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Abstract

This thesis carries out a case study of Altus Interventions Root Cause Analysis, focusing on the reporting program Synergi and the methodology surrounding it. The central thesis objective is to map the current methodology and suggest improvements. The following research questions were formulated to limit the scope:

RQ1: ***What is Altus Interventions current Root Cause Analysis methodology?***

RQ2: ***What efforts can be made to improve Altus Interventions current Root Cause Analysis methodology***

With semi-structured interviews followed by thematic analysis, a qualitative approach was utilised to capture Altus Interventions' current standing in relation to a set of guidelines and criteria on root cause analysis. The thematic analysis resulted in a set of themes representing concrete improvement areas.

The main findings were that Synergi is a functioning program to perform root cause analysis, but a list of challenges is hindering full utilisation of the program. The first main area of improvement is to align Synergi to the company vision and strategy by creating a bottom-up engagement for Synergi use, which requires management to convey results from Synergi to the organisation. Further, by updating and making procedures more visible, ownership and engagement might increase.

The second area deals with improving the competence in Synergi reporting and processing, which can be done by highlighting the importance of plausibility and reproducibility and clearly stating a company-wide definition of root cause and its practical implication.

Third, with updated and visible documentation, different roles can be expected to carry out their responsibility, which today is somewhat unclear.

Finally, it is advised to double down on Synergi for root cause analysis and improve the program for this use. Recommendations to improve the program is improving data input and identify the possibilities for program development.

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Finally, a thank you to Altus Intervention and the employees who took the time to participle in interviews and shared their insight.

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List of Abbreviations

RCA – Root Cause Analysis

QHSE – Quality, Health, Safety and Environment

IPA – Importance-Performance Analysis

DOE – United States Department of Energy

TRIZ – Theory of Inventive Problem Solving

CENELEC - European Committee for Electrotechnical Standardization

1. Introduction

Continuous improvement methodologies have become an integral part of modern industry. The methods have, under different names and in different forms, helped companies achieve remarkable results. One famous example is Motorola's implementation of *Six Sigma*. The methods led to the company having a defect rate as low as .0015%. *Lean production* is a second famous methodology that originated in the company Toyota in 1988. Its success has since inspired companies worldwide in implementing the methods [1].

Implementing philosophies such as the two mentioned above requires a considerable investment of time, money, and effort from a company. While undoubtedly useful, it might be more suited to focus on specific methodologies embedded in such philosophies. Root Cause Analysis (RCA) is one of these methodologies that have taken on its own life outside of the original overarching philosophy [2]. RCA aims to identify underlying causes for problems and implement measures to prevent reoccurrence.

Altus Intervention and the Oil & Gas Service industry find themselves under pressure from oil and gas operating companies to perform high-quality service with minimal downtime. RCA can help address these challenges by providing a systematic methodology to tackle problems leading to non-productive time and other issues. However, RCA literature suggests a variety of different processes and tools. This "goody bag" of different choices presents both challenges and opportunities. It requires thought and cautiousness to select the techniques that yield the company's best result. Similarly, it provides the opportunity to pick the techniques that best fit the companies need.

This thesis will carry out a case study of Altus Interventions RCA-system, called Synergi. Altus' process will be mapped and compared to a generic RCA process, then a set of measurables will be presented from guidelines and criteria. These measurables form the basis for semi-structured interviews that aims to identify challenges related to Synergi and its RCA methodology. Finally, the challenges will be discussed, and insight and suggestions will be presented.

1.1. Objectives

The central thesis objective is to map the current RCA methodology at Altus and suggest improvements based on RCA guidelines and criteria. The insight gained will be considered in its application to the rest of the industry. The premise of the thesis is that by having a sound RCA methodology, a company increases its operational quality, safety and reduce cost, among other(s) factors, by continually finding and eliminating root causes of problems. Implementing or improving an RCA methodology will improve the company's safety and the economic and environmental perspectives. Literature, standards, public and internal documents, and interviews will be studied and presented to reach the objectives.

The following two research questions have been formulated to scope the thesis focus:

RQ1: ***What is Altus Interventions current Root Cause Analysis methodology?***

RQ2: ***What efforts can be made to improve Altus Interventions current Root Cause Analysis methodology?***

Answering these research questions were done by qualitative research and semi-structured interviews with employees. First, the RCA methodology was outlined based on internal documents and conversations with critical employees. Then, a qualitative analysis using semi-structured interviews were conducted within the ramifications of guidelines and criteria before a thematic analysis is applied to identify themes and challenges. Finally, suggestions for improvements will be proposed at the end of the text.

The author was an apprentice for the company for two years, which resulted in a certificate of apprenticeship in Wireline Well Intervention, Altus's discipline. After the apprenticeship, the author went on to study mechanical engineering, in which this paper is the bachelor thesis. This background yields the opportunity for insight into the company and its processes while still bringing an outside viewpoint. While this thesis revolves around RCA's process or methodology, the company is specialised in Well Intervention, which requires both technical knowledge and insight. To better understand RCA's applied context in this case, a background in mechanical engineering is well suited. Finally, this paper aims to provide insight and valuable suggestions to Altus and the industry.

1.2. Thesis Structure

The thesis structure is linear. First, chapter 1 presents a general introduction by presenting the thesis and its objective, root cause analysis and Altus Intervention. Secondly, chapter 2 presents the theory applied in the thesis. The methodology is then put forward in chapter 3, including the research strategy, design, and method. The following chapter 4 presents the results, which include Altus Interventions current RCA methodology, the thematic analysis results, and the observations from the guidelines and criteria. Finally, the discussion takes place in chapter 5, with a conclusion of each theme.

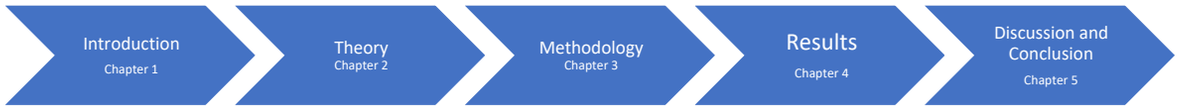

Figure 1: Thesis Structure

1.3. Background

Following the inception of the Oil and Gas industry in Norway in the latter half of the 20th century, Altus Intervention was founded in 1980 as Maritim Well Service. The company sprung out of Kværner when they expanded their business in specialised products and services. They started delivering wireline services to well-intervention offshore one year after startup. In 1986 the company expanded from mechanical wireline to logging technology, and we started to see the company as it is today. Today, the company is well established as a well-intervention company on the Norwegian continental shelf and has expanded to do intervention in North America, the Gulf of Mexico, the Middle East, Malaysia, Denmark and the U.K. [3]. With 1100 employees, the company delivers mechanical and electrical wireline, tractor and logging services, plug & abandon operations and more. Operationally, the organisation covers a broad spectrum. Planning and executing offshore operations, research and development, maintenance of equipment, logistics, and personnel training are among some of the areas that make offshore well-intervention quite complex.

With such an involved and complex operation, the need for sound quality systems arises. Altus practices different systems to maintain high quality. One such system is Synergi, a web-based reporting tool used to report Quality, Health, Safety and Environment (QHSE) incidents [4]. Synergi provides a method of registering events, suggest causes for the events and actions taken to correct and prevent reoccurrence. The methodology resembles a root cause analysis process, but Altus faces challenges with utilising the program and

methodology to the fullest. A primary challenge is to identify root causes consistently. The research found that the actions taken often are temporary fixes that do not eliminate the underlying problem. Another challenge is to address the correct level of the causes. The research also found that the cause identified is too shallow to tackle the underlying problem, resulting in insufficient action to remove the underlying problem. Conversely, going too deep to identify causes is also a problem, resulting in implementing actions on a too detailed level. Finally, most actions taken are immediate or corrective actions. Very few include preventive actions that will reduce or remove reoccurrence.

2. Theory

2.1. Root Cause Analysis

Root Cause Analysis

Root Cause Analysis (RCA) does not have a standard definition. It is a collective term used to describe a method to identify the root cause of a problem. Andersen and Fagerhaug suggest the following definition:

> *Root cause analysis is a structured investigation that aims to identify the true cause of a problem and the actions necessary to eliminate it* [5].

While some authors limit RCA to solely identifying the cause, Andersen and Fagerhaugs broader definition includes elimination-action as a part of the definition. Chapter 2.1.1 will discuss the different scopes of RCA.

RCA is a reactive process. A sign of an existing problem, termed a symptom, arises. Instead of identifying and eliminating the first problem behind the symptom, RCA investigates deeper to find the underlying cause. The literature uses different nomenclature to describe three phenomena. This thesis will use Symptom, Cause and Root Cause to stay consistent with Andersen and Fagerhaug and most of the literature. The three terms can be exemplified in the following hypothetical case:

Imagine Tom watching T.V. one day when suddenly he smells smoke. The smoke is a symptom of a problem in Tom's apartment. He gets off the couch and investigates the smell. Entering the kitchen, Tom sees the smoke coming from the electric kettle. Identifying the kettle as the cause for the smoke, he throws it away and buys a new one. Two days later, when making breakfast, the new kettle erupts in fire. After putting the fire out, Tom calls an

electrician. It turns out the socket supplied too much current to the electric cattle causing it to overheat.

When investigating the symptom, the examiner might find multiple causes in various forms and on different levels. The first level behind the smoke is the cattle burning and is labelled as a Cause. Deeper underlying reasons might present multiple causes. Replacing the cattle did not fix the problem, which differentiates it from the Root Cause. Only after investigation and conversation with the electrician is the fundamental underlying issue – the root cause – identified.

Table 1: RCA symptom, cause and root cause

Name	Other Names	Example
Symptom	n/a	Smoke
Cause	Visible Problem/physical cause	Kettle too hot
Cause	First level cause/physical cause	Kettle overheated
Cause	Higher-level cause/physical cause	Broken socket
Root Cause	System Cause	Improper instalment of the socket

Combination of causes

The example above indicates a single dimension for the problem causes, each underlying cause directly following the previous in consecutive order. Reality might be different. Multiple independent causes might produce a problem, as seen in c) of Figure 2. Similarly, multiple causes might, in combination, produce the problem, as seen in b). Independent and combination of causes can be true for Root Causes and Causes. While RCA has been criticised for suggesting linear chains of causes [2, 6], it is avoidable using the dependent and combination approaches.

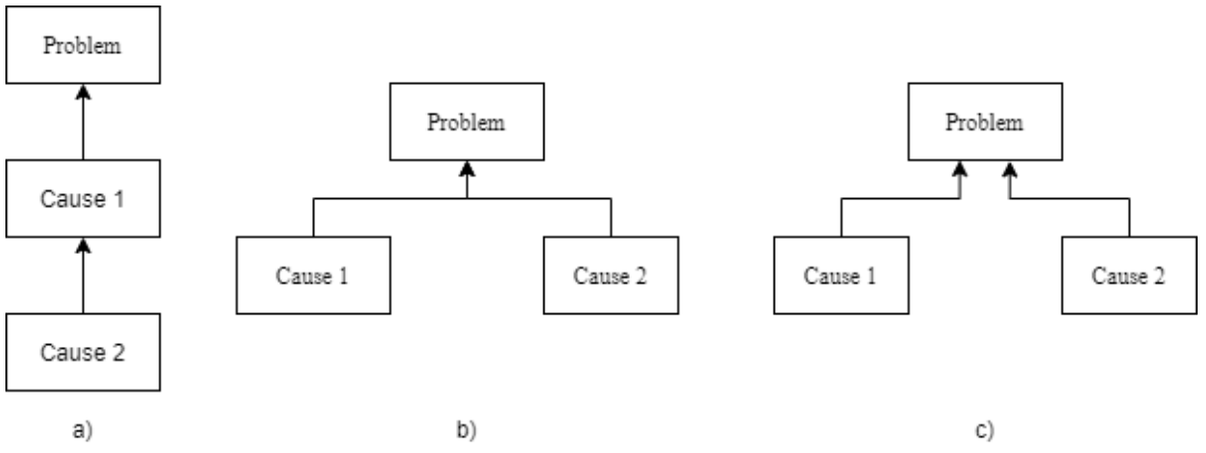

Figure 2: Relationship of Causes

Too shallow or too deep

Having looked at RCA's fundamental concept above, it is natural to questions when to stop looking for deeper causes. No formula or flow diagram can indicate when the correct root cause is found. It is always possible to dig deeper. Conversely, concluding before finding the root cause is a temporary fix, and the root cause might resurface again as the same or a different symptom. Balancing between the two requires intuition and knowledge about the problem, which introduces subjectivity into the analysis. Savannah River Plant used a practical definition of root cause to make it more apparent when to stop:

> *Root Cause: The most basic cause that can reasonably be identified and that management has control to fix* [7].

While a more concrete definitions, both “reasonably” and “control to fix” are two terms that are not clearly defined. Without a quantitative system for deciding what is “reasonably identified” and “management has control to fix”, it remains a subjective judgement.

Corrective action density

When companies collect reporting on numerous incidents and provide corrective actions, the number of actions may pile up. When the number of actions becomes very high compared to the personnel involved or responsible, it can be labelled as high corrective action density[8]. Conversely, the same concept can be applied to cases if a company practices a reporting system where a case handler is assigned to each case. If a company has 150 employees and 300 corrective actions or reports each year, each employee will have, on average, two

corrective actions. Usually, a much smaller number of employees are involved in the corrective actions, resulting in a potential work overload as this work is often in addition to their everyday routine.

Furthermore, the involved employees may also be working on multiple cases simultaneously, resulting in poor diagnosing and actions. To get an idea of the corrective action density or reporting density, one can take the number of cases or reports and divide by the number of employees involved. There is no hard limit on what is considered sufficient or too much. Multiple factors are in play, but the number can be used to highlight the amount of work put upon the involved personnel.

Prioritising Cases

Duke Okes suggests a solution to the corrective action density problem by having a filter and guidance for its use [8]. The filter will sort the different cases into categories, where each category has a different approach based on the problem. For instance, some cases require no investigation, and others require finding some underlying issues, while some need a thorough investigation to identify the underlying root cause. Criteria and procedures for filtering different problems are subject to each organisation, as the variance in the content of events and corrective action density is large. Some methods, however, are broad in their application. Priority matrix, criticality matrix and importance-performance analysis are all heavy utilised tools for prioritising based on quantitative measures. The latter one is explained in detail in chapter 2.1.2.1. As an example, by using a generic criticality matrix shown in Figure 3 below, the criticality of the problem can be used to navigate a flow diagram, as shown in Figure 4. Higher criticality requires more investigation into the underlying causes, while lower criticality cases are monitored and have fewer resources applied to investigate.

Probability						
	6	12	18	24	30	36
	5	10	15	20	25	30
	4	8	12	16	20	24
	3	6	9	12	15	18
	2	4	6	8	10	12
	1	2	3	4	5	6
	Severity					

Figure 3: Generic criticality matrix

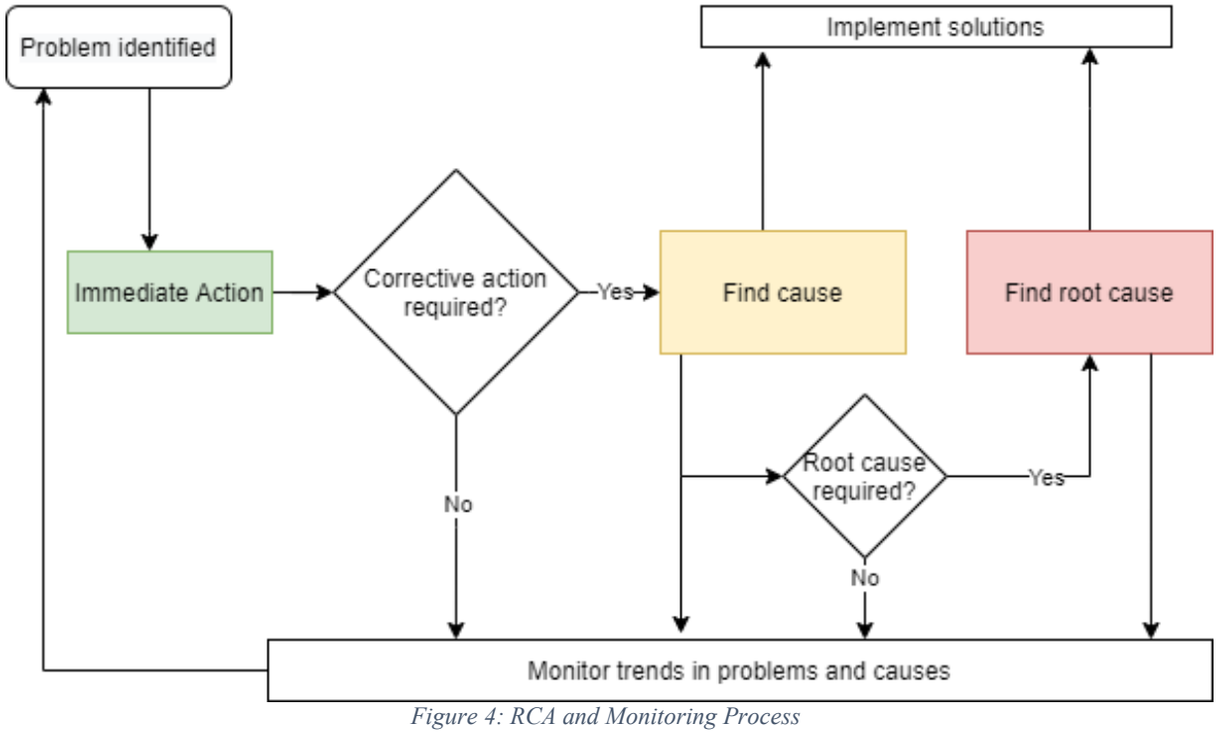

Figure 4: RCA and Monitoring Process

2.1.1. Process

As mentioned in chapter 1, RCA was a methodology often embedded in many more extensive overarching methodologies. The method first took its own shape in 1988 at Savannah River Plant [2, 7]. The initial version included the Root Cause definition mentioned in chapter 2.1, coupled with a tool called Events and Causal Factors Charting. In the time since its inception, RCA has evolved in scope and applicability. Savannah River Plant introduced the concept to the nuclear industry, and in 1992 the United States Department of Energy (DOE) published RCA guidelines[9]. Today, companies and institutions use the methodology in a variety of sectors due to its broad applicability. There exist multiple books and papers on the topic, all with their version of the methodology.

The process from Savannah River Plant in 1988 was a mere one-step process; find the root cause by using Events and Causal Factor Charting. Since then, there has been an expansion of the process and inclusion of tools. The tools will be discussed further in chapter 2.1.2.

The literature offers different approaches to carry out an RCA. While the different approaches' content is more or less the same, the detail ranges from a broad four or five steps to a more detailed 11 steps process[5, 9-11]. Every process can be divided into two parts:

finding the root cause and fixing the root cause. The number of steps included in each of those two parts depends on the level of detail required.

Figure 5: Different RCA Processes

Some approaches focus primarily on finding the root cause part. This thesis will focus on the expanded version, including steps that encompass problem understanding, problem cause brainstorming, problem cause data collection, problem cause data analysis, root cause identification, problem elimination and solution implementation. Using the expanded version allows for a clear distinction between steps, making it more convenient to analyse systematically.

Figure 6: Andersen & Fagerhaug Process

Step 1: Problem Understanding

The first step of RCA is *problem understanding*. It is hard to identify the causes behind a problem without having a good understanding of what the problem is. There are multiple ways to do this, but a visual or diagrammatic method combined with text is recommended in the literature applied in this thesis. Two tools: flowchart and importance-performance matrix, presented in chapter 2.1.2.1, are typical tools used in problem understanding.

Step 2: Problem Cause Brainstorming

Problem cause brainstorming is a step that aims to come up with possible causes before data is gathered and analysed. This step is placed second to avoid biases that can come from looking at data early. Examples of bias that can prevent an open mind are priming, framing and anchoring bias[12]. Brainstorming as a tool is presented in chapter 2.1.2.2.

Step 3: Problem cause Data Collection

Next up is *data collection*. It is essential to gather sufficient data to carry out an analysis of a high standard. Sampling, surveys and check sheets will be discussed as tools for this in chapter 2.1.2.3.

Step 4: Problem Cause Data Analysis

A natural successor to data collection is *data analysis*. In this step, data is turned into meaning through different tools. There is a myriad of data analysis methods, but a simple approach is practised in this thesis. Kaoru Ishikawa, who is considered one of the great contributors to quality management, coined the term *seven basic tools of quality*, which he claimed solved 95 per cent of the problems he encountered [13]. Among these were histogram, control chart and Pareto chart. These three tools are detailed in chapter 2.1.2.4.

Step 5: Root Cause Identification

Root cause identification is the apex of the process. Everything done previously is in the service of carrying out this step to the best of its capability. By using different methods, this step identifies the root cause(s) of the problem. Even though it is perhaps the most critical part of the analysis, it can be completed relatively quickly if sufficient work is done in the previous steps. As with many of the steps, a multitude of tools are available and ranging in complexity. Using the ideology of Ishikawa and Andersen & Fagerhaug, relatively simple but powerful tools are discussed in chapter 2.1.2.5.

Step 6: Problem Elimination

After finding the root cause(s), actions must be taken to prevent reoccurrence. Failing to do this may result in the problem surfacing again, which undermines the efforts put into the analysis. It is preferred to spend enough time creating the correct actions rather than saving time and missing the mark. TRIZ is discussed for problem elimination in chapter 2.1.2.6.

Step 7: Solution Implementation

Finally, after conceiving the action needed to eliminate the problem, the action must be implemented. This phase may include organising the implementation, developing an implementation plan and carry out the implementation itself [5].

Individual investigations vs streamlined process

RCA might be used to carry out investigations of larger hazardous events. An assembled team carries out the investigation. The team looks at the problem, creates a process, and selects associated tools related to the specific case. Furthermore, the team carries out the RCA over weeks or months before concluding it and closing the investigation.

An alternative approach to RCA is to have a streamlined process for corrective action, with monitoring of trends. The streamlined process includes having a pre-defined RCA process with preselected tools for a systematic procedure. Additionally, the process includes categorising the problems for trend monitoring and filtering out more severe problems for investigation. This case study of Altus Intervention falls into this second approach. The streamlined RCA approach is not much discussed in the literature, which is more concerned with large-scale RCA investigations. By drawing on the practice of these traditional processes and applying them to this modern, streamlined version, it is a relatively unexplored RCA area.

2.1.2. Tools

Multiple tools can assist in the different RCA steps presented. Numerous tools are available, ranging from high complexity such as machine learning to low complexity such as histogram, a basic statistical tool. This chapter presents the tools discussed in the thesis. The selection method is detailed in chapter 3.1.3.

2.1.2.1. Problem understanding Tools

Flowchart

A flowchart is a diagrammatic representation of a workflow, process or algorithm. Algorithmic flowcharts are primarily encountered in programming and mathematics, detailing sequenced instructions for a finite number of steps. Workflow and process

flowcharts are used in various industries to describe everything from minor procedures such as fixing a light bulb to complicated systems to present the conceptual structure [14].

There are multiple practises to flowcharts. Figure 7 depicts a typical representation of a flowchart. Beginning with a starting point or input point, the flowcharts represent the process between the starting point and potential endpoints as a series of symbols with connecting arrows indicating the process movement.

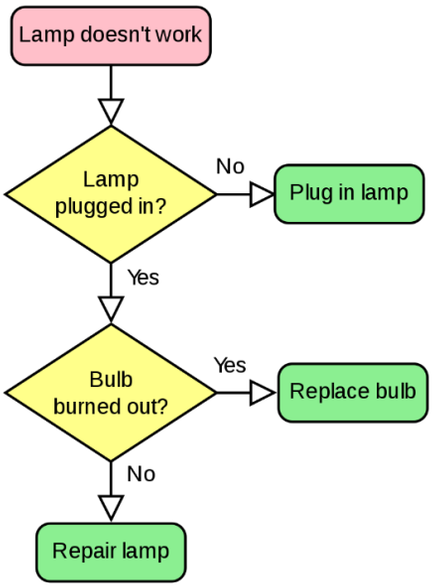

Figure 7: Flowchart Example

The boxes represent different meanings depending on the shape. The triangle represents a choice. In figure 7, there is one input but two ways to continue based on the answer to the triangle question. The arrows have an answer to the question attached, and one follows the arrow with the respecting answer.

Conveying ideas in a flowchart may help visualise the process, making it more tangible and straightforward. The visual aid might be helpful for both experts and non-experts. The experts can use the flowchart as an analytical tool, while the chart's simplicity fits non-experts. The approachability of flowcharts makes it a powerful tool for cross-functional presentation, visualising and analysing a process. The American National Standards Institute (ANSI) created a standard for flowchart symbols in the 1960s, and the International organisation for Standardization (ISO) adopted the standard in 1970 [15].

There are many existing spin-offs from the basic flowchart, keeping the fundamental elements and adding new techniques. A few more known examples are the activity diagram, swimlane diagram and decision tree.

Importance-Performance Analysis

An importance-performance analysis (IPA) aims to identify which problem, factors, or issues are most important to analyse. With many potential problems identified, it might not be easy to prioritise which ones to solve. Martilla and James developed the technique in 1977 as a managerial tool to suggest strategies in marketing [16]. The technique has since found use in multiple fields[17].

The IPA is a two-by-two matrix diagram, similar to the Eisenhower Matrix but with different axis' and quadrant names. The horizontal axis is "Importance" and indicates growing importance towards the right. Vertically, the axis is "Performance" and indicates the problem's performance at that time, with better performance towards the top.

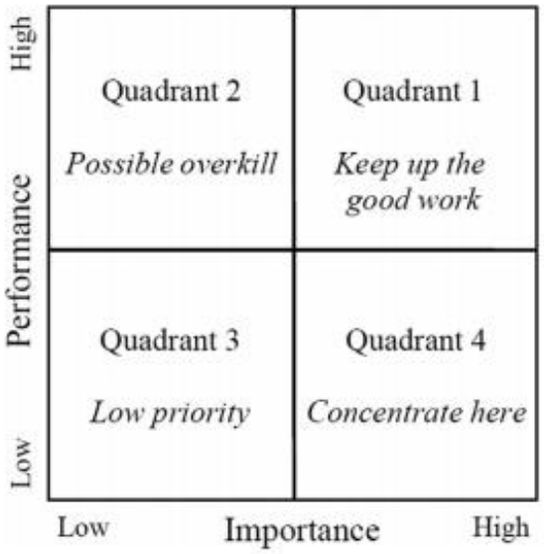

Figure 8: Importance-Performance Diagram

By assembling a list of problems, factors or issues (called elements) and then assigning a discrete value (in a scale from low to high) to both performance and importance will give them a spot inside one of the four quadrants. Quadrant 1, keep up the good work, results from high importance and high performance, indicating that the element is getting the proper attention to keep the performance high as an essential part. Quadrant 2, possible overkill, represents elements that have high performance and low importance. Not necessarily an issue, elements in this quadrant perform well despite their low importance, but if they take up valuable resources, it may be a sign of sub-optimal resource use. Quadrant 3, low priority,

holds the elements that are low importance and low performance. Despite their low performance, these elements are not prioritised due to their low priority, making them lesser issues which demand lesser resources. The final quadrant 4, concentrate here, is the most critical part of ISO. The quadrant contains elements of high importance and low performance, indicating a mismatch and need for improvement.

The ISO technique may present a helpful way of categorising and prioritising problems, factors or issues. However, it is not without its flaws. In his 2014 paper "Importance-performance analysis: A valid management tool?" Ivan Sever pointed out several issues, including conceptual and methodological issues such as no precise definition of the term "importance".

2.1.2.2. Problem cause brainstorming Tools

Brainstorming

Brainstorming is the activity of generating ideas for a topic of choice. In the context of this thesis, the ideas would be causes, and the topic is the problem. A group of people, although the activity can be done solo, typically gathers. Then a topic is selected and put on a piece of paper or a blackboard. Everyone involved proceeds in coming up with ideas related to the topic. A key point of brainstorming is to produce a high volume of ideas. Further, nothing is criticised or discarded. Combining high volume and low entry-level creates many ideas which might not have been uttered without this type of activity.

2.1.2.3. Problem cause data collection Tools

Sampling

Sampling is a statistical method of gathering data from a sub-section of a larger population, analyse the data and then apply the insight to the population as a whole. Three statistical criteria are required to create a high-quality sampling: representativeness, sample size and sample techniques[18]. If done correctly, sampling can give insight into data based on a small group's data collection, which can be valuable in multiple disciplines and companies. The population can be a group of machines, customers or whatever the company want to investigate. Although powerful, sampling can take much time to prepare and carry out with high integrity.

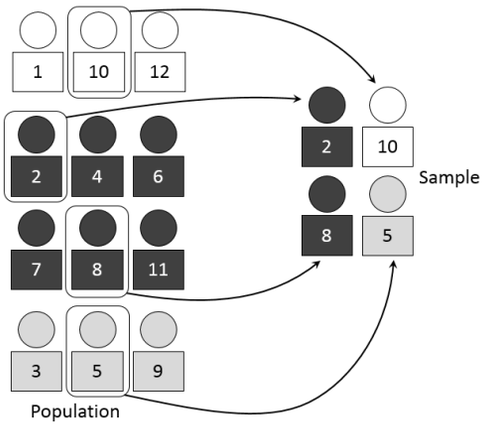

Figure 9: Sampling from a population

Check Sheets

Check sheets are a way of collecting data, typically in table form. Pre-defined cells are created to collect occurrence and frequency [5]. The example presented in Figure 10 shows a check sheet for a motor assembly. Typical defects are presented together with each day of the week. Each time a defect occurs, the workers add a mark in the cell representing the day and event. The data can then be analysed to gather insight.

Defect Types/ Event Occurrence	Dates							TOTAL
	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	
Supplied parts rusted		|||||||	|||||	||||	||			20
Misaligned weld			|||			||		5
Improper test procedure								0
Wrong part issued								3
Film on parts								0
Voids in casting				||||	||			6
Incorrect dimensions							||		2
Adhesive failure								0
Masking insufficient								1
Spray failure			|||||					5
TOTAL		10	13	10	5	4		

Figure 10: Check sheet for motor assembly

2.1.2.4. Problem cause data analysis Tools

Histogram

A histogram groups data into categories or discrete values and displays them as bars with height representing their values. If continuous numerical data is used, multiple ranges are

created, each range representing one column. If the data is categorical, each column represents a category. After the category or ranges are made, the height of the column is based on the vertical axis, which is usually numerical. Sorting data this way gives a visual interpretation of the data, which may help gain analytical insight. It can also show more statistical traits of the data set based on how the histogram looks, which then can be analysed by someone with basic statistical training [18]. Figure 11 below show different data distributions in histograms.

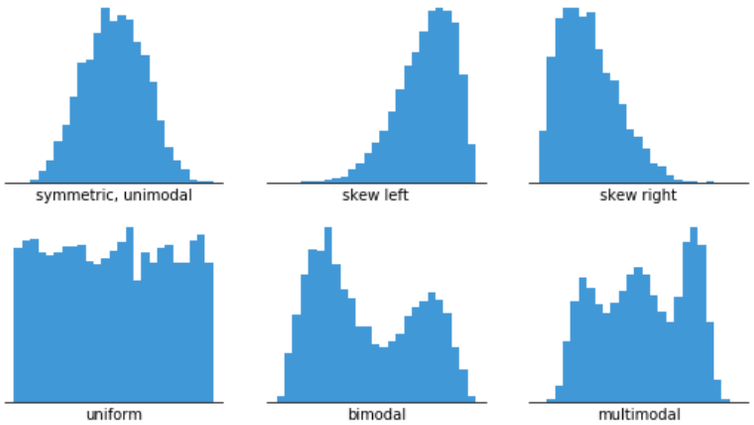

Figure 11: Examples of different data distribution in a histogram

Pareto Chart

Pareto chart is similar to a histogram but with a more specialised objective. The vertical axis represents the frequency or cost of defects, and a line graph presents the cumulated frequency/cost defect rate. The Pareto chart highlights the categories with the highest defect rate by listing the columns in descending order from the left. The name comes from the Pareto principle, which states that 80% of problems come from 20% of the causes. Focusing on the highest contributors, listed first in the Pareto chart, action can be taken towards the most problematic causes.

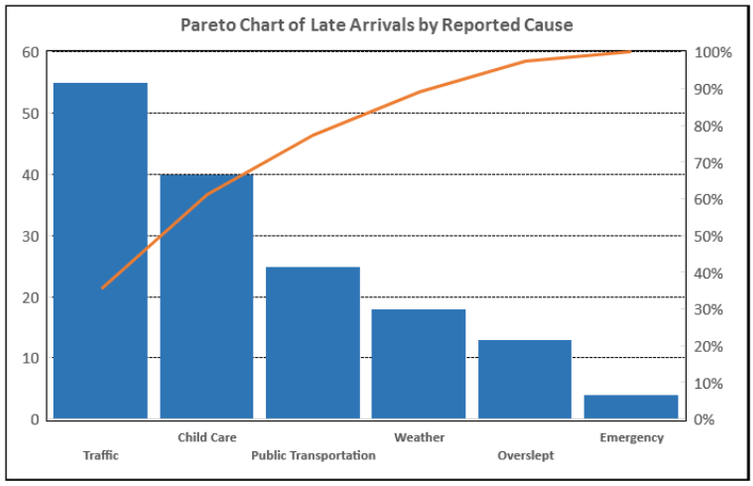

Figure 12: Pareto Chart of Late Arrivals by Reported Cause

Control Chart

A Control chart is a statistical tool to study changes over time. It is applied to data where measurements are supposed to be stable within a belt. A factor times the standard deviation decides the belt size. A control line is drawn based on the normal value of the data. Next, an upper and lower limit is set by taking the normal value and adding half of the belt size for the upper limit and subtracting for the lower limit. If a data point is registered outside of the belt, it is a warning sign because it changes more than normal. The data point outside the belt might be an anomaly or the first sign of some problem and should potentially be investigated.

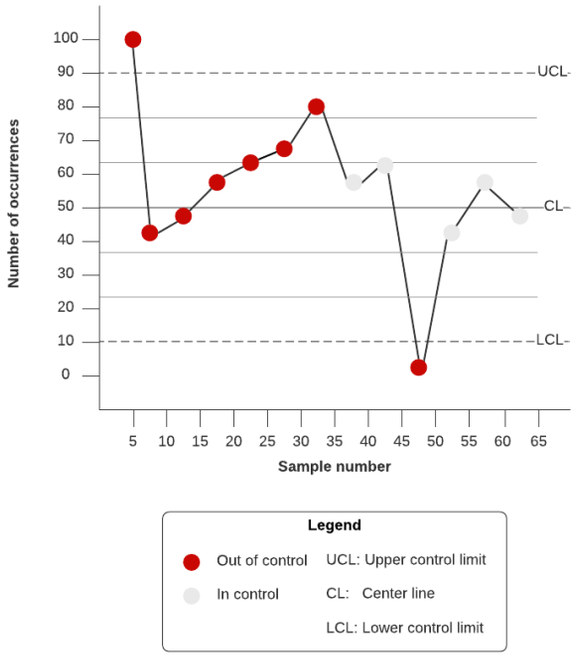

Figure 13: Control Chart

2.1.2.5. Root cause identification Tools

Fishbone diagram

Fishbone diagram, also known as a cause-and-effect diagram or Ishikawa diagram, is a causal diagram created by Kaoru Ishikawa [13]. The aim is to identify potential causes for a problem by stating categories and providing potential causes inherent to a respective category. First, state the problem that requires investigation, typically in a box representing the fish's head. Then draw a straight horizontal line, body-line, from the head. Next, draw lines connected to the body line, called bones. Each bone represents a category. After drawing up this diagram, write down each potential cause in the respective category. Primary causes are indicated as arrows pointing directly to the category. Secondary causes, which are causes that led to the primary causes, are noted as arrows pointing into the primary cause.

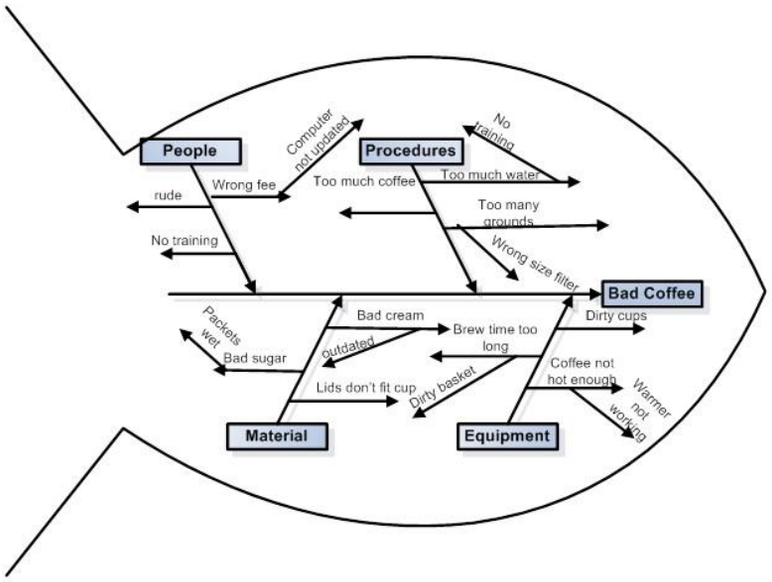

Figure 14: Ishikawa Diagram

As one of the seven basic tools of quality control, a fishbone diagram is a powerful tool. It is visual, making it easy to brainstorm, present and see connections and get a holistic view of the problem and its causes. Disadvantages might be an oversimplification of complex problems, where the predetermined setup of the diagram might do a poor job in representing the problem causes, especially in cases where there are interrelationships between the causes.

Choosing the categories can be done freely. However, there are pre-defined categories that might prove as a good starting point. 6Ms is one of the more common frameworks and provides a good starting point for categories [19]. The 6Ms are man, machinery, materials, method, mother nature and measurement.

Five Why's

The five why's technique is similar to the fishbone diagram but is more singular in its approach. It starts with the problem at hand, and by asking "why?" one is digging deeper into what caused the problem. By asking why five times, one gets deep into the problem and might start unravelling the underlying causes. Although the tool is called five why's, it does not require five specific why's to a problem. The aim is to dig deeper into the problem to think about what might have caused it.

2.1.2.6. Root cause elimination Tools

TRIZ

The Theory of Inventive Problem Solving (TRIZ) is a problem-solving tool developed by engineers in the 1940s. Since then, the tool has seen wide use in Samsung, General Electric and Boeing, among many other successful companies[20]. TRIZ includes a set of principles to generate problem-solving ideas that are based on research in the field of inventive problem-solving. To use TRIZ, the problem is first defined. Next, a principle that suits the problem is identified from the over 40 principles in the TRIZ database. After identifying the principle, the original problem is set in the principle frame and a specific solution for the problem is generated within the principle frame. The total depth of TRIZ requires a detailed discussion and will not be put forth in this thesis.

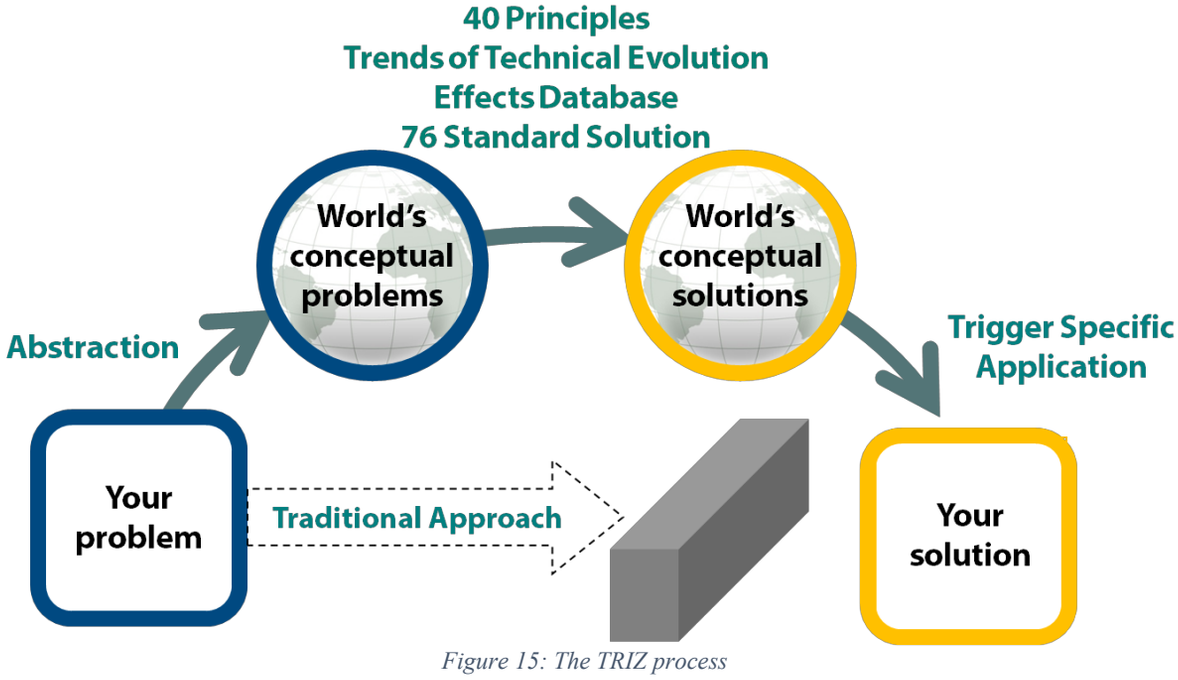

Figure 15: The TRIZ process

2.1.3. Guidelines and Criteria

This thesis will present and use eight guidelines from the standard DOE-NE-STD-1004-92, titled "Root Cause Analysis Guidance Document" by the United States Department of Energy (DOE) [9]. In the standard, these eight guidelines are described as effective correction action program points and are listed in column one of Table 2 below. The author extracted the measurables in column two of Table 2 from the guidelines. Altus Interventions approach to each measurable will be determined through interviews with key employees.

BS EN 62740:2015, titled "Root Cause Analysis" by CENELEC, is also used to complement these guidelines with more RCA specific support [21]. BS EN 62740:2015 provides nine criteria to rank the characteristics of different RCA tools. The criteria are listed in Table 3 below, and a detailed description is found in Appendix A. The selection process and reasoning behind the guidelines and criteria are detailed in chapter 3.1.2.

Table 2: DOE Guidelines and related Measurables

Guidelines	Measurables
G1: Management emphasis on the identification and correction of problems that can affect human and equipment performance, including assigning qualified personnel to effectively evaluate equipment/human performance problems, implementing corrective actions, and following up to verify corrective actions are effective	G1.1: Top-down focus G1.2: Identifying problems G1.3: Correcting problems G1.4: Qualified personnel G1.5: Follow-up
G2: Development of administrative procedures that describe the process, identify resources, and assign responsibility	G2.1: Existing procedures G.2.2: Content of procedures
G3: Development of a working environment that requires accountability for correction of impediments to error-free task performance and reliable equipment performance	G3.1: Existing environment G.3.2: Accountability for corrections
G4: Development of a working environment that encourages voluntary reporting of deficiencies, errors, or omissions	G4.1: Voluntary reporting
G5: Training programs for individuals in root-cause analysis	G5.1: RCA training programs
G6: Training of personnel and managers to recognise and report occurrences, including early identification of significant and generic problems	G6.1: Early identification of problems
G7: Development of programs to ensure prompt investigation following an occurrence or identification of declining trends in performance to determine root causes and corrective actions	G7.1: Ad-hoc investigation triggered by trends
G8: Adoption of a classification and trending mechanism that identifies those factors that continue to cause problems with generic implications.	G8.1: Classification and trending mechanism

Table 3: CENELEC Criteria

Criteria
C1: Expertise required
C2: Tool support
C3: Scalability (with complexity)
C4: Graphical representation
C5: Reproducibility
C6: Plausibility checks
C7: Intellectual rigour
C8: Time sequence
C9: Specificity

3. Methodology

This thesis applies a case study method, a close and detailed look at a single case: the root cause methodology of Altus Intervention. Choosing this approach was advised by the thesis supervisor and supported by the external supervisor from Altus Intervention. Furthermore, a qualitative approach, with semi-structured interviews followed by transcription and thematic analysis, was utilised to capture the current standing of Altus' RCA methodology in relation to a set of deliverables devised from the guidelines. The research process is presented in Figure 16 below in chapter 3.1.1.

This chapter covers the research strategy (3.1), research design (3.2), and research method (3.3) applied. The research strategy describes the general orientation to conduct the research. Further, the collection and analysis of data are set in a framework described in the research design. Lastly, the research methods detail the data collection methods [22].

3.1. Research Strategy

3.1.1. Research Process

The research process is presented in Figure 16. Before any other step could be taken, a literature review was necessary to get an overview of RCA's application and use. The first step was carrying out a broad conventional literature search, as presented in 3.1.2, to get an RCA overview. Next up was identifying challenges in Altus' RCA process by examining internal documents and spreadsheets and conversations with the Vice President of QSHE. Then the research questions were stated based on the literature review and in conjunction with the supervisors to guide the research. After defining the research questions, both guidelines and criteria were identified as a basis to conduct the analysis. Creating a data collection and analysis framework was then done in research design before writing an interview guide. Following this, the interviews were conducted and transcribed in NVivo[23]. After transcription, the analysis program NVivo was further utilised to conduct coding and thematic analysis to analyse the interviews presented in the results chapter together with the RCA methodology of Altus Intervention. Finally, a discussion on the results chapter related to the research questions was conducted and concluded as a summary after every theme was written.

1. Literature review	To get an overview of the topic from an academic point of view as well as insight into the company process, a literature review was first conducted. Presented in 3.1.2
2. Research Questions	The research questions was formed to adress the challenges in addition to scope and guide the research. Presented in 1.1
3. RCA Guidelines & Criteria	To form good data basis to conduct an analysis, a list of guidelines and criteria was selected. The guidelines and criteria containes sound recommendations on par with the literature at large. Presented in 2.1.3
4. Research Design	Case study with qualitative researchs in the form of semi-structured interviews. The subjects were selected together with supervisor from Altus to include key-personnel. Presented in 3.2
5. Interview Guide	The interview guide was written to stay on topic and gather data related to the research. Presented in 3.3.2 and Appendix A
6. Interviews Conducted	The interviews was conducted with the use of TEAMS, follower by transcription of the conversations in NVivo.
7. Thematic analysis	Nvivo was further utilised to code the interviews. The coding was then developed into themes to help answer RQ2
8. Results	The results of mapping Altus Interventions RCA methodology, presenting the themes with related excerpts and presenting the observations from guidelines and crietria was all written out in the results chapter. Presented in chapter 4.
9. Discussion and conclusion	The results were discussed in relation to RQ1 and RQ2 with a conlusion in a summary after each theme. Limitations of the research and recommendations for improving Altus Interventions RCA methodology, further research and application of the research. Presented in chapter 5

Figure 16: Research process

3.1.2. Selection of Literature

The selection of literature started with finding databases. The starting point was Oria, a search service that displays results offered by the university library at the University of Stavanger [24]. Different filtering options, such as category and discipline, were utilised to limit search results and find material closely related to the thesis topic. Oria naturally led to Scopus and Science Direct databases, where further searches were executed [25, 26]. Additionally, Google Scholar was used to including a third reputable database independent of the university search engine [27].

Gaining insight into similar theses written on the subject to find inspiration and lessons learned was done through UiS Brage and NTNU Open, two databases for publishing bachelor and master thesis for the University of Stavanger and Norwegian University of Science and Technology, respectively[28, 29]. Four theses were found on the topic and gave valuable insight into their RCA application in different case studies[30-33]. However, none of these theses concerned a streamlined RCA process or used thematic analysis for their analysis.

Initially, the process was exploratory, mainly looking for books and review articles of RCA to overview the topic. An investigation of the topic's origin, history, and modern state with RCA as the focal point led to related topics such as continuous improvement methodologies, preventive measurement methods, LEAN, Six Sigma, and individual tools used in RCA, mentioned in the introduction chapter. It was decided to limit the theory to RCA while explaining its close relationship to other disciplines and topics to avoid introducing too many topics with overlapping content.

After gaining an overview of the literature, history, and related theses, guidelines and criteria were found in two high-quality standards concurrent with the general literature. The standard Root Cause Analysis Guidance Document (DOE-NE-STD-1004-92) from the U.S. Department of Energy (DOE) included a set of guidelines presented in 2.1.3 [34]. The status of DOE-NE-STD-1004-94 is archived, and the last update was in 2010, but it is still considered most fitting by both the supervisor and the author. Each guideline is backed up by literature and covers the overarching strategy of RCA and was therefore used as a basis for the analysis. The international standard Root Cause Analysis (IEC 62740_2015) from the European Committee for Electrotechnical Standardization (CENELEC) included criteria to compare different RCA tools [21]. The criteria complemented the guidelines from DOE, which contended more with the RCA process's overarching strategy.

Together, the guidelines from DOE and criteria from CENELEC created the foundation for the analysis backed up and supplemented by the theory presented in chapter 2.

3.1.3. Selection of process and tools

The selection of the different processes and tools presented in 2.1.1 and 2.1.2 was made during the literature review. After reading multiple books, articles and papers on RCA, the same process started to repeat itself and was then described. While nearly every text regarding RCA seemed to apply the same process as described in 2.1.1, the most significant differentiator was the choice of tools. While 2.1.2. has an extensive list of tools; this does not begin to cover the amount used in the reviewed literature. Selecting the tools presented in this thesis from the large amount found in the literature was a matter of finding tools that could potentially be implemented at Altus Intervention. In conversation with the supervisor from Altus, the following criteria for tool selection were created by the author:

- Potential to be implemented into the current RCA system at Altus
- Easy to use
- Broad applicability
- Can be used by one person alone

3.2. Research Design

The research was designed after the literature search was completed, and the research questions had limited the scope of the thesis. A case study approach was selected as a framework in which to complete the research. A case study is the study of one unit or case. As RQ1 and RQ2 displays, the case is the RCA methodology of Altus Intervention. Qualitative research is often used in case studies through interviews to gain a deep and direct understanding of the case.

The analysis is based on the data from semi-structured interviews. Table 4 below presents the interview participants of this research with a vague job description to connect the relevance of the interviewee's role to the analysis. No more personal information was given to keep the interview subjects anonymous. Doing so was a deliberate choice to create a safe environment during interviews to get honest and subjective opinions. Reference to the interviewee number will be used during the results and discussion so that Table 4 below can be referenced for the job title for context.

Table 4: Research Design

Interviewee Number	Location & Date	Job Title	Duration [min]	Number of Words Transcribed
1	Teams. 16.04.21	Upper Management	43:20	4 920
2	Teams. 20.04.21	Mechanic	30:14	2 603
3	Teams. 21.04.21	Wireline	65:49	6 380
4	Teams. 23.04.21	QHSE	28:45	2 996
5	Teams. 23.04.21	Tractor	59:32	5 706
6	Teams. 28.04.21	Upper Management	42:51	2 745

3.3. Research Method

3.3.1. Interview Subjects

A list of potential interviewee subjects was put together with the external supervisor through a generic purposive sampling method. Generic purposive sampling aims to sample participants strategically so that those samples are relevant to the research questions[22]. It is

not intended to create a generalised and randomised sample to apply statistical and probabilistic methods. On the contrary, the research questions are the criteria behind the selection process. This sampling method is suitable for a case study where an in-depth examination is vital, and the research questions deal with a process used by the employees. The subjects were selected for their critical insight into the RCA process in different functions and managerial levels.

3.3.2. Data Collection

The data collection method employed semi-structured interviews with employees with critical insight related to the research questions. An interview guide was first created based on the guidelines, which served as a core for the interviews to stay on topic (see Appendix A). However, the semi-structured format aims to capture the interviewees' point of view. By employing a looser format, the subject can depart from the guide and speak on tangents. With a focal point by using a guide while also encouraging a flexible conversation, the subjects could speak freely and provide information that reflects their subjective opinion on the topic.

Internal documents on Synergi, trends and data was also examined and aided towards the presentation of Altus Interventions RCA process, together with public information online from Altus' websites and DNV Synergi Life's website [3, 4]. The process results are detailed in chapter 4.1 and answers RQ1, which is required as background to answer RQ2. The internal documents include sensitive information and will not be included in this thesis.

3.3.3. Data Analysis

Thematic analysis is a method applied by the analyst to form a theoretical understanding of the data, where the data is transcripts from the interviews. It is worth noting that since these interviews would later be translated from Norwegian to English, there exists an additional, albeit a minor, interpretation. This is, however, somewhat mitigated by the fact that the analysis and thematic coding were all done through their original transcriptions. After transcribing, the analyst codes the transcripts. The codes can include a varying amount depending on the research. In this thesis, the coding was mainly based on the deliverables derived from the guidelines. Additionally, natural codes can come about from repetitions, similarities, differences, missing and contradicting data. It is up to the analyst to determine which codes can add insight to the research questions. The coding is further analysed and put

into themes. The themes are detailed and discussed in chapter 4.2 and are vital in answering RQ2.

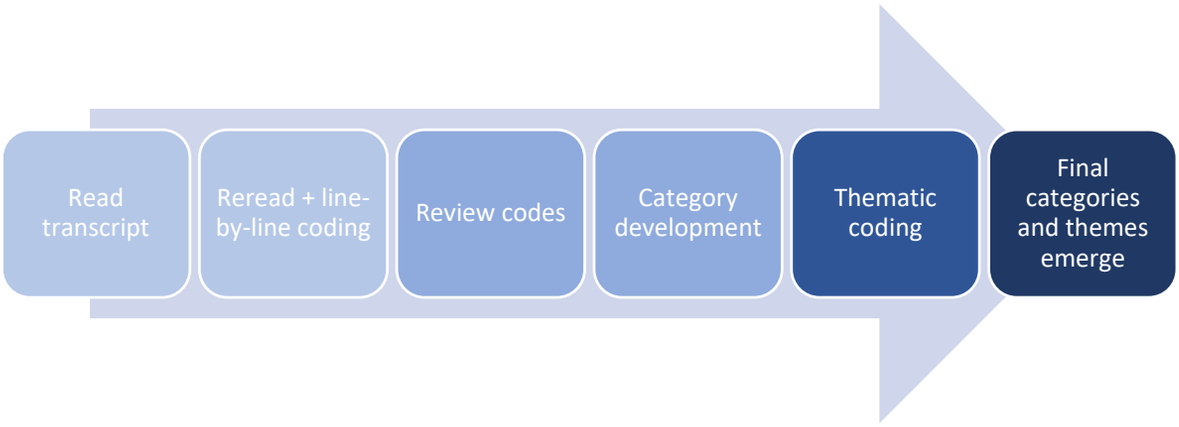

Figure 17: Thematic analysis process

3.4. Quality of Study

3.5. Validity

Validity is the integrity of the conclusions that are generated from the study[22]. There are three areas of validity that is usually considered in qualitative research. The first is respondent bias, which concerns the honesty of the participants' responses. Second, researcher bias is the influence of previous knowledge and assumptions the researchers have on the study. Third, reactivity occurs when the participants are affected by the researcher.

The interviewees were made anonymous, and the transcripts were not attached to the thesis to reduce respondent bias. Additionally, a prolonged involvement with many subjects was established before the interview to build trust. This involvement included previous meetings and email exchanges.

Clarification with the participants if responses were imprecise or clarify the meaning for the researcher was conducted in the interviews or by email post-interview to reduce researcher bias. Peer debriefing was also used, where the researcher consulted with a fellow student that has used coding and thematic analysis in qualitative research.

The interview guide was sent to the subjects in advance, and the questions were asked as stated to reduce the researchers' influence on the answers. Furthermore, the interviewees were not interrupted during the conversation, and the researcher did not discuss his opinion regarding the topics.

3.6. Reliability

Reliability deals with the consistency, stability, and reproducibility of the measurements and is more straightforward in quantitative research, where numerical methods can be applied to display the reliability accurately. In qualitative research, reliability can be increased by applying a generalised and randomised sample, with the notion that asking many people the same question will, in aggregate, reveal a more reliable answer. However, as pointed out in chapter 3.3.1, a generic purposive sampling was utilised to answer the research questions within the time frame of this study. This was done intentionally to better suit a small-scale sample to gain insight into the case study. With the decision to apply a generic purposive sampling, the following decisions were made to maintain reliability.

The interview guide was written early to guide the interviews and is available in Appendix A. Next, the interviews were recorded on Teams and a recorder and later added to NVivo. Transcription was done in NVivo, and line-by-line coding was utilised to generate codes as closely related to the statements as possible. Further, higher-level codes and thematic development was done as described in chapter 3.3.3. A journal was kept of the decisions and reasoning behind the coding and themes. The candidates were treated anonymously in the thesis, and thus, the transcripts are not included in the thesis. The decision of not including the transcript decreased the reliability but was deemed necessary to increase validity.

4. Results

The results chapter comprises four sub-chapters detailing the results from internal documents, informal conversations with the QHSE Vice President and semi-structured interviews. First, chapter 4.1 presents Altus Interventions RCA methodology, which answers RQ1. Second, 4.2 introduces the themes that emerged from the interviews before 4.3 and 4.4 presents the guideline and criteria observations that resulted from the data analysis, respectively. Together, 4.2, 4.3 and 4.4 presents the data necessary to discuss and answer RQ2 in chapter 5. This chapter only reports the findings from the research. All further interpretations and discussions are made in chapter 5.

4.1. Altus Interventions current Root Cause Analysis methodology

In order to answer **RQ1: What is Altus Interventions current Root Cause Analysis methodology?**, two characteristics at Altus is presented before Synergi; the core reporting program is detailed in 4.1.1.

First, multiple programs are utilised. While Synergi is the primary program for reporting incidents or events, there are other programs for different purposes. While the focus of this thesis is on the RCA part of Altus, some other programs need to be mentioned to understand the methodology fully. The programs are used for more than is described here, but those areas fall outside the scope of this thesis and are therefore not included. Figure 18 below illustrates the programs that are most relevant to the research question. Complaint is a part of ERP/M3 and contains all the identification numbers and categorisations of equipment and is the working program for the workshop to perform maintenance and track the equipment. Synergi, which is presented in detail in the next sub-chapter, is connected to IOPS/DWI. IOPS/DWI is a program that reports all operations. The blue circles below are not linked to the programs in yellow, so double reporting often occurs in Synergi and Complaint.

Figure 18: Illustration of the multiple programs at Altus Intervention

Second, Synergi is the core tool of Altus' RCA methodology. As chapter 4.1.1 will present, multiple steps and tools used in RCA are included in the program. The Criteria table displayed in chapter 4.4 will further highlight the similarities of Synergi and an RCA process. For this reason, Synergi is presented in detail in the next chapter.

4.1.1. Presentation of Altus Interventions Synergi

Today, Altus uses DNV GL's Synergi Life, a web-based tool, to perform its reporting on Health Safety and Environment (HSE) and quality incidents. Synergi Life is a risk management software with tools to manage non-conformance, incidents, risk, risk analysis, audit, assessments, and improvement suggestions [4]. As a third party provides the software, the content of the software is relatively static. It required development time by DNV and thus expenses by Altus to change. As a result, the included tools and set up in the software is what Altus must conform to.

Registering cases in Synergi can be done by anyone working in the company. After submission, a case-handler will be assigned to the case for follow-up. The case-handler will follow up on the submission to check if adequate and correct data is provided. Furthermore, the case-handler is responsible for ensuring the completion of the case's causes, actions, and general processing.

Synergi is using the data gathered from the cases. The data is accessible from a database for different purposes, such as ad-hoc analysis and trend monitoring. If KPI trends under/over certain levels, the QHSE team will open an investigation.

If an incident occurs or a problem emerges, Altus's employee will create a Synergi case as per usual. Unless it is an infrequent occasion where the incident or problem is hazardous, in which case an investigation will open to handle the problem as a particular case with a designated team, the case will go through Synergi's streamlined RCA process.

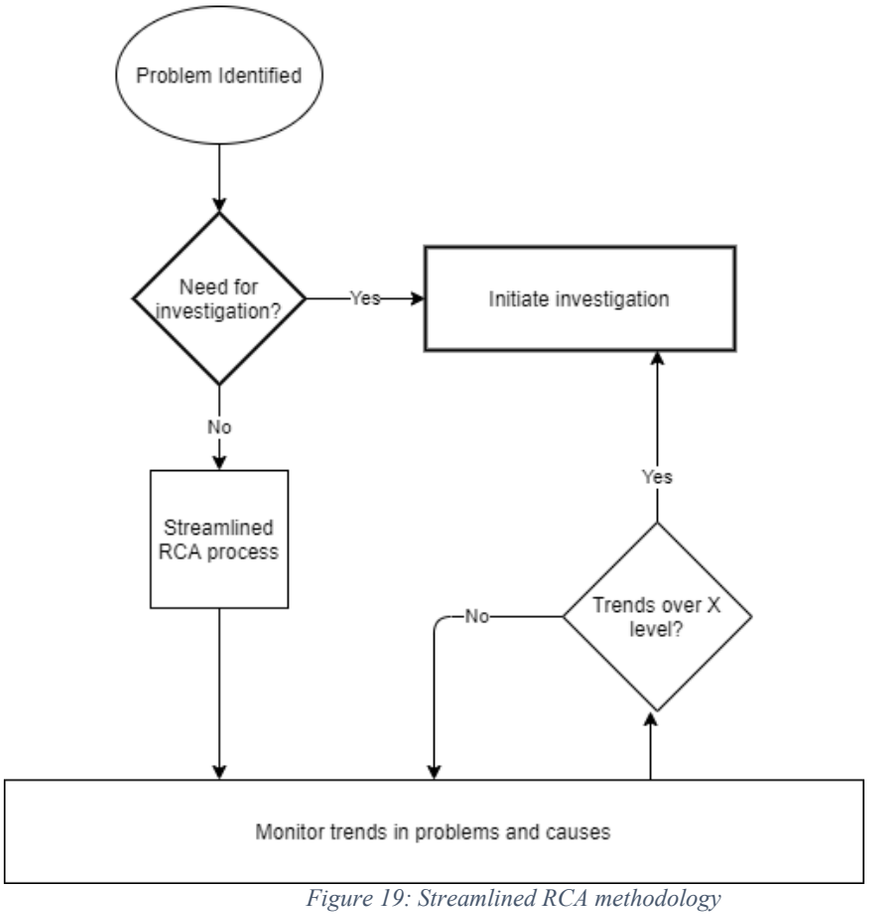

Figure 19: Streamlined RCA methodology

Case Registration

There are ten steps when registering a case in Synergi. The person filing the case is responsible for filling out as much data as possible to make it as clear as possible what happened. After case submission, a case-handler will be assigned to follow up the case process until closure. The intention to register and follow up with Synergi cases is to end up with proper and sufficient actions to avoid similar future incidents.

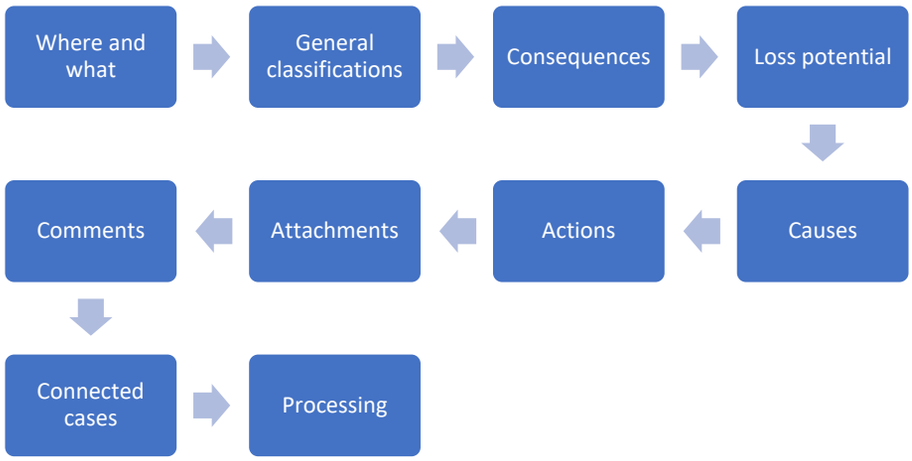

Figure 20: Altus' RCA process flow

Where and what

The first step creates the foundation for the analysis. A title and case description are required, along with time, responsible department, contact person, location, contractor, customer and case categorisation. When selecting the latter four, the system provides a list of pre-defined options.

General classifications

The second part involves more detailed information about the equipment and product line. Product-, serial-, part-, job- and software number, as well as service type, are all included. Again, the software provides lists for each category with recurring input.

Consequences

After filling out the case description and details, the next stage is to document the case or incident's actual consequences. The user can add consequences to the case by selecting pre-defined categories. Further, the user can write comments in a comment box to explain or clarify the consequences. After selecting the consequences, the user must report each consequence's severity by sliding a bar ranging from minor to catastrophic. The severity bar is displaying options specifically related to the consequences chosen. After selecting the consequences and their severity, the final part of this step is to fill out more detailed information about the selected consequences. For instance, if the consequence selected is a

"dropped object", the detailed information will include, among others, the type of object, weight, and height of fall.

Loss potential

The loss potential is essentially a risk diagram to evaluate the risk of the potential worst-case scenario. A two-axis risk diagram with severity and frequency increasing up and to the right is mapping the potential risk. As in the consequence step, an accurate description of the consequences is provided by using a severity bar related to the specific consequences. The tricolour of green, yellow, and red is giving a visual representation of the risk. Green being low risk, yellow medium and red high.

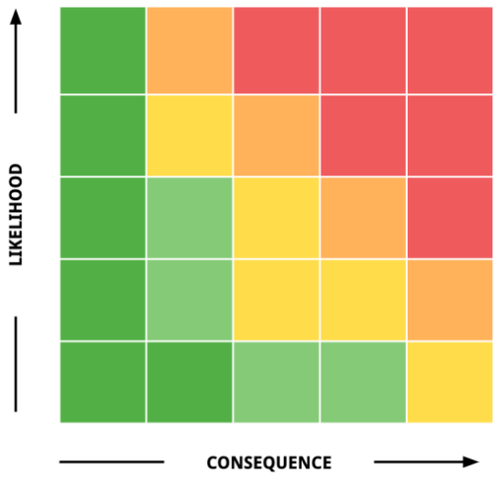

Figure 21: Risk matrix

Causes

Stating causes is a critical step in an RCA process and is the next part of the Synergi. The system presents four main categories: equipment, organisation, human factors and environment, under which the user can add pre-defined sub-causes. When initially creating a new case in Synergi, the user will add the sub-causes that is evident at the time. The case-handler will later do a 5-why analysis to identify the correct root cause. The user is encouraged to suggest multiple causes that might have contributed to the situation. The case handler will identify the correct root cause(s) after the fact of case registration.

Actions

As cases often concern unexpected situations that interfere with operations, some immediate action is often required. These immediate actions, however, often tackle the higher-level

causes rather than the root causes. Analysis and implementation of corrective actions are therefore necessary to prevent future reoccurrence. For this reason, both immediate and corrective actions are a part of this step in Synergi. Each action has a description, type, comment, deadline, responsible department, completed date, responsible user and status bar. The description and comment explain what the action was or requires. The deadline is the date the action is to be completed, and the responsible person and department is the person and department responsible for the action to be implemented within the deadline. The case-handler may change or add actions during the processing of the case. The status bar of each action consists of four steps: proposal, implementing, cancelled and completed. It is the person responsible for the action that is required to change the status according to the relevant action.

Attachments

Files, links and references can be uploaded to support the case. The attachments may be anything that helps illustrate the incident. Some examples are drawings, pictures and procedures. The case-handler is responsible for adding enough "evidence" to support the case if needed.

Comments

In this step, the user and case-handler can add comments if needed.

Connected Cases

Connecting cases is possible by linking a case to another as either subordinate, superior or related. Doing so is not always relevant, and thus it is not required. The possibility exists to trace similar or related cases. A subordinate case means that the case is linked hierarchically below a different case, indicating a more significant issue. Conversely, a superior case is above a different case hierarchically. Related cases will be on the same level.

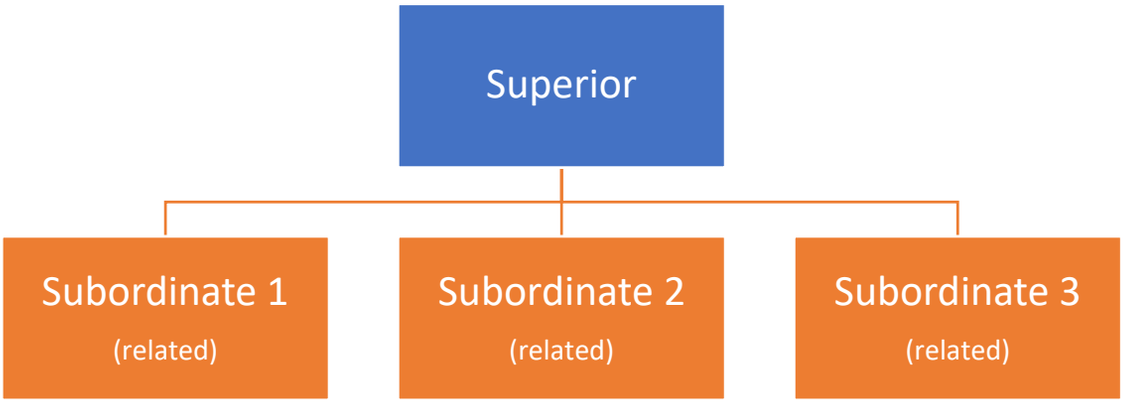

Figure 22: Connected cases

Processing

Processing is the status of the case. The case-handler is responsible for changing the status to the correct step, which consists of rejected, processing, approved and closed, and a due date for the case. When all root causes are identified and all actions are closed, the Synergi can be closed. The case responsible have the authority and should reject cases if they are not completed.

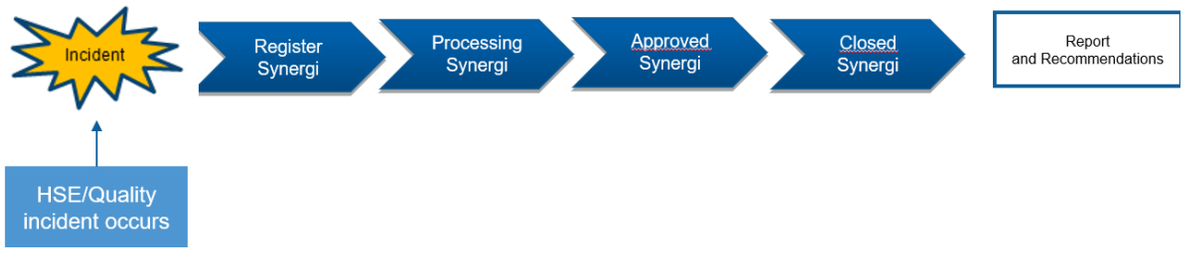

Figure 23: Processing status in Synergi

4.2. Ways to improve Altus Interventions current Root Cause Analysis methodology

The analysis of the semi-structured interviews provided much insight into the RCA methodology of Altus Intervention. To answer "**RQ2:** ***What efforts can be made to improve Altus Interventions current Root Cause Analysis methodology****?"* the interviews had to be analysed and presented. This chapter put forth the four main themes and 12 sub-themes that emerged from the thematic analysis. The thematic phrasing was done so that the themes can be used to improve the methodology and answer RQ2. Figure 24 illustrates the themes, and the four following sub-chapters presents each main theme with related excerpts and analysis.

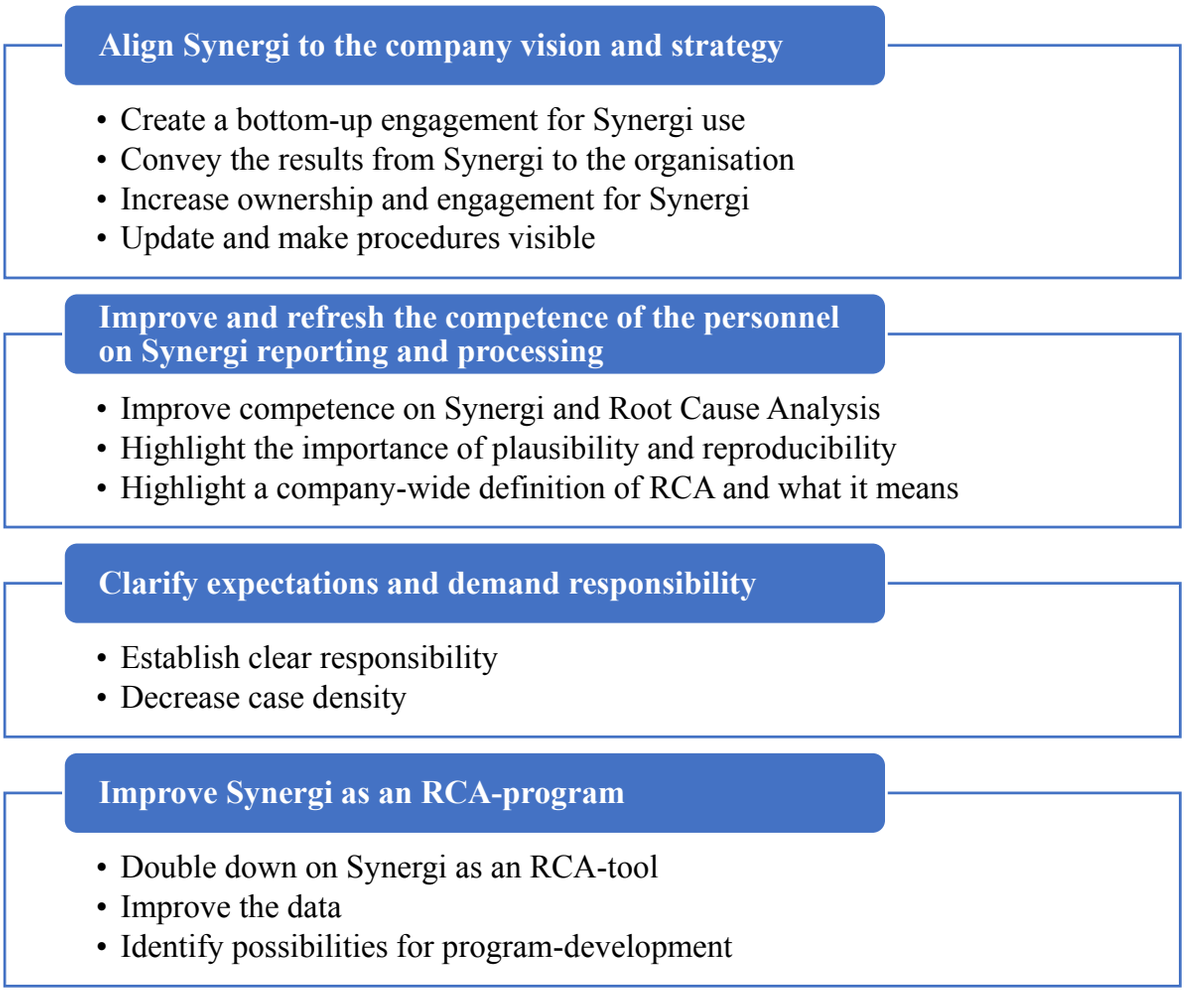

Figure 24: The resulting themes from the thematic analysis

4.2.1. Align Synergi to the company vision and strategy

A unified vision is critical to creating engagement throughout an organisation, and any strategy is the practical formulation of that company's vision. Aligning Synergi and the related root cause methodology into the strategy is therefore pivotal in manifesting a backing within the organisation. Four sub-themes that are tangible recommendations within the theme of "Align Synergi to the company vision and strategy" are presented below with corresponding extracts from interviews that support the theme.

Create a bottom-up engagement for Synergi use

All the interviewees mentioned a considerable variation in engagement for the use of Synergi. Especially the bottom-up engagement for Synergi was characterised as a burden on the workforce.

> I think most people see it as a big burden. And something that demands very much time…It just becomes a tremendous burden when it comes to… "well, I am supposed to work on equipment. And then I have to sit here with all these synergies as well". It becomes an extra burden. {1}

> Synergi is incredible disruptive of work… We are not set up for that. We are set up for the maintenance and delivery of equipment in relation to the shipment plan. {2}

> ... but we know that there are several ways to look at Synergy. Of course, many people think of Synergy more as something terrible and nonsense. {3}

> It is probably seen in many cases as an evil. And not as help. {5}

The quotations above illustrate how it appears to be a negative attitude towards Synergi within parts of the organisation. Reporting in Synergi takes time away from what participant {2} described as what they (the department) are set up to do.

Convey the results from Synergi to the organisation

In response to a question on why the bottom-up engagement is low, one interviewee responded that management does not anchor the effect of Synergi well enough:

> Management must take the lead and anchor this in their organization, departmentally, on how this is done, when it should be done, why it is done, and the effect of the result on the bottom line should be visualised. {4}

> So that ... must have this under the skin themself, and convey it in such a way that others feel like doing it in the same way. {4}

The interviewee argues that the leaders or managers in different parts of the organisation should understand how to go about Synergi and root cause analysis and convey the importance to their group. In a related question on the display of effects to the organisation, participant {1} expressed it as an area of improvement:

> But perhaps in relation to what you say that we are able to present changes in trends or the change in actions or behaviour or routines that reflect that one or more have made input here or come up with input or suggestions for actions that one can see implicit that what has been contributed has an effect We could probably be better at that. {1}

The same point was made by interviewee {5} as a reason why the bottom-up engagement might be lower:

> Because it helps no one there and then, and it is difficult to see far down the road that there is much value in investing the extra resource in getting this 100%. {5}

Interviewee {6} mentioned a monthly report with an overview of trends and statistics sent to the leader group but is not shared with the entire organisation due to sensitive corporate information. In a reflection on this, he pointed out that showing relevant information to the rest of the organisation might have a positive benefit:

> Now they [the management team] see that we are able to trend it towards faults in equipment and the like. I think they see more benefit from it. And that is probably what is needed [offshore] and, that it will be an advantage that they see the whole picture. That the information they put in we manage to extract that data from {6}

Increase ownership and engagement for Synergi

The varying degree of engagement is not just at the ground level, although it appears more prevalent in that area. There is evidence of a lack of ownership for Synergi-cases among the case handlers. The following extract describes the challenge of multiple case handlers when it comes to implementing actions.

> Because we often end up writing a Synergy and measures, and then you pass it on to another person, then that person will spend a week to think of how to do this. Then it is often difficult to set actions, and you may have to chase this through to get this in place. {3}

There seems to be a lack of ownership or engagement when a case is sent to a new case handler, making the case stagnate:

> There are many cases that become stuck because some departments have difficulty implementing measures for various reasons. {3}
>
> Many people have the technical insight into the core of the case itself, but one may lack, and may have, a slight tendency or attitude that this is not my problem. And thus you do not feel responsibility and ownership of the synergy. {4}
>
> But this notion of assigning the synergies to an owner of the synergy, the synergies often become fluid in the system without an actual owner, which then makes the cases fall between two chairs. {5}

Update and make procedures visible

A common view amongst interviewees was that the documents related to Synergi were outdated and potentially not well known to the users. Whether employees not using or knowing about the documents are due to them being outdated, or their existence not being informed about was not made sure.

> There is so much old history here, that we just have to get to grips with it [The procedure] and get it done. So it's being updated, one at least. With exactly how to fill in and create a Synergy. {4}
>
> But we have procedures then, which actually says a bit about the requirements we set for those who are to be caseworkers and how they should be ... But I do not know if they are so well known either, but they are there in that sense. {1}
>
> There are only general procedures in relation to the registration of Synergy by QHSE. This is the procedure for Synergy, a guide for Synergy that we have been waiting for now for a couple of years. The old one disappeared from the system .... And that's a big problem as I see it, because we need a procedure or guide for the whole organization for Synergy. {5}

As the first extract above highlights, there are ongoing initiatives on updating the documentation. However, as participant {1} mentions, it is not sure if the documents are well known. A second excerpt from {4} below amplifies the notion that the documents are little used because of their lack of updates and the ongoing work on informing the employees about the updates.

> Including refresh courses that … have in relation to Synergy. And inform and broadcast from QHSE's side the importance of this. Until today, it may indicate that there are not so many who have followed or looked at them because they are wrong. {4}

Interviewee {6} mentioned that highlighting root cause analysis and the more profound understanding of what it is would have a positive effect on case handling:

> ... And the documentation is well and good, but I think you have to be very clear on root cause analysis and understanding of what it actually is. And if we had made it happen, we would probably have seen changes in case processing too. {6}

4.2.2. Improve and refresh the competence of the personnel on Synergi reporting and processing

A second theme naturally emerged from most interviewees, namely the competence of the employees with Synergi use and root cause analysis. It is important to emphasise that the lack of competence appears as a symptom of the different challenges mentioned in this thesis and not inherently from the employees themselves. The theme is broken down into three sub-themes that encounter how competence can be improved.

Improve competence on Synergi and root cause analysis

Multiple statements from different interviewees implicit point to a lack of competence on Synergi, especially as both a reporting tool and as a root cause analysis tool. Periodic statements from the interviewees were on insufficient actions or lack of data from initial reporting, which the extracts below illustrate:

> So there are a lot of unrealistic actions. Especially many people tended to write "make sure it doesn't happen again". {2}

> I see lots of synergies that are like "component failed. Make sure it does not happen again". Ok, what component then, sort of? What was this for? Was it on a winch, was it on a pump or something? No item number has been left. No ID number has been submitted. It is not clear which installation you were on. It's so flawed ... {1}

> And the way actions are set. We probably have a bit to go on there. To put some right actions. Because when the actions are like "fix it" or this must be fixed ", then there is so little concrete that often they are left hanging for years because you do not know what to do with them. {6}

In the first case, the measure was to make sure it did not happen again, which illustrates a lack of insight from the person initiating the measure into the phases of root cause identification and problem elimination. The first extract above exemplifies the competence of a case handler, which is initiating measures or actions. However, the second extract mentions that initial reporting, which any Synergi user can do, periodically exhibits a lack of data connected to the case. Both examples show that Synergi users on different levels all need to improve their competence in Synergi-reporting.

Highlight the importance of plausibility and reproducibility

The varying level and insufficient actions resulting from Synergies reveal a potential lack of plausibility and reproducibility to the methodology.

> ... and then it was very individual to what extent the synergies, both in relation to how they were formulated and how the actions were defined, what kind of response you got. And a very small degree of systematic approach and methodology around answers which is required to get a uniform assessment of perhaps the same type of case. The same type of case can actually have completely different outcomes because those who process it, both as case manager and those who have actions both have completely different information, both based on what is in the synergy, but also completely different approach in relation to what they should answer. {1}

This extract comments on the lack of a systematic and methodological approach in Synergi. Without a systematic approach, the outcome will inevitably contain a degree of randomness, which devalues the plausibility and reproducibility of both the causes and actions provided.

One the topic of varying level of Synergi use, interviewee {5} highlighted why he thought this variability existed:

> There is a reason for that. We do not have procedures or guidelines on how to do this and what the minimum requirements are. And we do not have training, in practice, structured in relation to how Synergy should be. And we do not have any qualification requirements for one to be allowed to be a case handler in Synergi. {5}

This highlight pointed out that without sound guidelines or procedures and training, people use Synergi as they think is the correct way instead of following a systematic approach.

Highlight a company-wide definition of RCA, and what it means

As commented by {1} above, different approaches to executing a case are due to different expectations of dealing with a case. One fundamental definition that guides an employee through a Synergi case is the definition of a root cause and root cause analysis and what that means in practice. Commenting on this definition, one of the interviewees said:

> Root cause analysis, it is not so long since I managed to convince myself that I only had to go to a certain level of root cause. And it has something to do with ... You have this 5-why, as they call it. And we have also included that in Synergy, so that we can drill ourselves down. Earlier, I did not think it was enough with the 5-why. I would like to go even further, and I would like to go down to some things like risk management. But then I have actually accepted that it may be a little too general again. Because if you are going to go on everything that is at risk, then it will be such an overkill. In a way, you have to use that root cause to drill yourself down to a point that allows you to make an intervention or change that allows you to get an improvement. {3}

This critical insight regarding drilling down to a level where one can implement actions that improve the outcome is vital to a practical and effective root cause analysis. A lack of understanding of this definition is a probable reason for the actions mentioned in this chapter regarding impractical actions. Interviewee {3} had the realisation of the practical importance of an RCA definition from an internal document on the topic:

> But that guide was actually pretty good, because then I accept that "OK, when I have to find the root cause, I have to go so far down that we can do something about it". {3}

4.2.3. Clarify expectations and demand responsibility

Synergi is implemented as a distributed system at Altus Intervention. In theory, everyone can be involved in a Synergi-case, either by initiating a case (which can be done by anyone), having responsibility for processing the case, or implementing actions related to the case. A distributed system has its positives and challenges and has been a topic in the interviews, especially the effects such a system has on responsibility and capacity.

Establish Clear Responsibility

There exist two formal roles in a Synergi-case: the user that initially reports in the case, categorised as a normal user, and the case handler, who takes over the case after submission

and is responsible for its processing. However, a third role is also mentioned indirectly in the interviews. As stated in the two extracts below, a case handler enacts actions that some other person in the organisation is to carry out:

> In Altus today, we have a case handler who more or less initiates various actions that other people must perform. So then we are already on two people involved. And if the two people aren't structured and have an attitude to Synergy processing and understand what this is about, then this will slip. {4}

> And with a distributed system, I mean that there are a lot of people involved. Potentially, everyone is involved in all synergies. So, not everyone is involved, but everyone can be involved to some degree. That is, in one moment I get a synergy. In the second moment you get a synergy. The third gets a third synergy. Maybe within the same area, because the person who has distributed the cases has sort of been like "…, he can do it, so I set him up". He other who got the case he thinks "…, he knows this, so I put it to him up". And then it becomes a bit random where they go, and then there are a lot of people who have to process actions. {1}

Although the role is implicitly intuitive: carry out the actions put forth by the case handler, there is not established a clear responsibility for this role in the documentation. The documentation includes the roles and responsibilities of the case handler, but there might be a level of ignorance or indifference by some of the case handlers that lead to less ownership and engagement, as discussed.

The extract below also mentions two types of case handlers: Operation Supervisor and Customer Service Leader, and that they do not necessarily are made aware of Synergies that are made, in which they are the case handler.

> Whoever is the Operation Supervisor, who follows up the operation, he does not necessarily know that the Synergy is made. The synergies, as we operate as of today, they must then be owned by Customer Service Leader in those cases where there is downtime in the event of an incident or there is further follow-up against the customer in that case. In those cases where it is not, it is the Operation Supervisor that will own the case, and follow it up further. {5}

Decrease Case Density

A recurrent theme in the interviews was on the topic of capacity. The company is overwhelmed by the number of Synergi-cases and related actions, as made evident by all the interviewees:

> There are as many actions as people employed in the company. {2}

> And we have so many synergies that it is a problem for the organisation to undertake them all in a very orderly way. {1}
>
> Of course, you could have many people working full time with Synergi. So it's a bit about limiting yourself a bit in the right way. {3}
>
> I calculated the amount of Synergies a couple of years ago. In order to be able to handle all these Synergies that were at that time and came in at that time, we had to completely solve more than one Synergy case per day to keep up. And of course, there is not that capacity. {5}

As {1} mentions above, the large number of cases threatens the company's capacity to perform a thorough case handling. With such a high number of cases, the need to prioritise becomes necessary:

> And if you are able to prioritise away all the issues that you really should not spend so much time on. This may sound awful, because you're potentially prioritising things that are important to someone. But the amount kills us to a great extent. {1}
>
> That you can actually find a root cause. But it is demanding work, and there is a bit of that compared to when this happens, it takes the team so much time. When things start to go over a week or two, there are so many other things that are prioritised, so then this comes a little behind. {3}

The priorisation is done using different criteria such as criticality, current trends, non-productive time and others.

A second side effect of a high capacity coupled with a distributed system is the potentially uneven distribution of cases in the company. With the possibility to include anyone in the company in a case, and there is a varying degree of engagement and ownership towards the cases, it is natural that some employees are involved in a large number of cases while others are involved in a low amount. This leads to a high density of cases for some employees, making it challenging to carry out a thorough process:

> ... and then there will be very many who will process actions. Possibly someone gets a lot of actions, and then there is very little consistency in the answer. Or someone gets a lot of actions, and does not have the time to do very much of it, so it will be a quick processing. {1}

Interviewee {5} promoted a suggestion to create a team that works specifically on investigations to focus on performing a thorough investigation and decreasing the number of critical cases:

> Because of the problem with the workshop. That they work for mobilisations, and have to get things out the doors. That is the main reason why … started assisting with those investments.

> But it is not enough as it is today ... There are lots of investigations where things are not done in a structured way. My view is that we need an investigation team to get the investigations away from critical timelines so that we are not pushed into the situation where we have to get things out the door, and that we get to take things when they come in. The only way I see we can do that is to have a small investigation team that only goes on investigations. The only way I can see that we can manage to get optimal expertise on investigations, is to have a dedicated crew working with it. And that crew should also inform and train the personnel in issues that are experienced. {5}

One argument interviewee {5} pointed out above is that such a team would reach the required competence to perform such investigations. This level of competence was also echoed in this extract by interviewee {2}:

> Finding out the root cause is pretty hard work. Then you have to be competent. And you should have a thorough understanding of the operation of the equipment and the whole typography, the whole methodology around it. And there can be many disciplines that need to be looked at. {2}

4.2.4. Improve Synergi as an RCA-program

The final theme concerns the development and improvement of Synergi. The three main themes presented above covers culture, documentation, training and engagement, while this theme is tackling what can be done to improve the Synergi program. The three sub-themes are interconnected with using Synergi as a reporting tool or as an RCA tool.

Double down on Synergi as an RCA-tool

What became evident during the interviews was the sceptical approach to Synergi as an RCA tool. The reason behind the scepticism was a lack of root cause identification in Synergi:

> That is the system we have. And it does the job, to an extent. But we see some limitations that we have touched on before in relation to the root cause module. There are a number of shortcomings that describe how we arrive at the right causes. {6}

> The whole Synergy tool is a tool that I am not happy with in general. Because you can create reports, you can take out analysis. But you never get to the root cause as it is today, I believe. You only get halfway. And we have just, from January, introduced a 5-why analysis in our tool. And no one understands what to do, so it has had little effect so far. {4}

The 5-why tools were recently added to Synergi to improve the root cause identification, but lack of training, understanding and a good overview in Synergi has led to minor improvement. More tools that are not a part of Synergi is now being using parallel with Synergi to improve the process. One interviewee uses the word patchwork about this:

> And that is not entirely optimal. There will be some patchwork. And we try to do what we can to have it in the same system. It is not streamlined, so it is a logical move so that now there is root cause analysis. {6}

This patchwork consists of One-Pagers, which details the case concisely, and a con-conformance report is being added outside of Synergi:

> 5-why has arrived, but we are missing the link from the incident in Synergy. And this is where this non-conformance report comes in. And I know very well why they want it in there, but it should rather be added as part of the system. And then to get to the 5-why in the end. So Synergy does not work as it should for the investigation itself. It works for reporting, but not for processing other than setting actions. But you do not get a good overview and a good process through the case. {5}

> We see that we have greater value from using one-pagers in relation to resolving the cases, than we have from the Synergy case {5}

Two points were made on how to improve or overcome this challenge. First, as interviewee {5} mentions above, instead of adding tools that assist the process outside of Synergi, the tools should be included in Synergi itself. Second, interviewee {4} mentioned that if Synergi was fully utilised, that it might work. Furthermore, that training is a part of this:

> But if you really used Synergy for what it's worth, it might be good enough. But that's the training. {4}

Improve the data

In a perfect world, the categories in the reports from Synergi will represent the root causes. However, with varying quality and lacking data input, this view might not represent the real world. In response to a question on how to identify root causes, interviewee {1} said:

> If we manage to become much more structured on the input we provide in the synergy. That is, so you get good data to work with for those who are to be case handler and have actions. {1}

> I do not think we are able to create the data basis out of the synergies that make them see that this is a very valuable tool {1}

These comments highlight the point that was presented earlier on competence in Synergi reporting and including sufficient data. Having a sound data basis is essential to gather a correct picture of the situation:

> If you enter the correct information, there is a lot to extract. A part is about how you choose to take out the report, and then there is a part that goes on what is entered, so that you get the data you get out, that the report gives you a real picture. It is the categoriaation of cases and criticality and such things. There are many who provide input there, so the right picture ... It is probably far from the case that it is exactly the right picture. It gives you enough information to grasp things and work on them. {3}

> Unfortunately, you can say that, such as when entering a Synergy simplified, the threshold for entering information is very low. And possibly so little information that Synegi does not become useful. This is not something you can search for, because you can only enter text. It tells you nothing about who has been involved, etc. {3}

The second excerpt points to how the low threshold for submitting data in a Synergi case can lead to the submitted case not being usable.

Identify possibilities for program-development

When it comes to using Synergi as an RCA tool, the 5-why tool has been implemented in Synergi. Furthermore, multiple tools are used outside of the program to carry out the analysis. Multiple interviewees mentioned that by developing and improving Synergi, it would become a more powerful RCA tool:

> ... But again, we say we'll do a root cause analysis. Yes, what was the root cause then? Shouldn't there then be a separate field where one defined: this is the root cause. Then we can gather all the root causes and see here it goes that way or here it goes that way. Here we do not have the root cause, but here we have the fault mechanism: leakage, short circuit, linked to those and those ID numbers. Then you start to get some tools that you can use to analyze. "Oi, those ID numbers are all short-circuited. What is the root cause of that then? The root cause of that type of fault for that type of equipment is O-ring that does not clog ... Then you start to get some tool that you can use for something. {1}

The fact that Complaint and Synergi are two programs used widely within the organisation was also a topic of conversation. In many places, the two programs cause double reporting, and one program comes at the cost of lesser use of the other:

> But we in the technical part, we are much more a fan of the complaint system. Simply because the complaint is measurable. It can give you graphs and trends on all equipment. You can take reports on it. and it is already in our work system. We get a report every month: "The pump there has failed quite a few times in the last six months. Maybe we should have looked into it a bit. Maintenance routines, have we got a new supplier for parts. What is it?" I do not think Synergy is useful at all for such things. {2}

One interviewee suggests connecting the two programs to take advantage of the data and parallel processing that often takes place in both programs:

> There should be a cross-reference between Complaint and Synergi. And then I mean not only that it should say that "this refers to Synergy number XX", but that it is a cross-reference with an autolink between the two systems so that when you are inside the Complaint you can go directly via a link and into The synergy to get it full .. So in Synergy it is usually more comprehensive around the whole event, while in Complaint it is often a short text, preferably, which describes the problem with the specific tool. While in Synergi you take all the tools that have been in the string with you, and get the whole picture. And we currently lack a link between the two systems. {5}

> In addition, it should be automated, so that when you write a synergy, that Complaint is automatically created into M3 system. There is no reason why we should really improve two places. So there is a huge potential for improvement. When you write a Synergy, you can then automatically generate that Complaint into the system so that the maintenance and investigation part is taken care of at the same time. {5}

This suggestion would benefit the challenges mentioned from the workshop, where Complaint is primarily utilised, and Synergi takes a second priority:

> But as of today, there is no link between the systems, and that means that you do not always get that ... So those who work in the workshop look at the Complaint when they work with a tool, do not necessarily see that there is is a Synergy to that tool. {5}

4.3. Guideline Observations

Table 5: Guidelines Observations

Guidelines	Measurables	Observations	Themes
G1: Management emphasis on the identification and correction of problems that can affect human and equipment performance, including assigning qualified personnel to effectively evaluate equipment/human performance problems, implementing corrective actions, and following up to verify corrective actions are effective	G1.1: Top-down focus G1.2: Identifying problems G1.3: Correcting problems G1.4: Qualified personnel G1.5: Follow-up	G1.1.1: Altus practises a top-down focus on RCA G1.2.1: Altus has a sound system for identifying problems G1.3.1: Altus does not consistently correct the root cause(s) G1.4.1:The personnel have varying knowledge about RCA methodology G1.5.1: The current follow-up methods can be improved	Align Synergi to the company vision and strategy Improve and refresh the competence of the personnel on Synergi reporting and processing
G2: Development of administrative procedures that describe the process, identify resources, and assign responsibility	G2.1: Existing procedures G.2.2: Content of procedures	G2.1.1: The procedures need to be updated and made visible G2.2.1: The responsibility should be clearly stated in the procedures	
G3: Development of a working environment that requires accountability for correction of impediments to error-free task performance and reliable equipment performance	G3.1: Existing environment G.3.2: Accountability for corrections	G3.1.1: The environment around Synergi needs a higher bottom-up engagement G3.2.1: There needs to be more accountability	
G4: Development of a working environment that encourages voluntary reporting of deficiencies, errors, or omissions	G4.1: Voluntary reporting	G4.1.1: People report, but the data is varying.	Clarify expectations and demand responsibility
G5: Training programs for individuals in root-cause analysis	G5.1: RCA training programs	G5.1.1: There has not been enough RCA training. Initiatives have started	
G6: Training of personnel and managers to recognise and report occurrences, including early identification of significant and generic problems	G6.1: Early identification of problems	G6.1.1: Synergi focuses on reactive reporting	
G7: Development of programs to ensure prompt investigation following an occurrence or identification of declining trends in performance to determine root causes and corrective actions	G7.1: Ad-hoc investigation triggered by trends	G7.1.1: There is good trend monitoring and reporting, but this requires manual work G.7.1.2: There is no link between the two most crucial reporting programs	
G8: Adoption of a classification and trending mechanism that identifies those factors that continue to cause problems with generic implications.	G8.1: Classification and trending mechanism	G8.1.1: There is good classification and trending mechanisms, but insufficient data is compromising the reporting.	Improve Synergi as an RCA-program

Table 6: Criteria Observations

4.4. Criteria Observations

Fagerhaug Steps	Problem Understanding	Problem Cause Brainstorming	Problem Cause Data Collection	Problem Cause Data Analysis	Root Cause Identification	Problem Elimination	Solution Implementation
Altus Synergi Steps	Where and What Consequences Loss Potential	Causes	General categorisation and recording Attachments	Excel/database	5 Whys	Actions	Actions
Criteria							
C1: Expertise required	+	+	+	O	+	n/a	n/a
C2: Tool support	+ (Synergi)	+ (Synergi)	+	O	+	n/a	n/a
C3: Scalability (with complexity)	+	+	+	+	-	n/a	n/a
C4: Graphical representation	-	-	n/a	+	O	n/a	n/a
C5: Reproducibility	O	O	O	+	O	n/a	n/a
C6: Plausibility checks	O	O	O	n/a	-	n/a	n/a
C7: Intellectual rigour	O	+	+	+	O	n/a	n/a
C8: Time sequence	O	-	n/a	+	-	n/a	n/a
C9: Specificity	+	O	+	O	+	n/a	n/a

5. Discussion and Summary

The discussion consists of four parts. The first sub-chapter presents a summary of the results and their relation to the research questions. Next, the second sub-chapter then interprets the results with a summary at the end of each theme. The third sub-chapter discusses the limitations of the thesis before the last sub-chapter presents an overview of the recommendations for improving Altus Interventions Root Cause Analysis methodology, further research and broader application of the research.

5.1. Summary of results and relation to the research questions

The two research questions guided the scope of this thesis:

RQ1: ***What is Altus Interventions current Root Cause Analysis methodology?***

RQ2: ***What efforts can be made to improve Altus Interventions current Root Cause Analysis methodology?***

RQ1 was answered in chapter 4.1 by presenting the core reporting system, Synergi, and the managerial process and people involved with the program. The main findings concerning RQ2 are the four main themes and 12 sub-themes presented in chapter 4.2. The themes were developed from interviews based on the guidelines presented in 2.1.3. Further, observations were done based on measurables from the guidelines, with each observation corresponding to a respective measurable. Together with the criteria, the observations form the second main findings presented in 4.3 and 4.4.

5.2. Interpretation of the results

RQ1

While RQ1 is concerned with detailing the Altus methodology of RCA, some further discussion beyond simply stating the method is required to better understand the method compared to the theory presented in chapter 2.

When looking at Synergi in aggregate, it includes, in various form, all the steps presented by Andersen & Fagerhaug. Including all of these seven steps are not a requirement, but focusing on different essential parts of an RCA methodology with distinct phases is suggested in the

literature. As illustrated in table 7 on page 51, each step from Andersen & Fagerhaug matches one or more steps in Synergi. However, a fundamental difference can be identified in the thought process behind the steps. The literature, in general, focuses first on brainstorming (2.1.2.2) potential causes before collecting data and analysing it and then coming up with a root cause (2.1.1). Synergi, on the other hand, dives straight into selecting causes, and with the help of 5-why (2.1.2.5) in the same step, identifying the root cause directly after describing the event. Having this more rushed approach, as seen in Synergi, might lead to selecting causes prematurely. It could also be argued that this is a necessity in Altus Intervention, as the number of cases is high and demanding on the workforce, as was evident in the interviews. Synergi also operates with a case handler, who can investigate and change causes if necessary. Using the approach utilised by Synergi thus puts more importance on the case handlers' ability to assess the causes critically, as secondary information from the database and trends might change the perspective of the case post-registration.

Similar to the difference in thought process discussed above, the data collection and analysis part of Synergi also takes an alternative approach compared to the standard RCA methodology. The data collection is done in the “where and what” and “general classification” steps of Synergi with the use of a variation of check sheets (2.1.2.3). By filling in the information in these steps, it is possible to identify information on the equipment and installation that was included in the event. This information can aid the case handler in selecting causes. Where Synergi differentiates from a traditional RCA methodology is in its ability to gather aggregate data. The data from each case reported in Synergi is stored in a database and further imported to an excel-document to track multiple trends. Using tools like histograms, Pareto charts, control charts and more (2.1.2.4), Altus can look at trends and data in a much larger picture than what an individual case provides. This level of data management is a considerable benefit and is supported by DOE’s guideline G7 and G8.

On the other hand, both good data registration and case handler awareness and analytical skill are required to utilise the data. As will be discussed in more detail below, “improve the data” was one of the sub-themes that emerged from the interviews. Sufficient data analysis requires good data input, which seems to be a challenge for Altus. There is also much double-registering in Synergi and Complaint because of the lack of connection between the two programs, as mentions in 4.1. Some departments in Altus work more closely with Complaint, and the interviews highlighted that there exists much double registering in Synergi and Complaint, which might reduce the ingoing data to Synergi if it is done as an afterthought.

Establishing a connection between these two programs could increase the data analysis in both programs and reduce workload and will be discussed in detail below.

When it comes to utilising tools in Synergi, the program is doing so to a varying degree. “Problem understanding” only consists of text, with no diagrammatic option. However, the risk matrix used in “Loss potential” can be used together with trends to establish an Importance-Performance Analysis (2.1.2.1) with the risk on one axis and a suitable trend, be it on equipment type or operation type on the second axis. Using such a diagram can aid in prioritising cases, as discussed in chapter 2.1.2.1. The tools used for data collection and data analysis are discussed above and has excellent potential.

5-why is recently added to Synergi and is a helpful tool to identify causes behind symptoms. However, as the literature points out, getting to the correct level is challenging. 5-why can aid in digging deeper, but it is also linear and does not account for a combination of causes (2.1) in a way that, for example, a Fishbone diagram can (2.1.2.5). Finally, the two Andersen & Fagerhaug steps, “problem elimination” and “solution implementation” are both included in “actions” in Synergi. Altus uses no tools in this step. While TRIZ (2.1.2.6) is a tool that would be helpful to implement, it is a challenge to include in Synergi due to development time. Additionally, there is already limited capacity to process Synergi cases, and implementing TRIZ would further increase the complexity and time of processing.

Altogether, Synergi and the methodology surrounding it has a sufficient foundation to perform a root cause analysis. As discussed above, some improvements can be implemented, but the primary areas of improvement exist in the training and culture of personnel concerning using the program correctly. The emerging themes highlight these areas and will be discussed below in relation to answering RQ2.

RQ2

The main points of improvement were formed through the thematic analysis of the interviews. An overview of the themes and the observation related to the guidelines can be seen in Table 6 on page 50. Table 7 on page 51 also illustrates the criteria ranking. Each main theme will be discussed below, together with the relevant observations and criteria measures for each theme.

Align Synergi to the company vision and strategy

With a functioning program such as Synergi as a basis for RCA, the most significant improvement area discovered was to demonstrate to the organisation how Synergi aligns with the company vision and strategy. As observation G1.1.1 points out, Altus does practice a top-down focus on RCA. The upper management is focused on using Synergi to identify underlying root causes for reported cases. However, there seems to be a challenge in creating a bottom-up engagement for Synergi use. The interviewees pointed out that many employees regard Synergi as a significant burden in everyday work life, either due to the amount of time it takes to write and process the cases or because their department is not structured to utilise Synergi. These two statements contradict each other. Upper management is focusing on using Synergi throughout the organisation. However, parts of the organisation express it as a burden, which indicates a mismatch in the perception of how Synergi is used. It can thus be suggested that upper management should work to improve the bottom-up engagement for Synergi use. Three themes from the interviews provide concrete ways to do this.

By conveying the results from Synergi to the organisation, management can explicitly show how Synergi affects quality, safety and cost. As discussed above, the data collection and analysis that the Synergi database and subsequent excel extraction provides is a powerful tool that can visually show the organisation how different trends evolve. Providing such reports might impose more work on the people involved with the reporting and should be considered. However, it is safe to assume that such reports might improve the engagement to a degree where the extra work is justified.

Although the lower engagement appears more prevalent from the bottom up, the interviews stated a varying degree of engagement on different managerial levels. Another possible explanation for the lower engagement is the lack of ownership and subsequent engagement for Synergi. It was challenging to pinpoint precisely why there is a lack of ownership. Most likely, it is a result of the different challenges presented in chapter 4.2. One credible reason is the combination of outdated procedures concerning Synergi and the lack of clearly stated responsibility.

As observation G2.1.1 highlight, the procedures need to be updated and made visible. This observation was also such a reoccurring topic of conversation that it became one of the sub-themes. Having outdated procedures which are hard to locate will affect everyone that works with Synergi. Normal Synergi users that register cases will lack the knowledge and thought

process behind the information he or she is to fill in when creating a case, which potentially results in lousy data input. Lousy data input further decreases the quality of the reporting from the Synergi database and results in the quote multiple interviews expressed: “bad data in, bad data out”. Further, the case handler, who is the most critical part of sound Synergi processing, as discussed above, will use an individual approach to process the cases if not supported by a fleshed-out procedure. Without a standard procedure to process the Synergi, the processing will inhibit a considerable variation in quality due to individual differences.

In summary, the first main area of improvement is to align Synergi to the company vision and strategy. Upper management is focusing on using Synergi throughout the organisation to prevent reoccurring events but lacks engagement from the bottom-up and different management areas. Suggestions are given to align the organisation to the vision and strategy by creating a bottom-up engagement for Synergi use, which requires management to convey results from Synergi to the organisation. The second suggestion is to increase the ownership and engagement of Synergi across multiple levels, which can be achieved by updating and making procedures more visible.

Improve and refresh the competence of the personnel in Synergi reporting and processing

Making a system like Synergi work well throughout an entire organisation of the size like Altus Intervention, with well over 1000 employees, is challenging. Anyone can, in theory, submit a case in Synergi, and a different case handler will process them and submit actions throughout the relevant areas. Described as a distributed system by interviewees, Synergi requires a level of competence in Synergi reporting and processing for everyone involved in the organisation. This distributed system is a valuable way of continuous improvement with the RCA application if working as intended. Moreover, for Altus, it works to a certain extent. With that said, the interviews clarify that the competence in Synergi reporting and processing is lacking. As mentioned in the results chapter, the lack of competence in Synergi reporting and processing appears to be a symptom of the different challenges mentioned in chapter 4.2 and is not inherently from the employees themselves.

When actions from a case handler come in the form of “make sure it does not happen again”, and reports detailing the event as “component failed” with not much more information, it is evident that there is a lack of understanding behind the reporting or action. The lack of

understanding comes from missing competence in RCA reporting and processing (2.1). It can also be argued that this type of reporting and processing lacks engagement and ownership, which is addressed above. On the matter of competence, two areas of improvement were identified in the results chapter.

First, highlight the importance of plausibility and reproducibility. A natural place to do this would be in the procedures or courses regarding RCA. Plausibility and reproducibility are two criteria from CENELEC (2.1.3) and applies to adequate data input and solution implementation challenges. Plausibility is a way of checking the "correctness" of the information, and reproducibility is the degree to which the results, be it in the form of information or actions, are reproducible. The two criteria are detailed in Appendix A. A way of increasing plausibility is by adhering to a checklist. Synergi has an integrated check sheet (2.1.2.3) in the form of pre-defined boxes to write text and pre-defined lists of categories that can be selected as described in 4.1.1. By selecting and filling out these options, the program makes sure sufficient data is presented in the report.

Nevertheless, due to the extensive scalability of Synergi, meaning it is a program that can report small events to significant complex events, many of these options related to the check sheet is optional. The optional approach puts the decision making of including it or not on the person reporting the case. This optional choice is similar to how case handlers can assess and change causes post-registration, thus putting more importance on the case handler than the Synergi program, as discussed above. In this case, the importance is put on the user reporting the case. This trend of importance on users' decision-making instead of on the program with obligatory registration further supports the need for improving and refreshing the users' competence. Increasing the reproducibility can be done by filling out all related information to the case. As pointed out in the interviews, the information is often lacking. By highlighting the importance of plausibility and reproducibility in procedures and Synergi training, users and case handlers can become more aware of their role in making sure these two criteria are held in high focus.

The second area of improving competence in Synergi reporting and processing came from observation G1.3.1: "Altus does not consistently correct the root problem(s)" and G1.4.1: "The personnel have varying knowledge about RCA methodology". Chapter 2.1 discusses the definition of RCA and explores how a practical definition of what a root cause is can help guide the entire RCA process. The definition helps guide the entire RCA process, as it states what constitutes a root cause. Interviewee {3} mentioned how the definition of a root cause

helped him understand how to drill down to a point where actions could be taken to remove the problem. By clearly highlighting a practical definition of RCA to the organisation, it is possible to have case handlers identify actions that target the root cause because it is clear what differentiates a root cause from a cause or symptom. A clear definition of the root cause can also guide the 5-why tool so that the drill-down is done at the correct level (2.1.2.5).

To recap, critical decision making is put on case handlers and users to include sufficient information and process a Synergi. To ensure that users and case handler recognise their importance, it is recommended to improve the competence in Synergi reporting and processing. This can be done by highlighting plausibility and reproducibility and clearly stating a company-wide definition of root cause and its practical implication.

Clarify expectations and demand responsibility

A running theme throughout this discussion is the emphasis on the user and case handler when it comes to Synergi. The two main themes discussed above is concerned with creating engagement and lifting the competence of Synergi users. A critical part of this is to update and make procedures visible. A second point in the context of procedures is to establish clear responsibility for the roles in Synergi. An unexpected finding was that a third role was mentioned indirectly in interviews. The normal user and case handler was already known, but a third user type is also included when a case handler creates actions that are then sent to some other person in the organisation to carry out. This was mentioned in interviews as a scenario where multiple people get involved in a Synergi case, and expectations for them to carry out different actions stagnate. This stagnation might be due to the lack of engagement or ownership, as discussed, but a possible explanation might also be the lack of clear responsibility in the procedures and the organisation. Observation G2.2.1: “The responsibility should be clearly stated in the procedures”, and G3.2.1: “There needs to be more accountability” is a result of this finding and led to the sub-theme “establish clear responsibility”. With three distinct roles all working on a Synergi case and potentially multiple people having actions to carry out, the procedures should clearly state the responsibility for each of these roles in relation to a Synergi case.

With procedures that include the suggestions discussed above, it is possible to start demanding more accountability from the Synergi users, as the roles and expectations are clearly defined and explained. With the importance of individual users to carry out a Synergy

RCA, the different roles should be held accountable for the actions and expectations. An absence of accountability can lead to ignorance or indifference, which makes cases stagnate.

On the topic of stagnated cases and multiple people involved in cases, the theme “Decrease Case Density” arose. It is clear from the interviews that the organisation is feeling overwhelmed by the amount of Synergi cases. It is reasonable to expect that improving the topics discussed previously may increase the efficiency of processing cases. However, prioritisation is a necessary evil in every organisation, and Synergi cases are no different. Altus uses tools like criticality, trends, non-productive time and others to prioritise cases. Decreasing case density does not mean reducing the overall number of cases but the distribution of cases in the organisation. As Duke Okes mentions in chapter 2.1 on corrective action density, by dividing the number of cases by the number of people involved, one can get a number representing the overall case density. By extending this method, it is possible to do the same for individual people or departments to gauge the case density. Having such a gauge as an indication makes it possible to assign more people to areas under a higher workload, potentially from areas with lower case density. Ultimately, this method is only a preliminary suggestion and would require more insight into the organisation's areas that are outside the scope of this thesis.

In short, if documentation regarding Synergi is updated and made visible to the organisation, it is possible to start expecting the different roles to carry out their responsibility. This might reduce the stagnation of case handling and action implementation. Further, by calculating the case density within parts of the organisation, people can get assigned to help with workload where needed and consequently reduce the bottlenecks.

Improve Synergi as an RCA-program

The final theme presented ways to improve Synergi as an RCA program. As mentioned in chapter 4.1.1, Synergi is developed by DNV. Improving the program requires expenses from Altus Intervention and thus poses a monetary decision. The third sub-theme: “identify possibilities from program development”, is thus suggested as a final point of improvement. Two actions can be taken prior to improving Synergi. The first is doubling down on Synergi as an RCA tool.

As discussed in relation to RQ1 and presented in observation G1.2.1, Synergi has the potential to carry out a root cause analysis. However, this is met with a level of scepticism within the organisation. The scepticism is understandable, as it is evident that Altus' employees find it challenging to identify the root causes within Synergi. With a recent implementation of 5-why combined with the lack of documentation and training as earlier discussed, it may be the case that the lack of root cause identification is due to these limitations and not the program itself. The first suggestion is thus to double down on Synergi as an RCA program. As interviewee {4} said, if Synergi is fully utilised, it might be good enough. This is supported by the findings in chapter 4.1 and the observation G1.2.1. However, Synergi is not a perfect tool. The patchwork of supporting tools outside the program highlights the need for development and will be discussed below.

The second point of improvement that is suggested prior to program development is to improve the data collection. The mentioned use of reporting and trends coming from data management is a great advantage, as observation G8.1.1 highlight. Nevertheless, data input must be of high quality for the data to represent the correct picture (2.1.2.4). This suggestion of improving data collection is closely related to the competence and training of users. While this has already been discussed to some degree, it is worth iteration the point to differentiate between Synegi and its ability to produce this data and the reason behind why the data might be lacking.

Finally, the last point of improvement is to identify the possibilities for program development. This theme concerns the patchwork of systems that support Synergi but exist outside of the program and the lack of connection between Complaint and Synergi. By using tools outside of Synergi, the process becomes more fragmented. As interviewee {5} suggested, these tools should be integrated into Synergi. As this might be expensive for the organisation to implement, it is suggested to identify these possibilities and their potential costs. By doing so, further analysis can be done to decide if the expenses are worth the implementation. The same argument can be made for creating a connection between Synergi and Complaint. This link would create a significant opportunity for better data registration due to the data already registered in Complaint and reduce double reporting. Additionally, it would make it possible for departments that work primarily with Complaint to follow up with Synergi more easily.

To summarise, Synergi is believed to have the potential to carry out a good root cause analysis. For this to occur, the organisation must double down on using it to identify root

causes, improve the data input, and identify the potential cost and upside in further developing Synergi.

5.3. Limitations

During the research conducted in this thesis, three factors were identified that could have improved the research outcome.

There were six participants in the interviews selected to create a small sample that could provide insight into the research questions. The participants spanned different departments and managerial positions in the company. However, it became evident during the study that many more departments were involved in Synergi due to the use of the program throughout the organisation. It would be beneficial to include more participants from different departments to get a better holistic representation of the company. This would also increase the validity of the study, as the sample size would increase.

Practising a prolonged interview period could also have been beneficial. Each subject was interviewed once during the research process, and the researcher was learning about the methodology and process surrounding Synergi and RCA at the same time. Conducting secondary interviews with the same participants with follow-up questions and repetitions of earlier statements could have reduced the respondent bias and researcher bias.

Finally, by using surveys in addition to the interviews, data could have been gathered from multiple people using forms. This would have been a possibility to gauge the organisation on a larger scale, as surveys could have been applied to a broader part of the organisation. Introducing a survey would also add a triangulation of methods by using more than one method, which would increase the generalisability and trustworthiness of the findings.

5.4. Recommendations

5.4.1. Overview of recommendations for Altus Intervention

To present the answer to **RQ2: "What efforts can be made to improve Altus Interventions current Root Cause Analysis methodology?"** in a way that clearly states the action points of each sub-theme, its relations to the main theme and the observables, Figure 25 below is a visual representation of the answer. A summary of each theme and sub-theme is found at the end of each theme in the discussion in chapter 5.2.

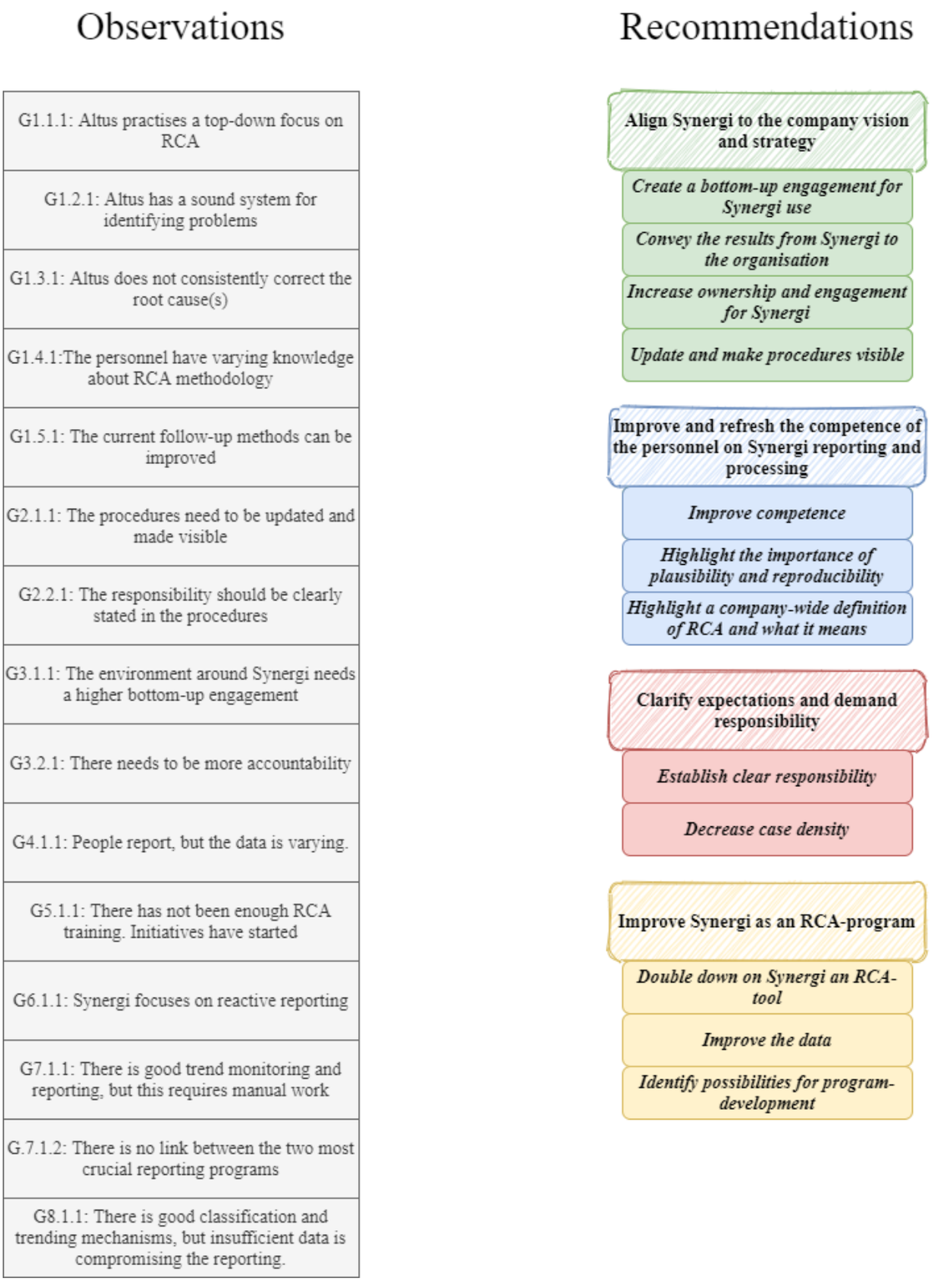

Figure 25: Observations and Recommendations

5.4.2. Further research

Further research based on this thesis is presented twofold. Firstly, the results of this study can be confirmed or challenged by more research with different methods. Especially the use of surveys as mentioned in limitations could provide a secondary method which could further cement or question the results of this thesis.

Secondly, the topic of streamlined RCA methodology should be investigated more thoroughly. As mentioned in chapter 2.1.1, most of the literature is concerned with RCA as a process put together to investigate a single event. One would not be unfounded in one's beliefs if one were to say that many companies practise some form of RCA analysis, and it could be beneficial to analyse and discuss more of these processes.

5.4.3. Broader application of the research

Although the research conducted in this thesis was focused on a case study with Altus Intervention, the following applications and lessons can be applied in other areas and the industry.

The method of thematic analysis used in this research is usually practised in social science, education and psychology due to the prevalence of qualitative research applied in those fields, often by interviewing people. However, engineering and industry organisations also consist of people. Even though engineering companies' purpose often includes processes, machinery, and other technical areas where quantitative research has excellent methods, people are present in all these areas as well. Out of all the public theses available at the department of science and technology in the University of Stavanger's online library, only two theses were found to apply this method. Applying a thematic analysis to interviews with people in technical organisations as has been done in this study provides an opportunity to approach research questions from a different angle.

The application of RCA as a streamlined methodology can be of use for any organisation with a lacking system of identifying problems and removing root causes. As each organisation is different, no standardised RCA system can be presented to fit everyone. This thesis highlights the steps of a standard RCA methodology and discusses the application in the form of a specific case study. Hopefully, the guidelines, criteria, and subsequent discussion put forth in this thesis might provide insight into shared challenges among other companies.

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Appendix A

Interview Guide

#	Spørsmål	Guideline
	Guidelines	
1	Hva tenker du om ledelsen sin vektlegging av bruk av Synergi? *I hvilken grad oppfatter du at Synergi bidrar til identifisering av årsakene bak hendelser?* *Og tilsvarende i implementering av tiltak mot årsakene?* *Er det oppfølgingen av tiltakene? I hvilken form?*	G1/G3
2	Hvem som helst med Synergi-bruker i bedriften kan lage en Synergi. Hvordan vil du si kompetansen til en vanlig Synergi-bruker er i bedriften? Med kompetanse menes da evnen til å oppgi tilstrekkelig informasjon til å gjøre en tilstrekkelig analyse av hendelsen. Når en Synergi-sak er registrert vil en saksbehandler bli tildelt saken. Hvilke kvalifikasjoner mener du en saksbehandler bør ha? *Hvordan opplever du selv kvalifikasjonen til saksbehandlerne?*	G1
3	Er du kjent med eksisterende prosedyrer og/eller dokumenter som beskriver Synergi-prosessen? *Hvis ja – Synes du dokumentasjonen er tilstrekkelig?* *Hvis ja – Vil du si dokumentasjonen beskriver ansvarsområdene for en Synergi-sak?*	G2/G3
4	Hvordan vil du beskrive bedriftsmiljøet rundt Synergi? *Vil du si det er et godt miljø for frivillig rapportering?* *Hva med nestenulykker og potensielle hendelser?*	G3/G4/G6
5	Har Altus noen form for kursing/trening for Synergi? *Er du kjent med begrepet rotårsaksanalyse?* *Hvordan vil du forklare rotårsaksanalyse?* *Har saksbehandlere trening i rotårsaksanalyse?*	G5
6	Brukes data fra Synergi til å måle trender? *Gjennomføres det undersøkelser basert på disse trendene?* *I hvilken grad vil du si at dataen fra Synergi blir utnyttet?*	G7/G8

Criteria Description

Criteria	Description	Levels
Expertise required	Is the method targeted towards the "sophisticated user" (does it require use of techniques such as theorem proving which requires specific expertise)? Is it suitable for use by domain experts only?	• Intuitive, little training necessary (+) • Limited training required e.g. one day (o) • Considerable training effort necessary, e.g. one week (–)
Tool support	Is tool support necessary?	• Can be well applied without dedicated tool support (+) • Tool support not required but usually needed for effective application (o) • Tool support necessary, can be applied only with dedicated tool support (–)
Scalability	Is the method scalable? Can the method be used cost effectively for simple as well as complex focus events? Can a subset of the method be applied to small, or to less-significant focus events and the full capability applied to large, or to significant focus events? So the question of scalability asks whether the complexity of analysis using the method scales with the complexity of the focus event	• Scales well with complexity (+) • Limited scalability, considerable overhead with every application (o) • Not scalable, the full method has to be applied (–)
Graphical representation	What is the nature of the method's graphical representation? The motivating principle is that a picture is better than a thousand words. It is often more comprehensible to display results of an analysis method as an image, a graph, or other form of illustration, than as purely written text. The desirable properties of a graphical representation are • to display clearly the semantics of causality (including denotation of causal factors, and taxonomy of factors), • to be cognitively (relatively) easily evaluated by a single person, • ideally, a graphical representation could also display the history of the analysis	• Graphical representation with clearly defined semantics and cognitively easy to understand (+) • Graphical representation, but without semantics (o) • No graphical representation defined (–)

Criteria	Description	Levels
Reproducibility	Are the results of the method reproducible? Would different analysts obtain similar results for the same focus event?	• The results can be reproduced, differences are only observed on the representation of the results, wording etc. (+) • A significant amount of the results can be reproduced, but some differences will be observed (o) • The results will depend on the analyst's expertise (–)
Plausibility checks	Are there reasonable, quick plausibility checks on the results obtained which are independent of the tool? What ways are there of checking the "correctness" of the results? One example would be checklists	• There are plausibility checks for almost all aspects (+) • There are plausibility checks, e.g. checklists, but they do not necessarily cover all aspects (o) • There exist only limited means supporting plausibility checks (–)
Intellectual rigour	How rigorous is the method? Rigour has two relevant aspects: • Does the method have a rigorous meaning, formal semantics, for the key notions of causal factor and root cause? Are the semantics easy to apply? • Are the results of the method amenable to formal (mathematical) verification? To what extent is an application of the method so amenable?	• Formally defined and can be formally verified (+) • Semi-formal definition (o) • Informal definition (–)
Time sequence	Does the method contain a representation of time sequence of events?	• Yes (+) • Only indirectly (o) • No (–)
Specificity	The extent to which the method limits analysis to necessary causal factors of the focus event rather than exploring a range of general problems with the system that existed at the time of the focus event and may have contributed	• Method only analyses necessary causal factors of the focus event (+) • Method can be used to analyse contributory factors as well as necessary causal factors of the focus event (o) • Method seeks problems in general whether or not they were necessary causal factors of the focus event (–)