJA by preparing risk matrices. Here are some suggestions for improving risk matrices [(7)]:

i. Report the average of probabilities and intervals which cover 90% of the assigned probabilities.

ii. Compute the average strength of knowledge

iii. Group whole sets of event A with P and SoK (Those with low SoK and high P are the events with highest judged risk)

iv. Use color to represent strong, medium and poor SoK.

v. Prepare a check list that covers A, C, P and SoK to highlight potential black swans to the analysts.

The following suggestions are also presented for ranking risk events based on probability, impact and knowledge:

- *Very high risk*: extreme consequences, high probability of such consequences and /or significant uncertainty (related to weak background knowledge)
- *High risk*: extreme consequences, small probability of such consequences and moderate or weak background knowledge
- *Moderate risk*: between low and high risk
- *Low risk:* no potential for serious consequences.

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7. LIST OF APPENDIX

Appendix 1

Risk and Uncertainty

Risk definition

The future will always be uncertain (whether incidents will happen or not) and so are the consequences of the incidents if they occur. Risk has two main components (i) the events and related consequences (ii) uncertainty about the occurrence of an activity and consequences. A new definition of risk presented in the guidelines to section 11 of the framework HSE regulations: “Risk means the consequences of the activities, with associated uncertainty”. The definition of risk by Aven is also presented below:

“Risk is related to future events A and their consequences (outcomes) C. Today we do not know if these events will occur or not, and if they occur, what the consequences will be. In other words, there is uncertainty U associated with both A and C. How likely it is that event A will occur and that specific consequences will result, can be expressed by means of probabilities P, based on our knowledge (background knowledge), K.” (Aven, 2008).

Development of risk concept

There are many categories of risk definitions. Aven (2012b) extrapolated six development paths as shown in Figure A-1. Development path D6 is characterized by different perspectives on risk. The first part is characterized by both U and P risk definition. The next part is U, Po and (C,P) and recently C, (C,U) and ISO. We could say that, focusing of this development path, that this path is a practical view that considers which risk perspective is suitable. An explanation of risk is “Potential/ possibility of a loss”. This definition express that a loss may or may not happen. Risk is (C,U) because of the potential/possibility linked to different outcomes.

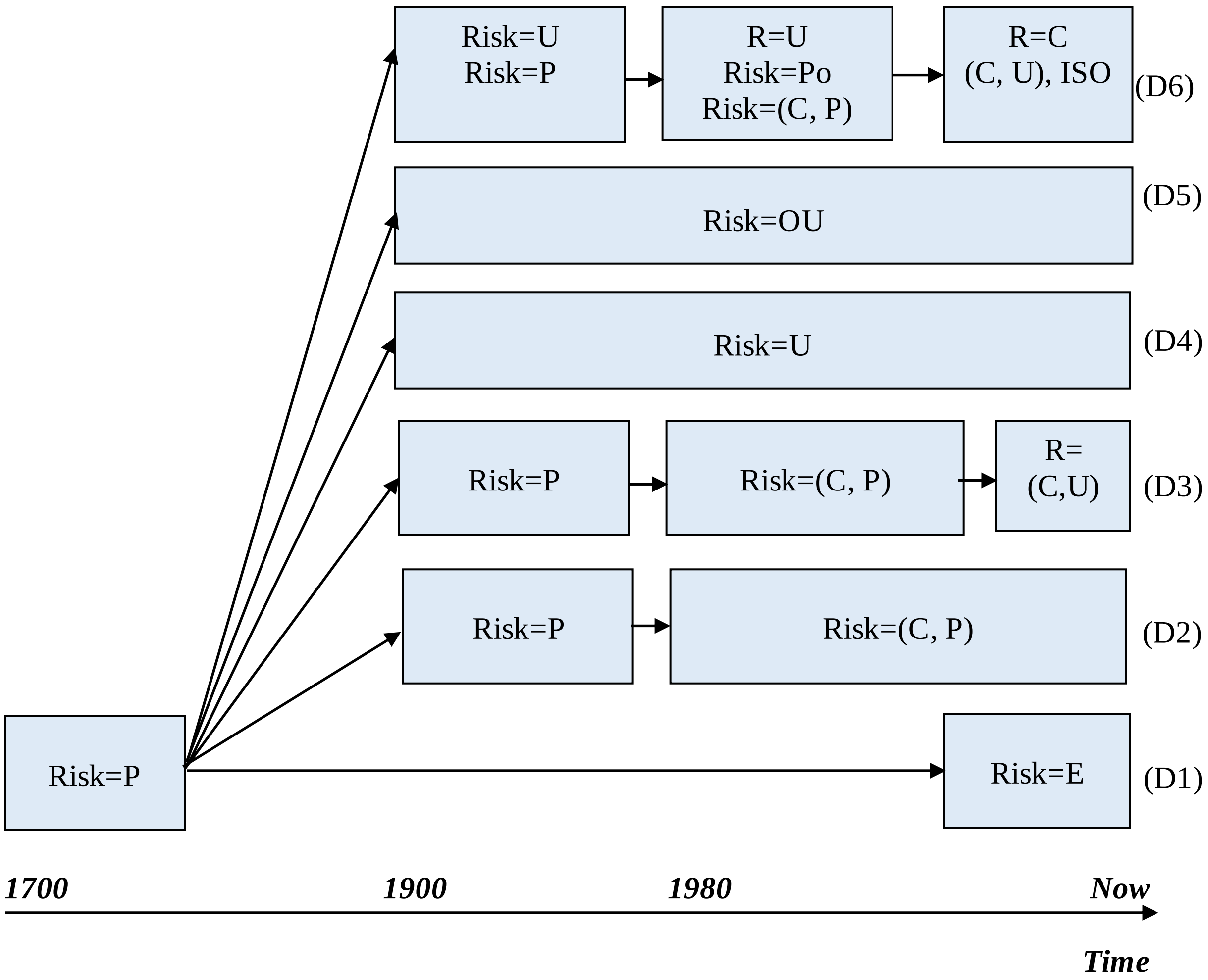

Figure A- 1: Six thought-constructed development paths for the risk concept, E=Expected value (loss), P=Probability (of an undesirable event), OU=Objective uncertainty, U=Uncertainty, C=Event/consequences, Po=Potential/possibility (of loss), ISO=ISO(2009a, b) definition of risk(based on Aven 2012b)[(2)]

If we use the newest risk perspective of the above developments paths, we can end up with:
E, (C,P), (C,U), U, OU and (C, (C,U) and ISO)

Uncertainty

The risk analysis is calculated through the experience of the people who carry out the risk assessment. But there is uncertainty related to their experience. Uncertainty U linked with probability of the hazard occurring and the consequence of the hazard. (Abrahamsen, Aven et al. 2009) say that the risk associated with an activity is to be understood as: “risk is uncertainty about and severity of the consequence (or outcome) of an activity with respect to something that humans value”. Severity can be referred to as intensity, size, extension, scope and other potential measures of magnitude and work on something with a human value (injury’s, assets and environments). Severity is characterized as consequences. The risk perspective in (Abrahamsen, Aven et al. 2009) is “risk cannot be adequately described and evaluated by reference to probabilities and expected consequences only”. In the figure A-2 we can see an illustration of the risk definition:

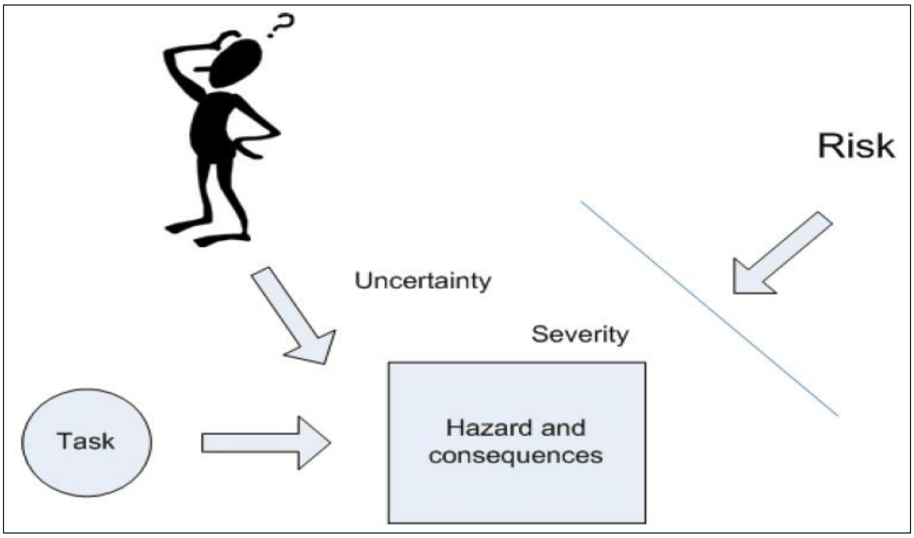

Figure A- 2: Uncertainty attached to calculation of hazards and consequence

Appendix 2

RISK MATRIX

Risk Assessment Matrix

The risk matrix is a common method which is used for risk ranking. A risk matrix is employed to assess or estimate risk by plotting the probability of an undesired event along one axis and the degree of consequences along another. This is performed for each assignment. Each block in the risk matrix describes a level of risk. The blocks with the same risk level are usually grouped together into one risk area. The size of the risk matrix can be different depending on risk ranking grades. A 3x3, 4x4 or 5x5 matrix can be useful in some organizations and not for others. For example, a 5x5 matrix (ref. figure A-3 and A-4), gives 25 blocks, the blocks representing risk grades. More blocks mean more risk ranking grades. Organizations can therefore assign the low, intermediate, high and extreme risk to the acceptance level of organization. The larger number of probability and consequence options in the risk matrix give greater scope for different levels of responsibility to the risk group.

Three types of risk matrices are used for ranking of risk. Quantitative risk matrix, blocks defined qualitatively or descriptively. Quantitative risk matrix, blocks defined quantitatively or measurable. Numerical scales are used in a quantitative risk matrix whereas non-numerical scales are use in a qualitative risk matrix. The third type of risk matrix is a semi-quantitative matrix with one scale defined quantitatively and the other qualitatively.

AS2885.1 2007 - Risk Matrix

		Typical Severity Classes	Catastrophic	Major	Severe	Minor	Trivial
CONSEQUENCES		**People**		Few fatalities, or several people with life-threatening injuries	Injury or illness requiring hospital treatment	Injuries requiring first aid treatment	Minimal impact on health & safety
		Supply	Long term Interruption of supply	Prolonged interruption; long term restriction of supply	Short term interruption; prolonged restriction of supply	Short term interruption; restriction of supply but shortfall met from other sources	No impact; no restriction of pipeline supply
		Environment NOTE: Significant environmental consequences may occur in locations which are relatively small & isolated	Effects widespread; viability of ecosystems or species affected; permanent major changes	Major off-site impact; long term severe effects; rectification difficult.	Localised (<1 ha) & short-term (<2 yr) effects, easily rectified.	Effect very localised (<0.1 ha) and very short term (weeks), minimal rectification	No effect; minor on-site effects rectified rapidly with negligible residual effect
FREQUENCY	**Frequent**	Expected to occur once per year or more.	Extreme	Extreme	High	Intermediate	Low
	Occasional	May occur occasionally in the life of the pipeline	Extreme	High	Intermediate	Low	Low
	Unlikely	Unlikely to occur within the life of the pipeline, but possible.	High	High	Intermediate	Low	Negligible
	Remote	Not anticipated for this pipeline at this location.	High	Intermediate	Low	Negligible	Negligible
	Hypothetical	Theoretically possible, but has never occurred on a similar pipeline	Intermediate	Low	Negligible	Negligible	Negligible

Figure A- 3: Risk Matrix table (10)

Risk Management Actions	
Extreme:	Modify the threat, the frequency or the consequences so that the risk rank is reduced to 'intermediate' or lower. For an in-service pipeline the risk shall be reduced immediately.
High:	Modify the threat, the frequency or the consequences so that the risk rank is reduced to Intermediate or lower. For an in service pipeline the risk shall be reduced as soon as is possible, typically within a timescale of not more than a few weeks.
Intermediate:	Repeat threat identification and risk evaluation processes to verify and, where possible, quantify the risk estimation; determine the accuracy and uncertainty of the estimation. Where the risk rank is confirmed to be 'intermediate', if possible modify the threat, the frequency or the consequence to reduce the risk rank to 'low' or 'negligible'. Where the risk rank can not be reduced to 'low' or 'negligible', action shall be taken to- a) remove threats, reduce frequencies and/or reduce severity of consequences to the extent practicable; and b) demonstrate ALARP. For an in-service pipeline the reduction to 'low' or 'negligible' or demonstration of ALARP shall be completed as soon as possible, typically within a timescale of not more than a few months.
Low:	Determine the management plan for the threat to prevent occurrence and to monitor changes that could affect the classification.
Negligible:	Review at the next review interval.

Figure A- 4: Risk Management Action (10)

- **Qualitative risk matrix**

Judgments are made to categorize hazards by qualitative risk matrix. Shown below is the 3×3 matrix. Three simple scales are used for both probability and consequence: low, medium and high. The risk for each scenario is the product of probability and consequence rating. Qualitative risk in this case therefore falls into 9 different areas (Probability × Consequence) : low × low, low × medium, low × high, medium × low, medium × medium, medium × high, high × low, high × medium and high × high. As shown in the below figure, the low × low region is lowest risk and the high × high region is the highest risk. The intermediate areas are not easy to explain. The USA's Environment Protection Agency has prepared a technical guide for hazard analysis (See Figure A-6) that shows risk level from a 3 by 3 matrix grouped into three categories: high (major concern), medium (concern) and low (no concern).

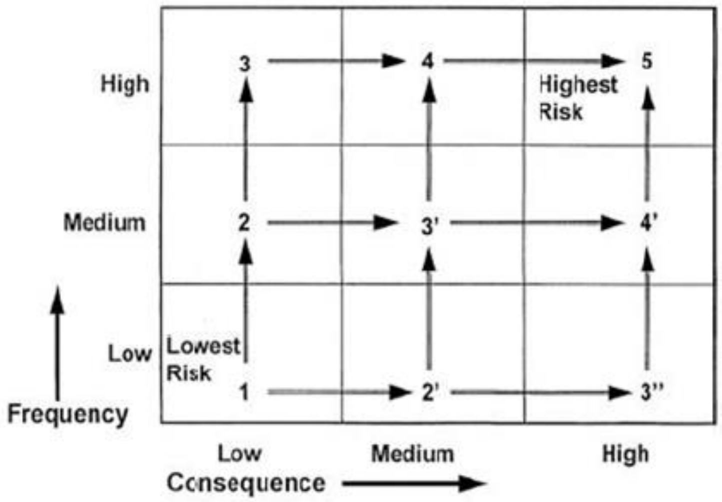

Figure A- 5: Qualitative risk matrix [17]

Matrix Region	EPA Risk Grade	Figure 1 Risk Grade
High*High	Major Concern	5
High*Medium	Major Concern	4
Medium*High	Major Concern	4'
Medium*Medium	Concern	3'
Low*High	Concern	3''
High*Low	No Concern	3
Medium*Low	No Concern	2
Low*Medium	No Concern	2'
Low*Low	No Concern	1

Figure A- 6: Risk grouping from US Department of Energy [17]

- **SEMI-quantitative risk matrix**

Semi-quantitative risk matrices are rarely used because of limited usefulness. It is limited in risk evaluation. No more detail is presented in this thesis.

- **Quantitative risk matrix**

Some hazard situations require analyzing using a quantitative risk matrix. As shown in the below figure, quantitatively scaled consequence and risk can be calculated for all regions in this matrix. Simmon [19] says each accident will be given a risk value in a quantitative risk matrix. All scenarios can then be ranked.

		Consequence level				
		1	2	3	4	5
Likelihood level	Descriptor	Insignificant	Minor	Moderate	Major	Catastrophic
5	Almost certain	5	10	15	20	25
4	Likely	4	8	12	16	20
3	Possible	3	6	9	12	15
2	Unlikely	2	4	6	8	10
1	Rare	1	2	3	4	5

Risk rating
Extreme
High
Moderate
Low

Figure A- 7: Example of quantitative risk matrix [18]

- **Enhanced perspective on risk**

Risk matrices alone, which are based on probabilities and consequences, can provide a confusing picture of risk. It is therefore necessary see beyond the probabilities.

An enhanced perspective involves new insights and an improved way of viewing risk. This includes knowledge building, experience transfer and learning and a new way of meeting unthinkable, unforeseen and potential surprises [6].

A dynamic understanding of risk is necessary to deal with this complex system. An enhanced risk perspective provides this. An enhanced risk perspective improves risk management and makes safety work more cost-efficient.

An enhanced risk perspective covers knowledge and uncertainty about the phenomena studied, assessment surprises and way of thinking (mindfulness). As shown in Figure A-8, the enhanced risk perspective in practice covers concepts and tools linked to understanding, assessing and managing knowledge and surprises [6]. A dynamic understanding of risk and an enhanced perspective on risk is also needed to provide the basis for dealing with a complex system.

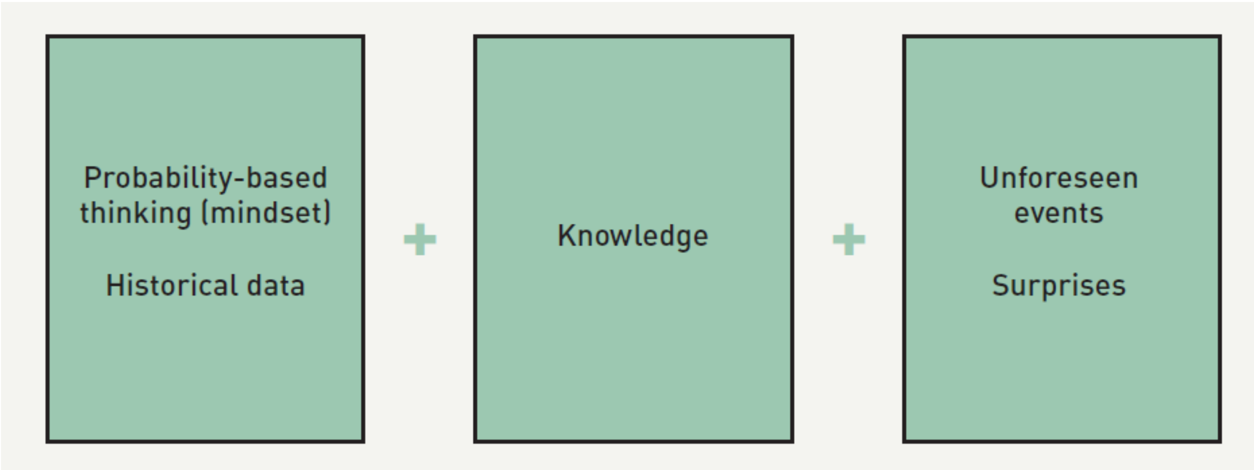

Figure A- 8 : What the enhanced risk covers [6]

Appendix 3

STANDARDS CHECKLIST FOR SJA

NO	Checklist for SJA no: SJA title:	Yes	No	N/A	Comments (must be completed if No is ticked)
A	**Documentation and experience data**				
1	Is the work team familiar with the work operation?				
2	Is an applicable procedure/set of instructions/job package available for the work operation?				
3	Have experience and/or undesirable incidents from similar work operations been taken into account?				
B	**Expertise**				
1	Are necessary personnel and expertise available for the work operation?				
2	Are necessary personnel present at the SJA meeting?				
C	**Communication and coordination**				
1	Has communication with possible other units/work teams been established?				
2	Are suitable means of communication in place?				
3	Are parallel activities coordinated within the system, area and facility?				
4	Has it been clarified who will be leading the work?				
5	Has sufficient time been allocated for the work operation?				
6	Has the response to possible alarms or emergencies been assessed?				
7	Are emergency response functions informed of possible conditions which could affect them?				
D	**Key physical safety systems**				
1	Are barriers for reducing the probability of undesirable leaks intact and will they remain so (safety valves, piping, tanks, control systems, etc)?				
2	Are barriers for reducing the probability of an HC leak intact and will they remain so (detection, overpressure, disconnection of ignition sources, etc)?				
3	Are barriers for isolating leak sources/leading hydrocarbons to a safe area intact and will they remain so (process/ESD systems, blowdown systems, Xmas trees, drains, etc)?				
4	Are barriers for extinguishing or limiting the scope/spread of a fire/explosion intact and will they remain so (detection/alarm, fire pumps, extinguishing system/ equipment, etc)?				
5	Are barriers to help ensure safe evacuation of personnel intact and will they remain so (emergency power/lights, alarms/PA, escape routes, lifeboats, etc)?				
6	Are barriers to help ensure the stability of floating facilities intact and will they remain so (watertight bulkheads/doors, open tanks, ballast pumps, etc)?				
E	**Equipment covered by the job**				
1	Is necessary isolation from energy dealt with (rotation, pressure, voltage, etc)?				
2	Are possible hazards from high temperatures dealt with?				
3	Is machinery protection/shielding sufficient?				
F	**Equipment for doing the job**				
1	Is lifting equipment, special tools and equipment/materials for the job known, available, checked and found to be in order?				
2	Does everyone have correct and adequate protective equipment?				
3	Have possible hazards from uncontrolled motion/rotation of equipment/tools been assessed and dealt with?				
G	**The area**				
1	Has an inspection been carried out to verify access to and knowledge of the work area and its working conditions?				
2	Has account been taken of work at height, several levels and dropped objects?				
3	Has account been taken of flammable gas/liquid/materials in the area?				
4	Has account been taken of possible exposure to noise, vibration, toxic gas/ liquids, smoke, dust, vapour, chemicals, solvents or radioactivity?				
H	**The workplace**				
1	Is the workplace clean and tidy?				
2	Are marking/signs/cordons required?				
3	Have transport conditions to/from the workplace been taken into account?				
4	Are additional guards required?				
5	Have weather, wind, waves, visibility and light been taken into account?				
6	Have access and escape been assessed?				
7	Have work position/threat of occupational illness been taken into account?				
I	**Local supplementary questions**				
1					

Appendix 4

STANDARDS SJA FORM

SJA title:			SJA no:	Dept/discipline:	Person resp for the SJA:
Description of the work:				Facility:	No of equipment/ pipeline:
				Area/module/deck:	
Preconditions:				WP/WO no:	No of appendices:
No	**Sub-task**	**Hazard/cause**	**Possible consequences**	**Measures**	**People responsible for measures**
Is the total risk acceptable?: (Yes/No)		Recommendation/approval	Date/signature	Check that the checklist for the SJA has been reviewed	
		Person resp for SJA	(Recomm)	Summation of experience after the job:	
Conclusion/comments:		Resp for execution of work	(Recomm)		
		Area/operations supervisor	(Approve)		
		Other post	(Approve)		

Appendix 5

STANDARDS PARTICIPANT LIST FOR SJA

SJA PARTICIPANT LIST	SJA TITLE:			SJA NO:			
SJA meeting Date:_____ Time:______ Place:_______ Responsible for the SJA:				Countersignatures for change of personnel, etc			
Name (block capitals)	Dept/discipline	Date	Signature	Name (block capitals)	Dept/discipline	Date	Signature

Appendix 6

SAMPLE OF HAZID FORM

Activity:								
ID	**Guideword**	**Hazard/observation**	**Consequence**	**Action/barrier**	**Risk**	**Evaluation – new Action/barrier**	**Rest risk**	**Follow-up**
1.1					**= A** **= T** **= U**		**= A** **= T** **= U**	**Person responsible:** **Due date:**
1.2								**Person responsible:** **Due date:**
2.1								**Responsible:** **Frist:**

Appendix 7

SAMPLE OF HAZOP FORM

Operation/activity:			Node description:		
ID	**Guideword**	**Cause**	**Consequence**	**Evaluation – new actions/barriers**	**Follow-up**
1.1					**Person responsible:**
					Due date:
1.2					**Person responsible:**
					Due date:
					Person responsible:
					Due date: