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Focusing quality efforts and improving prioritisation of nonconformities by utilising field return data

Case Study on a Manufacturing Company

Master's thesis in Quality and Operations Management

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Abstract

While there is a plethora of evidence displaying the benefits of both continuous improvement as well as sound improvement project prioritisation, there is limited research in this area in the context of nonconformities arising in the field. Furthermore, many companies still heavily rely on ad-hoc problem-solving and subjective judgements for dealing with nonconformities. This, in combination with the fact that scarce resources pervade all organisations in today's harsh market environment, sheds a light on the importance of improvement project prioritisation. This thesis thus seeks to bridge this gap and investigate how a manufacturing company can prioritise among nonconformities to assure that the most critical ones are being addressed. This includes investigating what attributes and methods should be utilised and how the outcome should be communicated throughout an organisation.

This thesis was performed at a case company and is based on qualitative and quantitative data collected through interviews, focus groups, observations, and a survey at the case company. The findings of this thesis suggest a prioritisation model which can be used to support informed and structured decisions for prioritisation. The proposed model is adopting a weighted multi-attribute approach for evaluation and prioritisation of non-conformities and integrates elements from both Pareto- and FMEA analysis, which aid the realisation of more effective and strategic quality improvements. With this thesis, we hope to illuminate the potential benefits that can be achieved by acknowledging and prioritising nonconformities from field returns while more research on the area is still needed.

Keywords: Nonconformities, field returns, Quality Management, continuous improvements, quality improvement projects, improvement project prioritisation, data-driven decision making, FMEA

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Contents

List of Acronyms

Below is the list of acronyms that have been used throughout this thesis listed in alphabetical order:

CAPA	Corrective and Preventive Action
EC	Engineering Change
ECR	Engineering Change Request
DDDM	Data-Driven Decision Making
FMEA	Failure Mode and Effect Analysis
NC	Nonconformity
QRM	Quality Risk Management

List of Figures

List of Tables

1
Introduction

This chapter will display the importance of quality and continuous improvement for manufacturing organisations to excel. There is no perfect manufacturing process in the realm of quality, and nonconformities (NCs) are thus unavoidable. Moreover, when an organisation is faced with multiple NCs, it is essential to prioritise the most critical ones. Therefore, this chapter will also include a background on the challenge of prioritising and selecting improvement projects. Additionally, a brief description of the case company under investigation will be presented. Subsequently, the purpose and specific research questions are raised. The delimitations of the thesis are also described, and lastly, the structure of the thesis is outlined.

1.1 Background

In today's fierce market, characterised by increased requirements for customisation, cost reductions, and product quality, organisations must continuously improve to survive and sustain their competitive position (Aouag et al., 2015). To meet these requirements, it is common for organisations to set high goals and targets for the quality of their products and services (Gremyr et al., 2020). Donauer et al. (2015) stated that even though it is nearly impossible in practice, achieving zero defects is often the target and desired state, which is paramount for any manufacturing company who aim for world-class performance. In addition, Freiesleben (2004) emphasises the correlation between image loss and nonconforming quality, which can have severe effects on the future of the business in terms of declined customer loyalty (Donauer et al., 2015). Thus, organisations must establish approaches for handling NCs when they appear.

Moreover, in today's highly digitised society with an increased amount of available data, organisations strive to become more data-driven and aim to base their decisions on high-quality data (Troisi et al., 2020). Adopting a more fact-based approach to decision making helps organisations avoid relying solely on subjective judgments or "gut feelings" and instead utilise employees' experiences to complement the data when deemed appropriate (Kirkham et al., 2014). For organisations to make sense of the available data and thus enable data-driven decision making, data visualisations are advocated as paramount (Knaflic, 2015). Being able to tell stories about complex data sets and use that story to make more informed decisions has become a tremendous competitive advantage. In addition, data visualisations have proven to be one of the most powerful tools for data communication. In terms of quality improvements, it has been adopted successfully to achieve attention and substantiate the need for improvement (Mueller-Hofmann, 2008).

One of the critical sources of data in the context of this thesis is the data accessible from field returns. A field return is when a delivered product stops functioning as intended and sent back to the provider (Ambilkar et al., 2021). Such failures are sometimes called field failures which are NCs that have not been detected in the product development or testing phase (Gazzola et al., 2017). In the domain of quality, NCs can be explained as a non-fulfilment of a specified requirement (Donauer et al., 2015). NCs that get through testing and inspection unnoticed and are first detected when delivered to the customer can have inestimable negative consequences on future customer relationships and sales. Poor quality is strongly related to customer dissatisfaction which impacts the corporate image (Ishaq et al., 2014) that, in turn, affects customer loyalty (Karunaratna & Kumara, 2018), which displays the importance of managing NCs. However, adding to the complexity manufacturing companies face today, improvement projects can be resource-heavy, and companies may have product life-cycle or budgetary constraints they need to take count of (Neureuther & Kenyon, 2004). Hence, the selection and prioritisation of improvement projects are vital activities that need to be managed to allocate resources and efforts to the right NCs that bring the most value to the business and to continuously and efficiently improve quality.

Despite the above-stated benefits and potential for quality improvements from acknowledging NCs, there has not been much focus on how to monitor, prioritise and select NCs for further investigation (Donauer et al., 2015), especially those that appear after production and delivery. Moreover, literature about utilising data to make high-quality decisions about quality improvements describes the complexity of understanding and interpreting raw data (Moore, 2017). Therefore, it is emphasised as a necessity to transfer data into knowledge before utilising it for strategic data-driven decision making (Mandinach et al., 2006). That said, there is a gap in the current literature on prioritising NCs from field returns to aid the selection of quality improvement efforts.

It is evident that the potential and valuable information that data from NCs arising in the field bring is of utter interest to any manufacturing company (Gazzola et al., 2017; Murray, 2017) and that the ability to prioritise and select NCs is a crucial activity. Taking everything together, this case study intends to fill the gap between the collected data from NCs arising in the field and knowledge about the most severe and important ones. As a result, more meaningful information concerning a particular NC will be present, which creates the possibility to make more informed decisions and prioritisations of quality improvement efforts.

1.2 The Case Company

The case company, hereinafter referred to as Company X, is a part of a larger global group, Group Y, that employs approximately 60 000 people worldwide. Company X's headquarter is located in Gothenburg, Sweden, and in 2020, the company employed around 400 people and generated sales of roughly 240 million USD. The company provides a wide range of industry-leading products within industrial automation technology and engineering. Moreover, Company X is active in a diverse set of markets, ranging from oil and gas to life science and chemical, to mention a few. These industries have different focuses and requirements, demanding the company to meet varied customer needs. The competition varies between different markets, where the company is market leaders in some and experience tougher competition in others. However, Company X always strive to become market leaders in the markets they decide to operate within.

Furthermore, innovation and technology are central to the company, displayed by its couple of hundred active patents. Despite Company X's relentless focus on developing new technologies, one of the main objectives is quality, where customer satisfaction and continuous improvement are the primary goals. The company's quality objectives include ensuring that the quality, speed, and responsiveness continuously improve year by year and that new products aim to have better quality than the previous generation. Company X continuously strive toward improving all aspects of the business through company-specific metrics, customer feedback, and disciplined management processes. For example, the company have plenty of KPIs facilitating the evaluation of the current improvement rate and utilising recognised methods such as Six Sigma and Kaizen to drive their improvement projects. In addition, the company stresses that quality is everyone's responsibility and that it should be incorporated into all roles, from top management to the shop floor. That said, Company X has a brand image and reputation that mainly relies on the high quality of its products.

1.3 Purpose and Research Questions

In the quest to become more data-driven and ease the selection of improvement projects, both Company X and organisations in general request a solution to prioritise the most critical NCs. Therefore, this thesis aims to develop a structured approach that will aid the selection process on when corrective action should be taken. The thesis further seeks to foster communication and knowledge sharing between organisational functions to achieve a joint agreement on how future improvement projects should be evaluated and treated.

To address the purpose of the thesis, the following three research questions will be investigated:

RQ1: What attributes should NCs from field returns be evaluated against to facilitate the prioritisation and selection of improvement efforts?

RQ2: What methods or tools should be used to facilitate the prioritisation and selection of improvement efforts of NCs from field returns?

RQ3: How should the suggested prioritisation of NCs be visualised and communicated to transfer knowledge between organisational functions?

1.4 Delimitations

First and foremost, the thesis solely concentrates on one company implying that the outcome primarily fits the case company even though some findings might be generalisable. Although some of the results may be generalisable, the applicability and validity of those findings are not tested. Another prominent delimitation of this thesis is that the approach only focuses on assessing the importance and priority of NCs arising in the field exclusively; NCs detected in product development or production are thus disregarded. Moreover, the proposed prioritisation model forms a foundation to determine when corrective actions should be taken. However, the solution, i.e. the kind of action, is not elaborated on or included in the model.

1.5 Thesis Outline

This report is divided into the following chapters: *Introduction, Literature, Method, The current state of affairs, Empirical findings, Analysis, Discussion,* and *Conclusions and recommendations.* The content of each chapter is briefly described in Table 1.1.

Table 1.1: The structure of the thesis and content of each chapter.

Chapter	**Content**
1. Introduction	The research area and its relevance to investigation is introduced together with a description of the case company. After that, the thesis's aim, research questions, and delimitations are presented.
2. Literature	Previous research on the subject found in literature is presented as well as other areas relevant to the analysis and conclusions. Further, a theoretical framework based upon the literature is presented.
3. Method	The methodology underpinning the study is presented.
4. Current State of Affairs	The current state of affairs is described to understand the context and internal processes central to the research and aim of the thesis. This chapter includes theory and empirical findings mutually.
5. Empirical Findings	The empirical results from the interviews, focus groups, observations and the survey are presented.
6. Analysis	The empirical results are analysed in combination with the theoretical findings. Based on the analysis, a model for prioritisation of NCs is proposed and described.
7. Discussion	Each research question is discussed and answered separately.
8. Conclusions and Recommendations	The conclusions of the thesis as well as recommendations to the case company are presented. In addition, future research is suggested.

2
Literature

In this chapter, the literature is outlined. The structure of topics covered is as follows: *Quality Management, Data-driven decision making, Prioritisation of product- and process improvement,* and lastly, *The theoretical framework,* which synthesises the literature and illustrates how the three areas will support in answering the research questions of the thesis. The connections between the research questions and theory are presented in Table 2.1.

Table 2.1: Connections between the research questions and the theory

Research Questions	**Theory**
RQ1: What attributes should NCs from field returns be evaluated against to facilitate the prioritisation and selection of improvement efforts?	2.1 Quality Management 2.3 Prioritisation of Product- and Process Improvements
RQ2: What methods and tools should be used to facilitate the prioritisation and selection of improvement efforts of NCs from field returns?	2.1 Quality Management 2.3 Prioritisation of Product- and Process Improvements
RQ3: How should the suggested prioritisation of NCs be visualised and communicated to transfer knowledge between organisational functions?	2.2 Data-driven Decision Making

2.1 Quality Management

The term quality often receives significant attention from researchers and practitioners, but there is no universal definition of its meaning. As Sower and Fair (2005) described it, *"Every quality expert defines quality somewhat differently, and there are a variety of perspectives that can be taken in defining quality."* (p.8). In the article *What is quality?* Hoyer et al. (2001) present several definitions of quality stated by some of the most important contributors to quality in the 20th century. Some of those are Crosby, who urges the importance of defining quality as conformance to requirements (Crosby, 1979, in Hoyer et al., 2001); Juran, that suggests quality to be defined as fitness for use (Juran, 1988, in Hoyer et al., 2001); and Deming, that emphasises that quality must be defined in terms of satisfying the current and future needs of the customer (Deming, 1988, in Hoyer et al., 2001). Despite the difficulty in formulating a universally agreed definition of the term quality, a common focus can be recognised among the descriptions – customer satisfaction (Wicks & Roethlein, 2009).

To ensure customer satisfaction Hoyle (2007) highlights the need for Quality Management. This is further emphasised by Hellsten and Klefsjö (2000), who describe Quality Management as a management philosophy based upon several core values. A similar approach to Quality Management is taken by Bergman and Klefsjö (2010), who defines it as achieving increased customer satisfaction with reduced resources. Further, Bergman and Klefsjö (2010) describe Quality Management's basic concepts as a cornerstone model based on five main principles: *focus on customers, focus on processes, base decisions on facts, let everybody be committed,* and *improve continuously.* In addition to these five principles, the authors emphasise the need for committed leadership to create a suitable culture that facilitates efficient Quality Management. Likewise, Dean and Bowen (1994) propose a similar approach based on three principles, *customer focus, continuous improvements,* and *teamwork*, each principle connected to practices and techniques. The authors further describe the close relationship between the three principles and emphasise that customer satisfaction is best achieved through continuous improvement activities driven by customer needs and supported by teamwork.

As accentuated by the approaches mentioned above, a strong focus on customers is essential for efficient Quality Management (Dean & Bowen, 1994; Bergman & Klefsjö, 2010). Customer focus has proven profitable (Zairi, 2000) and provides organisations with a distinct strategic advantage (Mittal & Frennea, 2010). However, as it can be challenging to define customer needs, it can be valuable to focus on the learnings provided by customer dissatisfaction (Zairi, 2000). In the case of arising quality issues found by customers in the field, the knowledge provided through customer feedback is an invaluable resource to achieve improved quality (Fundin & Bergman, 2003). Many customer-driven organisations invest in gathering customer feedback and successfully implement advanced customer feedback systems (Sampson, 1999). However, organisations find it challenging to utilise customer feedback such that it favours value creation (Fundin & Bergman, 2003). Since customers are continuously increasing their expectations of products and services, Fundin and

Bergman (2003) further suggest implementing cross-functional teams and a structured process that ensures that the knowledge gathered through customer feedback can be used for quality improvement activities.

In addition to customer focus, the importance of continuous improvements to establish effective Quality Management is highlighted (Dean & Bowen, 1994; Bergman & Klefsjö, 2010). Studies on the topic emphasise continuous improvements as an approach that enhances an organisation's creativity and competitive excellence (Oakland, 1999; Caffyn, 1999; Gallagher et al., 1997). However, for this to be true, it is essential to align suggested improvements with the organisation's goals, policies, and visions (Bhuiyan & Baghel, 2005; Lillrank et al., 2001). Further, for an organisation to successfully manage continuous improvements, it is essential to adopt an accepting attitude towards change (Lillrank et al., 2001), and it is emphasised that the work with continuous improvements must be long-term, management-led, conducted in cross-functional teams, and adopt a high level of customer focus (McAdam et al., 2000). The literature also highlights that formal improvement processes must be established for an organisation to succeed with its quality-improving activities (Lascelles & Dale, 1990). Such processes are advantageously data-driven and should utilise quantitative data to support essential subjective assumptions. Lascelles and Dale (1990) further describe that the quality improvement processes should place the customer's needs and requirements at the forefront of the organisation's quality improvement strategy. Although continuous improvements have many potential benefits for organisations' competitiveness (Ahmed et al., 1999), it is essential to highlight that organisations cannot improve everything at once (Larson, 2003). According to Larson (2003), the key to successful continuous improvements is choosing the right things and the proper order to improve. Therefore, the author suggests to base the decision making process on facts and to thoroughly assess risks of all possible improvement activities.

2.1.1 Quality Risk Management

Quality Risk Management (QRM) is a systematic process developed for assessing, controlling, communicating, and reviewing quality risks across the entire product lifecycle. A QRM process includes the identification of threats as well as the analysis and evaluation of the risks associated with the found threats (Lotlikar, 2013). Implementing an effective QRM system can facilitate better and more informed decision making within the risk management process (Reddy et al., 2014). Therefore, the risk assessment should be based on scientific knowledge and experience about the evaluated product or process (Lotlikar, 2013).

Quality Risk Management principles and practices are commonly and effectively adopted in many industries and have been used for a long time (Rodríguez-Perez & Peña-Rodríguez, 2012). However, a more systematic approach to how the risks should be evaluated has arisen over the years. It is no longer managed mainly based on experience, intuition, or "gut-feeling" (Williams et al., 2006). There are several different models and views on managing risks in the best possible way, ranging from the "do nothing at all" approach to striving to nullify the effect of all identified risks. The decision making regarding when to act and what risks to manage is described by Williams et al. (2006) as a trade-off between the cost/likelihood of insurance versus the cost/likelihood of risk. To address these trade-offs, several models in the literature suggest dividing risk management into three steps: *risk recognition, risk prioritisation,* and *risk management.* The entire risk assessment process and its three-part division presented by Williams et al. (2006) are visualised in Figure 2.1.

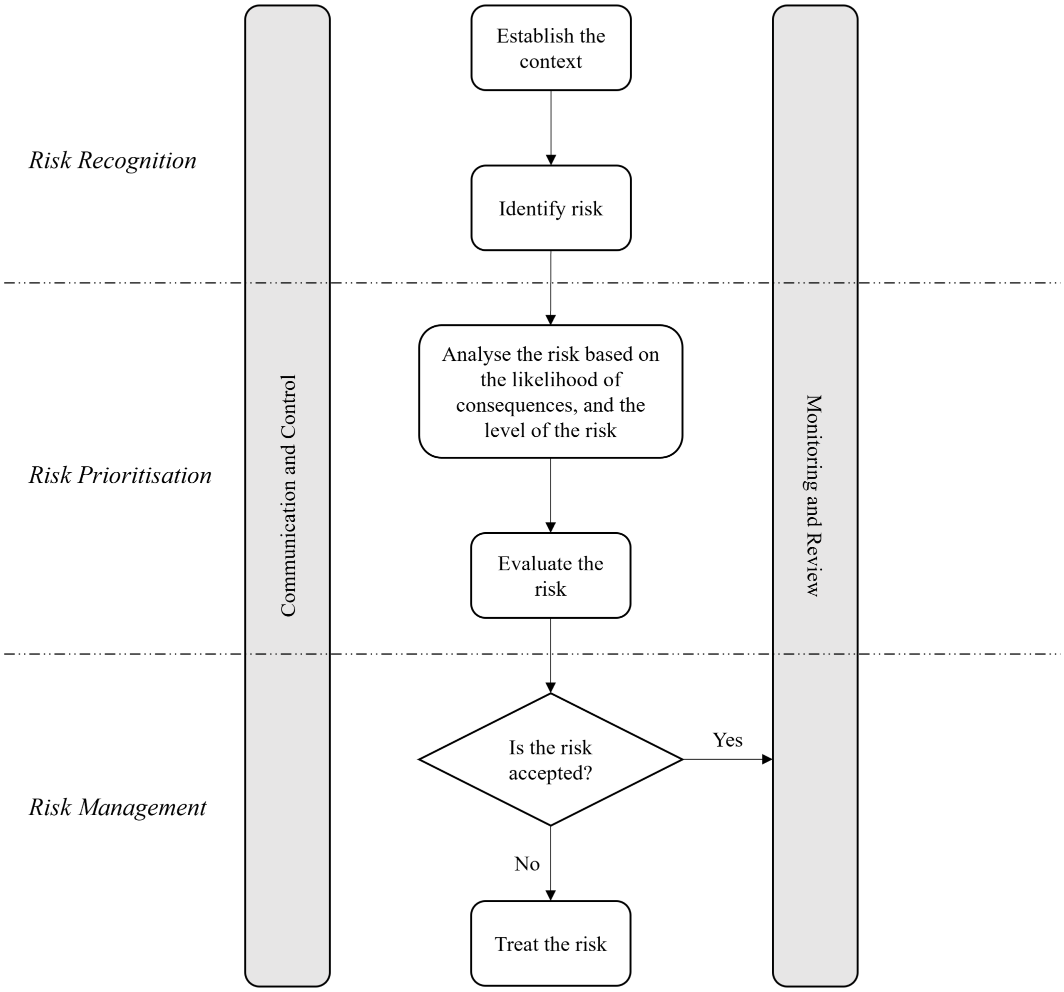

Figure 2.1: The risk assessment process (adapted from Williams et al., 2006).

As visualised in Figure 2.1, the initial risk recognition phase aims to establish the context, create an understanding of what is at risk, and identify what parts of the context may be affected (Williams et al., 2016). Further, in the second phase of the process, the focus is on understanding the nature and level of the risks. The risk prioritisation is divided into two parts, the analysis and the evaluation of the risks. The risk analysis is based on both the likelihood and the consequence of the occurrence and provides a level of severity of the risks. An essential factor in ensuring a successful risk analysis is the selection of the proper methods and tools (Lotlikar, 2013). Examples of some of the most commonly used tools are Failure Mode and Effect Analysis (FMEA), Fault Tree Analysis (FTA), flowcharts, Hazard Analysis and Critical Control Points (HACCP). In the evaluation, each risk is assessed against a risk-acceptance criterion and thereby ranked by its severity. In the last step, the risk management phase, a decision is taken on dealing with the risks. Most commonly, the risks are categorised by the four Ts model consisting of four alternative ways to address the risks (Lotlikar, 2013):

1. *Terminate* – Forbid or end activities related to the risk
2. *Treat* – Control through measures or create a contingency plan of how the risk should be managed
3. *Tolerate* – Accept the occurrence of the risk
4. *Transfer* – Ensure that the risk impacts another entity, for example, the insurance company.

The Quality Risk Management system and statistical tools allow organisations to adopt a risk-based approach toward Quality Management (Lotlikar, 2013). Furthermore, a Quality Risk Management system can be applied retrospectively and proactively. By establishing a practical QRM approach, the organisation ensures through corrective or proactive actions to provide high-quality products or processes (Rodríguez-Perez & Peña-Rodríguez, 2012).

2.2 Data-Driven Decision Making

Today's digitised markets allow organisations to easily collect large amounts of data and strategically use it to optimise decision making (Troisi et al., 2020). Milkman et al. (2009) describe that decisions based on limited data often become sub-optimal since these decisions do not consider all influential aspects. Those sub-optimal decisions might imply high costs, engage the decision-maker in needless conflicts or result in bad investment. Hence, to a broader extent, managers should base their business decisions on gathered data using data-analytic thinking, a concept called Data-driven decision making (Troisi et al., 2020). Data-driven decision making, referred to as DDDM, has been adopted in various forms and has evolved over time (Dodman et al., 2021). Consequently, there does not exist one single definition of DDDM; however, many similar descriptions can be recognised among the extensive literature conducted on the subject (Troisi et al., 2020). The following definition of DDDM by Diván (2017) will be used for this thesis.

"The data-driven decision making could be defined as the practice of basing decisions on the analysis of the data rather than purely on intuition". (p.51)

Even though DDDM is widely recommended as a strategic solution to ensure high decision quality, the transition towards DDDM is not straightforward (Hume & West, 2020). Additionally, Varvne et al. (2020) emphasise to successfully implement DDDM a lot is required from the transitioning organisation and its management. This is supported by Troisi et al. (2020), who also conclude five standard criteria suggested that organisations should employ to successfully implement and lead their DDDM strategies:

1. Learning orientation - Implying the importance of establishing a data-driven culture, where employees at all levels can make decisions based on insights extracted from data.
2. Technological infrastructure - Emphasising the need to adopt a technological infrastructure in which information can easily be managed and extracted to increase the integration and accessibility of data.
3. Specialised data analysis skills – Highlighting that specific data analysis skills are required to obtain relevant knowledge from the available data.
4. Proactive process management – Implying that there is a need to implement proactive process management, covering the handling of multiple data sources to optimise the use of the different data types.
5. Ability to renew the knowledge – Meaning that not until after step 1-4 has been conducted it is possible to stress the circularity of the process and, in response to the insights and knowledge gained through the handling of data and proactive process management, improve the decision making process and pursuing sustainability over time.

Further, to enable strategic DDDM, data must be transferred into knowledge to create sense-making (Moore, 2017). Raw data in isolation does not bring meaning to the decision-maker, and it needs to be converted into information and, ultimately, knowledge. Mandinach et al. (2006) propose a framework for data-driven decision making, illustrated in Figure 2.2, which displays how organisations can convert raw data into knowledge and utilise the knowledge to make more informed and fact-based decisions. The framework starts with data collection that needs to be organised and connected to a context to derive meaning and information. Then, the analytical process can start, and when this step is summarised, the information can be synthesised and prioritised to produce knowledge which can thus be used as a basis for decision making (Moore, 2017).

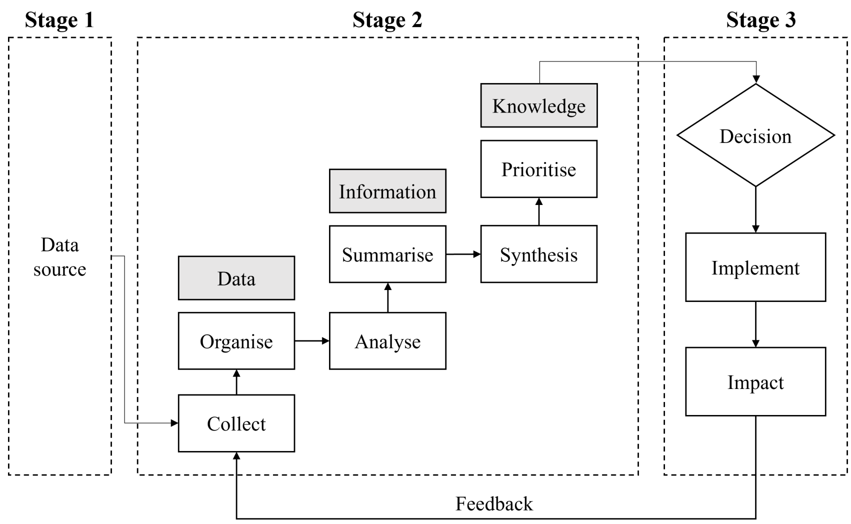

Figure 2.2: Framework for data-driven decision making (Adapted from Mandinach et al., 2006).

When it comes to selecting quality improvements, for which most organisations' resources are scarce, it is essential to prioritise the improvement projects (Marriott et al., 2013). Moreover, since the data gathered through NCs generally are of unstructured character (Wu, 2013), organising the data and transforming it into knowledge becomes even more critical (Mandinach et al., 2006).

Despite the challenges of implementing DDDM within an organisation, the usefulness and advantages justify the efforts required during the implementation (Dodman et al., 2021). The existing literature argues for different benefits with the transition towards the implementation of DDDM depending on the perspective taken by the authors. Brynjolfsson et al. (2011) concluded in their case study that DDDM increased both productivity and profitability of larger manufacturing companies, similar to Company X. Aigner (2013), on the other hand, emphasised the strategic advantage for an organisation to be able to transform data into knowledge which is gained through implementing DDDM. Moreover, to utilise the data and generate knowledge within the organisation, Aigner (2013) further emphasises data visualisations.

2.2.1 Data Visualisation and Communication

Data visualisations are graphical representations of data or information, and their purpose is to assist people in understanding the data (Brigham, 2016). Due to the increased availability of data and a growing desire for DDDM, it has become important to tell stories with complex data sets (Knaflic, 2015). As a result of the increased importance and new technologies facilitating graphical representations of data, the interest in data visualisations has grown fast (Brigham, 2016). Today, most organisations value and recruit resources that can convey key messages from large and complex data in a single image or visual (Gatto, 2015). Several studies on the topic of data visualisations emphasise that facts, effectively visualised in graphs, can increase the comprehension and memorisation of the recipient and argues for this as one of the most important benefits of data visualisation (Brigham, 2016; Hamzah et al., 2010, Robinson, 2016).

Moreover, Knaflic (2015) highlights that data visualisation can help organisations make more informed, fact-based business decisions. In addition, both Moore (2017) and Gatto (2015) describe that data visualisation is a suitable concept to assist with the sense-making of complex data sets by utilising the human visual system and way of thinking. Gatto (2015) further concludes that data visualisations are the only way humans understand trends and patterns. Due to this, they emphasise it as one of the most powerful tools to communicate data. To ensure that the data visualisation is as effective as the literature on the topic emphasises it to be, Hegarty (2011) suggests the following ten principles, described in Table 2.2.

Table 2.2: Principles of Effective Graphics (adapted from Hegarty, 2011)

Principle	**Explanation**
The Proximity Compatibility Principle	The graphical representation is compatible with both high and low display proximity.
The Relevance Principle of Graphics	All information presented by the graphical representation is relevant to the user.
Principle of Capacity Limitations	The graphical design takes account of limitations in working memory and attention.
Apprehension Principle	The graphical representation can be accurately perceived and using visual dimensions that are accurately judged.
Principle of Discriminability	Graphical representations which are used to visualise a difference between two variables should differ enough to be visually comparable.
Principle of Compatibility	The graphical representation is compatible with its meaning.
Principle of Salience	The most important thematic information is salient in the graphical representation.
Principle of Informative Changes	The properties of the graphical representation does not change if it does not carry any new information.
Principle of Appropriate Knowledge	The graphical representation is adapted to the knowledge of the audience, such that they can extract and interpret the information in the display.
Principle of Visual Momentum	If the graphical representations consist of different displays, the displays are consistentand visual aids are helping the user to make referential connections between the displays.

Despite the extensive benefits of data visualisations, Knaflic (2015) and Brigham (2016) discuss several diverse challenges to creating compelling visualisations. These challenges might lead to non-beneficial or even misleading data visualisations. Examples of such challenges are lack of knowledge regarding different visualisation techniques, insufficient data quality, limited understanding of what the audience can absorb, and limited access to an acceptable amount of data. Knaflic (2015) emphasises a framework constituting six pillars to address these challenges, as shown in Figure 2.3. In addition to this framework, Knaflic (2015) accentuate that it is of paramount importance to focus on visualising explanatory rather than exploratory. The author describes that the presentation of explanatory analysis makes the graphics more focused on the actual message that the presenter wants to convey instead of only highlighting the most noteworthy or interesting findings in the data set.

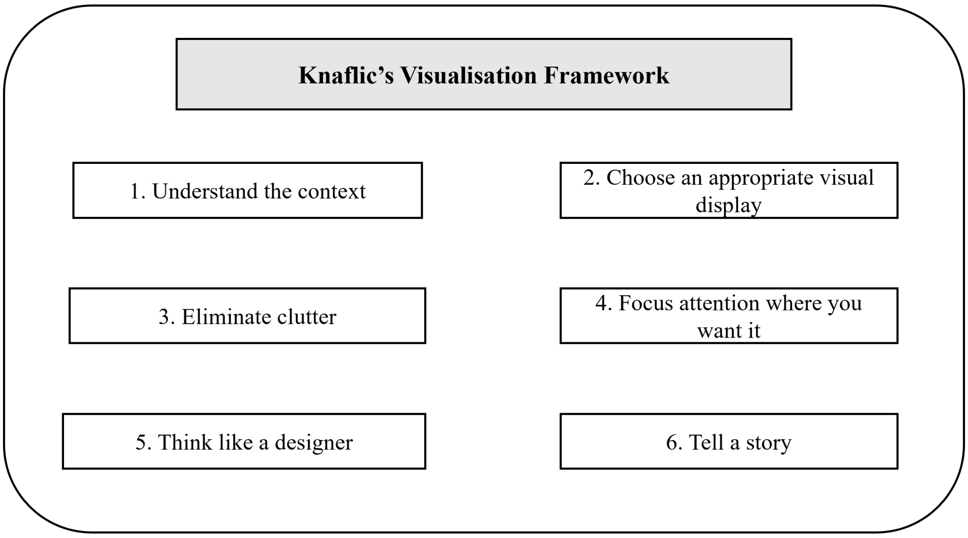

Figure 2.3: The pillars of Knaflic's (2015, p.12) visualisation framework

The first pillar, i.e., to ensure understanding of the context, implies defining the audience, previous knowledge, desired tone, technical level, and what message the visualisations should convey (Knaflic, 2015). To do this, Knaflic (2015) suggests assessing the *who*, *what*, and *how* by answering three questions; *Who* are the recipients of the visualisation?; *What* message do you want the visualisation to convey?; *How* can data be used to substantiate the message? The second pillar, choosing the appropriate visual display, implies selecting those types of graphical representations which most effectively communicate the message (Knaflic, 2015). It is emphasised by Knaflic to keep the visual displays simple and avoid using 3D graphics, pie- and donut charts as they often mislead the audience. Thirdly, Knaflic (2015) suggests eliminating clutter, as it takes up unnecessary brainpower from the audience and therefore distracts the audience from the key message of the graph. The fourth step in the framework for compelling visualisations, i.e. to focus the audience's attention on the core message of the visuals, is, according to Knaflic (2015), best achieved through strategically choosing attributes such as size, colour, and position. Fifthly, it is emphasised in the framework to "think like a designer", implying that the creator should consider how its recipient should use it (Knaflic, 2015). When assessing this, Knaflic (2015) suggests evaluating the visual's affordances, accessibility, and aesthetics. Lastly, Knaflic's (2015) framework accentuates the importance of focusing on telling a story with data visualisation, as the audience can remember stories in ways they cannot retain raw data. The last pillar implies that the story which the visualisation aims to communicate should have a clear beginning, middle, and end. Further, it is emphasised to include other strategies for effecting storytelling, such as the power of repetition.

2.3 Prioritisation of Product- and Process Improvements

Product- and process improvements are crucial activities for manufacturing companies to continuously deliver high-quality products that meet market needs and stay competitive long term (Teixeira et al., 2015). However, organisational resources in terms of time, capital, and personnel are limited, making it impossible to conduct all identified improvement initiatives (Marriott et al., 2013), nor are all identified improvement areas strategically sound to perform. Therefore, prioritising improvement efforts is a crucial task to ensure that critical and strategically important improvements that are most beneficial to the company are successfully realised (Donauer et al., 2015). Salah (2015) agrees with this and states that the effectiveness and success of improvement projects are highly dependent on prioritisation, selection, and classification of these. On the other hand, failure to prioritise can have severe effects as it impacts not only the projects themselves but also the company as a whole and its competitiveness (Davis, 2003, in Kirkham et al., 2014). Prioritisation and selection of NCs are particularly critical as it is strongly related to customer satisfaction and loyalty as a nonconforming product implies that one or more of the customer requirements are not met (Donauer et al., 2015).

In a study of 203 manufacturing organisations located in Europe, Kirkham et al. (2014) investigated the area of continuous improvement in relation to the prioritisation of improvement activities. The study aimed at identifying the most common strategies used by large organisations and SMEs where the researchers distinguish between subjective and objective methods. Subjective methods are described by Kirkham et al. (2014) as primarily based on personal beliefs, experiences, or feelings, whilst objective methods are based on proven methodologies. The result of the study highlights the importance of establishing structured and objective prioritisation of improvement initiatives to achieve the most effective results. In Figure 2.4, the perceived relative success of the respondents' methods for improvement project prioritisation is illustrated.

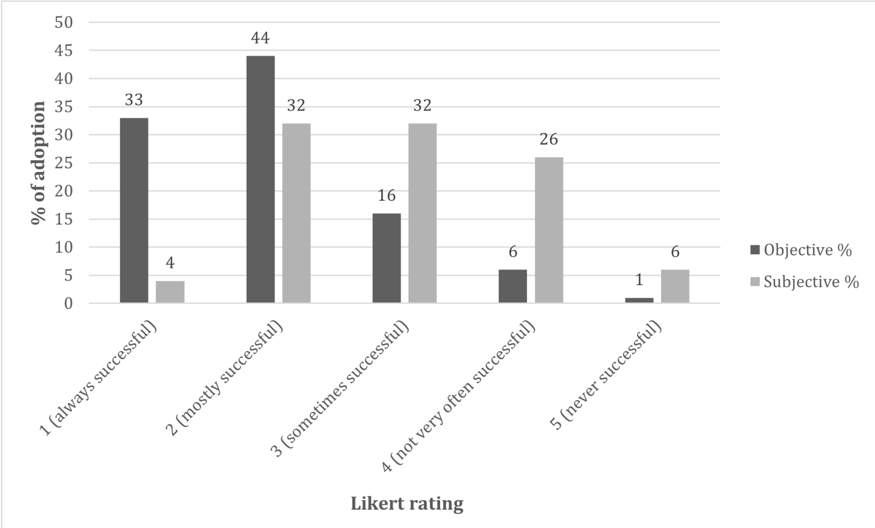

Figure 2.4: Perceived relative success of subjective and objective prioritisation methods found in the study conducted by Kirkham et al. (2014)

However, the study also revealed that subjective methods such as experience, judgement, or feelings are still prevalent in many companies. Out of the 64 large organisations that participated, 47 per cent utilised both subjective and objective approaches, 41 per cent only adopted objective methods, and 12 per cent relied merely on subjective ones. The three most common reasons for adopting subjective prioritisation approaches over objective ones were identified as: *lack of awareness/-knowledge* (43 per cent); *lack of resources available* (26 per cent); and *a feeling that subjective methods are more effective* (26 per cent), see Figure 2.5.

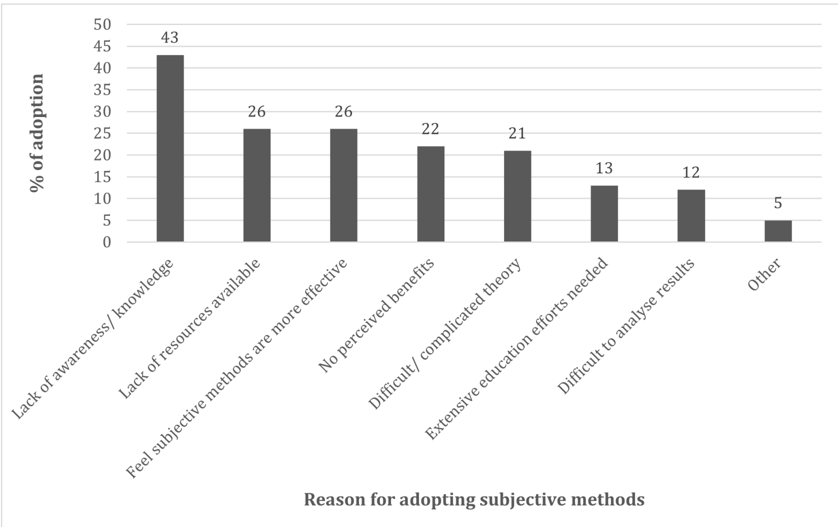

Figure 2.5: Reasons for adopting subjective over objective prioritisation approaches found in the study conducted by Kirkham et al. (2014)

The study performed by Kirkham et al. (2014) depicts the importance of adopting objective methods when prioritising improvement initiatives. Furthermore, Salah (2015) stresses that project prioritisation and selection should be aligned with the company's overall strategic goals and seen as a key part of strategic management. This somewhat strengthens Pikosz and Malmqvist's (1998) argument, suggesting that different organisations may adopt different strategies within their company-specific Engineering Change (EC) process, i.e. the formal process for product improvements, due to their different goals and business environment. For companies that wish to adopt a practical prioritisation approach, specific methods and criteria for evaluating and prioritising improvement initiatives are necessary to identify. These areas will be investigated in the following two sub-chapters.

2.3.1 Methods

As one of the primary reasons for failing with the implementation of improvement projects is connected to the project selection, it is essential to have appropriate methods to evaluate the importance of each project, both in terms of severity and in terms of increased competitive advantage (Salah, 2015). Further, it is paramount to decide whether subjective or objective methods should be used to prioritise potential improvement projects (Ziara et al., 2002). Subjective methods often used among larger manufacturing organisations include focus groups, customer visits, and brainstorming sessions (Kirkham et al., 2014), while objective prioritisation methods can be, for example, Pareto analysis (Larson, 2003), Cost-benefit analysis (Hira & Parffit, 2004), Analytical Hierarchy Process (AHP) (Pyzdek, 2003), and cause-and-effect matrices (Kirkham et al. 2014). However, as Kirkham et al. (2014) emphasised, most organisations use objective methods for project prioritisation. The study of 64 larger manufacturing organisations conducted by Kirkham et al. (2014) showed that the two most commonly used methods for project prioritisation are Cost-benefit- and Pareto analysis, which are objective approaches. Nevertheless, the third most widely adopted method for project prioritisation was subjective judgements based on either experience or "gut feeling", see Figure 2.6 According to Cai and Zhu (2015), using such subjective judgements as a complement in the decision making process is mainly due to current challenges to ensuring high-quality input data when adopting the objective methods and is thus currently deemed a necessary addition in some cases.

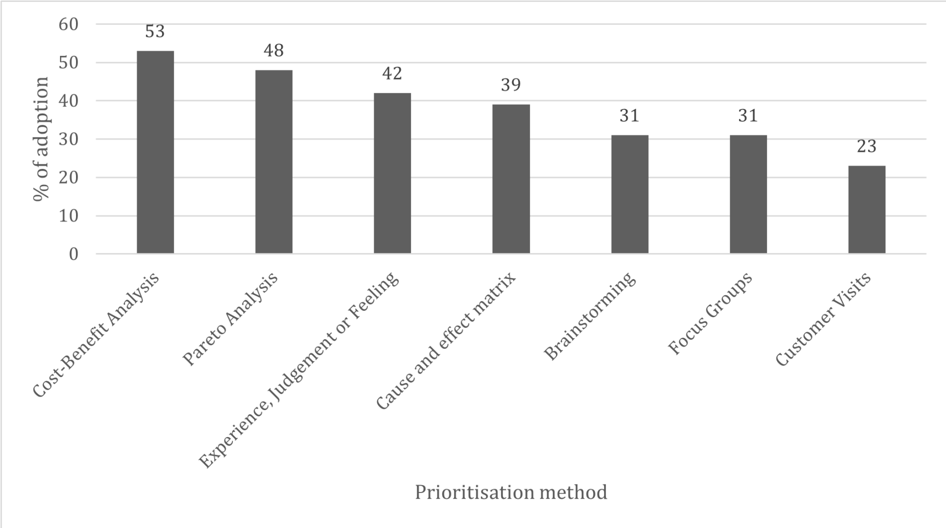

Figure 2.6: Most commonly adopted project prioritisation methods for large organisations found in the study conducted by Kirkham et al. (2014)

The subjective approaches toward prioritisation and selection of quality improvement projects are also criticised by Donauer et al. (2015). They suggest that improvement projects should be prioritised based on multi-attribute criteria and recommend using a weighted multi-attribute evaluation approach that integrates the Failure Mode and Effect Analysis (FMEA) and the Pareto Diagram elements. This approach implies visualising the NCs in a 2x2 matrix with two weighted multi-attribute axes. In the case study conducted by Donauer et al. (2015), the authors used the risk level attributes (x-axis) and the causes and impacts attributes (y-axis) as multi-attribute axes, see Figure 2.7. According to Donauer et al. (2015), this combination of dimensions enables organisations to refine their prioritisations and displaying the NCs in the suggested matrix enables structured identifications and selections of effective and strategic quality improvements. The authors further emphasise the simplicity of using a 2x2 matrix since it is intuitive and an already established way of communicating quality-related topics. Further, Lowy and Hood (2004) (in Donauer et al., 2015) stresses that 2x2 thinking improves the clarity of the visualisation, leads to problem-solving with higher quality, and thus follows the new upcoming trends of visual management.

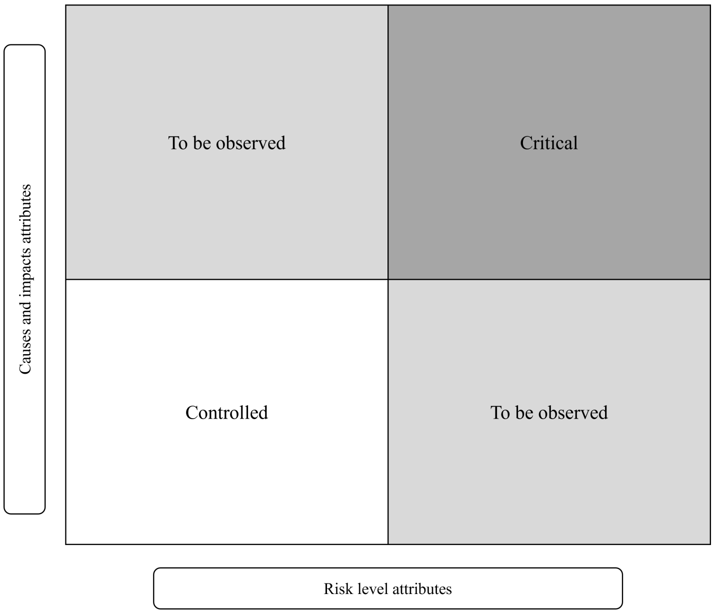

Figure 2.7: Conceptual model of the 2 × 2 matrix with multi-attributes (adapted from Donauer et al. (2015))

In the 2x2 matrix suggested by Donauer et al. (2015), the NCs located in the dark shaded area to the top right are *critical*. Thus an improvement project should be conducted immediately. The two light shaded areas to the upper left and lower right in Figure 2.7 so-called *to be observed* areas, implying that the development of these NCs should be observed over time, and if threatened to turn into critical, efforts should be taken. However, Donauer et al. (2015) emphasised that if resources are available when all critical NCs have been addressed, or if there are currently no critical NCs, the to be observed can preferably be addressed. Further, as discussed by Donauer et al. (2015), the risk level attributes might, in some cases, be more important than the attributes specific to the company. Thus, the light-shaded area in the lower right might be given a higher priority than the light-shaded area in the top right corner of the matrix. NCs located in the not shaded area in the lower-left quarter of the matrix are by the model deemed *controlled* and should thus not be prioritised.

In this thesis, a weighted multi-attribute model which includes influences of Pareto- and FMEA analysis, inspired by Donauer et al. (2015), is used to build a prioritisation model, which aim to facilitate the selection process on when corrective actions should be taken. In the below sub-chapters, the two methods are described in more depth.

Failure Mode and Effect Analysis

Failure Mode and Effect Analysis (FMEA) is a proactive tool commonly used to identify, evaluate, and prevent process and product-related failures (Bluvband & Grabov, 2009). The primary purpose of FMEA is to detect and prevent potential issues or failures at an early stage in the design or production process (Can, 2018).

FMEA is often utilised as a technique for reliability analysis, risk analysis, and quality improvements (Chen, 2017). The risk analysis in standard FMEA is based upon three risk factors, namely, Severity (S), Occurrence (O), and Detection (D). These risk indicators are graded with a numerical value from 1 (best case) to 10 (worst case), and these grades are used to calculate the risk priority number (RPN), see Equation 2.1 (Can, 2018).

$$RPN = S * O * D \tag{2.1}$$

When an FMEA is conducted, each potential failure is assessed individually, and the RPN is used to prioritise what corrective and preventive actions should be taken (Chen, 2017). According to Bluvband and Grabov (2009), conducting a conventional FMEA follows the six steps described in Table 2.3. Additionally, the authors highlight one common pitfall in each step and a proposed remedy to the difficulty.

Table 2.3: The Six Step Process of FMEA described by Bluvband and Grabov (2009)

Step of the FMEA Process		**Explanation**
Step 1: Failure Modes Identification	Included tasks	Creating a list of potential failure modes for each product or system.
	Common pitfall	Miss failure modes.
	Proposed remedy	Creating a general checklist based on the key question “What Can Go Wrong?”
Step 2: Ranking Procedure	Included tasks	Evaluating the risk factors’ severity, occurrence, and detection and rank the components numerically from 1 to 10.
	Common pitfall	Using irrelevant statisticsas a basis for the numerical value assigned to each risk factor of the failure mode.
	Proposed remedy	Including experienced team members, considering outliers, and avoiding using mean values.
Step 3: Total Risk Estimate	Included tasks	Planning corrective or preventive actions for failure modes, starting with the highest RPN failure.
	Common pitfall	Most FMEA procedures do not define the Risk Acceptance Criteria, i.e., a limit from it is assessed as necessary to conduct corrective or preventive actions.
	Proposed remedy	Calculating the Total Risk Estimate, i.e.,the overall risk level of the given project, and assign that to be the risk acceptance criteria.

Table 2.3: (Continued)

Step 4: Critical Items Identification	Included tasks	Separating the failure modes characterised with high priority by a high RPN from other failure modes with lower risk.
	Common pitfall	Wrongly define the criteria for what should be characterised as a high priority failure mode.
	Proposed remedy	The graphical tool Screen Plot is suggested to enhance the characterisation of the failure modes.
Step 5: Corrective Action & Preventive Action (CAPA)	Included tasks	Selecting the most appropriate and profitable corrective or preventive action.
	Common pitfall	As the FMEA procedure itself does not provide common guidelines for the optimal choice of action, this is often an intricate part of the process.
	Proposed remedy	Evaluating both the feasibility of the choice of action and what effect the action has on the RPN value.
Step 6: FMEA Effectiveness Evaluation	Included tasks	Evaluating the effectiveness of the failure mode and effect analysis.
	Common pitfall	Similar to step 5, the process of FMEA does not include guidelines for how to assess the effectiveness of the FMEA.
	Proposed remedy	Calculating the normalised improvement estimate.

By adopting FMEA, an organisation can, as previously emphasised, evaluate critical business failures and, by using the RPN, prioritise the appropriate corrective and preventive actions to minimise the effects of the NCs on the business (Sutrisno et al., 2016). However, Marriott et al. (2013) and Sutrisno et al. (2016) highlight the severe limitations of relying only on the RPN index when selecting and prioritising corrective and preventive actions. Sutrisno et al. (2016) highlight the inability of the FMEA methodology to assess or measure the effectiveness of the actions taken and the economic impact of the failure occurrence on the organisation. Marriott et al. (2013) further justify this and emphasise that an application of FMEA in isolation from other complementary tools for prioritisation would not distinguish between contributing or wasteful activities. Sutrisno et al. (2016) provide suggestions on several complementing tools, such as cost-benefit analysis (CBA), fuzzy logic, the analytical hierarchy process (AHP), process activity mapping (PAM), SWOT analysis, and include indexes, namely, risk overload index (ROI) or detection overload index (DOI).

Pareto Analysis

Pareto analysis is one of the seven basic quality control tools (Bajaj et al., 2018). It is emphasised as a simple decision making tool allowing the decision-maker to assess and compare quality problems and the impact of solving them (Brooks, 2014). Further, by utilising the concept of Pareto analysis, an organisation can establish better prioritisation of NCs by basing the selections upon what will have the most significant influence on the company's organisational goals (Brooks, 2014). The Pareto principle is based upon observations and implies that most often that some defects contribute more to poor quality than others (Powell & Sammut-Bonnici, 2014). This is referred to as *"perfect imbalance"*, and observational studies in several contexts showed that about 20 per cent of the inputs creates 80 per cent of the result (Brooks, 2014). In the context of quality issues arising in the field, the Pareto principle can be used to conclude that about 80 per cent of the NCs can be resolved by addressing 20 per cent of the underlying causes and thus ensure that the improvement efforts will have the biggest payoff (Powell & Sammut-Bonnici, 2014).

To further facilitate decision making by using the Pareto principle, it is suggested to visualise the findings from the Pareto analysis in a Pareto chart (Zasadzień, 2014). These charts are simple frequency block diagrams showing the relative frequency of different attributes, such as NCs arising in the field, in descending order (Grosfeld-Nir et al., 2007), see Figure 2.8.

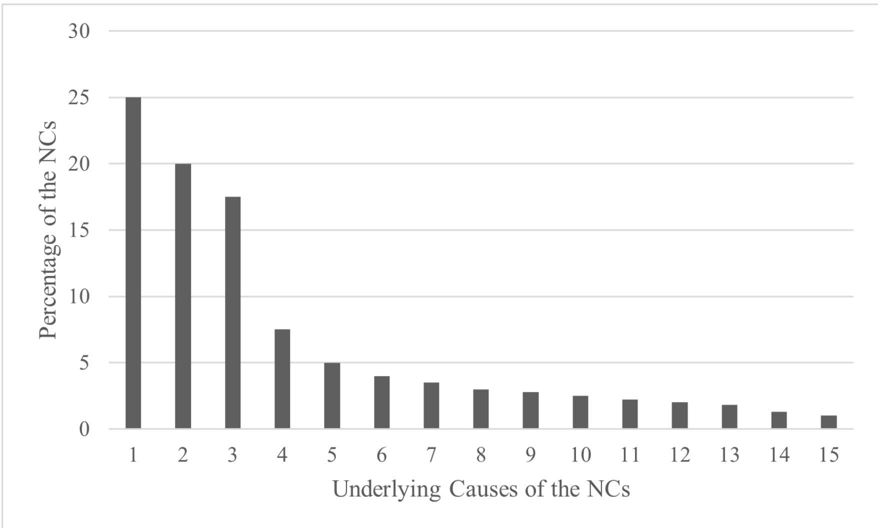

Figure 2.8: A Pareto chart (adapted from Grosfeld-Nir et al., 2007)

From this, the Pareto principle suggests that it is possible to identify the underlying causes (20 %) generating the most NCs in the field (80 %). However, as the idea of the Pareto chart is to be used as a basis for strategic decision making, it is emphasised by Grosfeld-Nir et al. (2007) as essential to ensure that the data gathered is of high quality to ensure mistakes in the classifications and thus lead to that irrelevant corrective actions are taken. In addition, Grosfeld-Nir et al. (2007) also highlight that the Pareto principles without scaling might not be efficient to use if the Pareto chart adopts an almost uniform contribution, see Figure 2.9.

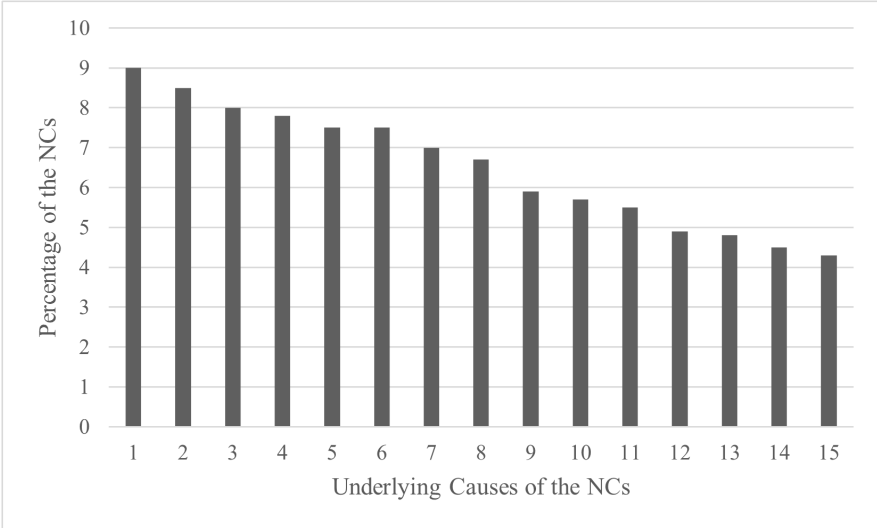

Figure 2.9: A Pareto chart with an almost uniform distribution not suitable for Pareto analysis (adapted from Grosfeld-Nir et al., 2007)

In literature, the Pareto analysis has been successfully combined with several diverse methods to, in the best possible way, facilitate the decision making process. Some examples are Ishikawa diagrams (Zasadzień, 2014), SWOT analysis (Powell & Sammut-Bonnici, 2014), and FMEA (Görener & Toker, 2013; Donauer et al., 2015).

2.3.2 Decision Criteria

There is no silver bullet regarding decision criteria for prioritising and selecting improvement initiatives. As aforementioned, the prioritisation should be linked to the specific company environment (Pikosz & Malmqvist, 1998) and connected to the overall strategy (Salah, 2015). This holistic focus is displayed in the literature on decision criteria for improvement projects. A literature review and compilation are summarised in 2.4. The criteria found are divided and classified into eight main criteria: *financial impact, customer satisfaction, strategic link, feasibility, safety, risk, learning and growth,* and *success probability.*

The financial impact may include the investment and cost of running the project (Antony, 2004), as well as the net cost savings (Harry & Schroeder, 2000, in Coronado & Antony, 2002). Jiang and Klein (1999) divide the financial criterion into five categories: benefit/cost ratio, rate of return, profitability contribution, growth rate, and payback period. Martin (2007) (in Salah, 2015) suggests direct cost savings, incremental margin, lower carrying cost or working capital, cost avoidance and other time metric improvements that may be considered soft savings when evaluating the financial impact. A slightly different view of the financial aspect is provided by Zhou et al. (2016), who focus on selecting quality improvement activities based on after-sales data. In their work, spare part price, warranty cost, and cost per unit are considered appropriate measures of the cost dimension.

Table 2.4: Literature compilation of suggested decision criteria for improvement prioritisation.

Decision Criteria	References
Financial impact	Antony (2004); Antony & Banuelas (2002); Coronado & Antony (2002); Banuelas et al. (2006); Gošnik & Hohnjec (2009); Goldstein (2001); Jiang & Klein (1999); Salah (2015); Zhou et al. (2016)
Customer satisfaction	Antony (2004); Antony & Banuelas (2002); Coronado & Antony (2002); Banuelas et al. (2006); Donauer et al. (2015); Gošnik & Hohnjec (2009); Salah (2015); Zhou et al. (2016)
Strategic link	Antony (2004); Antony & Banuelas (2002); Banuelas et al. (2006); Donauer et al. (2015) Gošnik & Hohnjec (2009); Jiang & Klein (1999); Salah (2015)
Feasibility	Antony (2004); Antony & Banuelas (2002); Banuelas et al. (2006); Goldstein (2001); Gošnik & Hohnjec (2009); Jiang & Klein (1999); Kornfeld & Kara (2013); Salah (2015)
Risk	Antony (2004); Donauer et al. (2015); Jiang & Klein (1999); Salah (2015)
Learning and growth	Antony & Banuelas (2002); Banuelas et al.(2006); Gošnik & Hohnjec (2009)
Success probability	Antony (2004); Goldstein (2001); Salah (2015)
Safety	Salah (2015)

Regarding customer satisfaction, Pande et al. (2000) (in Antony & Banuelas, 2002) suggest that the impact on meeting external customer requirements should be considered. Salah (2015) explains that the discrepancy between the current baseline performance and key customer output variables may aid in prioritising improvement initiatives, while Donauer et al. (2015) suggest including a customer evaluation based on customer complaints. Moreover, in a study performed by Gošnik and Hohnjec (2009), customer satisfaction significantly influenced the project selection, which somewhat validate the criterion's importance. Zhou et al. (2016) used the criterion of customer voice in their model where *customer complaint*, *customer satisfaction*, and *things go wrong (TGW)* acted as sub-criteria. The criterion customer complaint was measured as the number of customer complaints related to a specific NC. Customer satisfaction was explained as the discrepancy between prior expectations and the perceived product performance. The last criterion, TGW, was described as *"the description of product or service non-conformance according to the maintenance experience, product failure without maintenance and minor issues"* (p. 4).

The relationship between customer satisfaction and customer loyalty is described by Karunaratna and Kumara (2018), where customer loyalty is a measure of customers' willingness to continue doing business organisation long term and thus of immense importance to any business. Six determinants to customer satisfaction were identified that, in turn, are determinants of customer loyalty. The connections are illustrated in Figure 2.10.

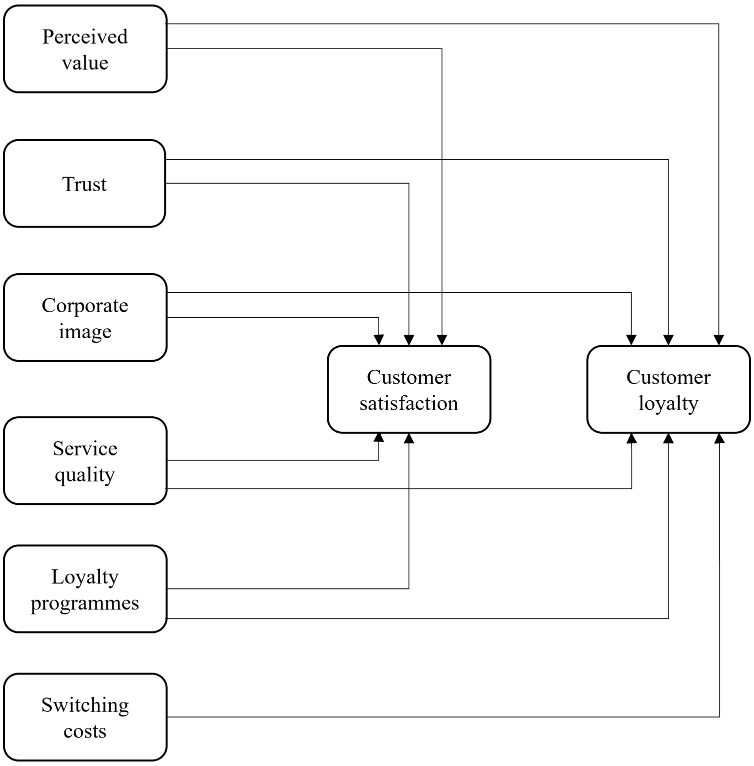

Figure 2.10: An integral model of the determinants of customer loyalty (Adapted from Karunaratna and Kumara, 2018)

Many authors stress the importance of aligning the project prioritisation and selection to the business strategy (e.g. Antony, 2004; Antony & Banuelas, 2002; Donauer et al., 2015; Gošnik & Hohnjec, 2009; Jiang & Klein, 1999; Salah, 2015). Moreover, according to Salah (2015), to succeed with the implementation of improvement initiatives, the selected projects do not only need to be of great impact on the business but also be doable and of manageable size, which leads to the criterion of feasibility. Feasibility can be described and measured in various ways. Pande et al. (2000) (in Antony & Banuelas, 2002) suggest that resources required for the project, complexity of the project, and availability of skills and expertise should be included in the equation. Goldstein (2001) highlights that one barrier to selecting appropriate improvement projects is the difficulty in collecting adequate amounts of data, which ultimately can lead to projects not being prioritised even though they might be of high importance. Availability of data has been recognised as an essential success factor in other works as well (e.g. Salah, 2015; Gošnik & Hohnjec, 2009).

The risk involved in the project is another suggested criterion (Antony, 2004; Donauer et al., 2015; Jiang & Klein, 1999; Salah, 2015). The risk can be evaluated by using the FMEA method to map the risks with the project (Bluvband & Grabov, 2009). This is illustrated in the case study performed by Donauer et al. (2015), who suggest using the FMEA criteria: severity, occurrence, and detectability to evaluate the risk of NCs. Moreover, learning opportunities in terms of new knowledge gained about the business, customers, or process are proposed by Pande et al. (2000) (in Antony & Banuelas, 2002) to consider when selecting improvement projects. This is illustrated in practice in the study by Gošnik and Hohnjec (2009), where some companies acknowledged the value of learning and growth when selecting improvement projects. Furthermore, Goldstein (2001) stresses that the project should have a high probability of success, which also is brought up as necessary in Salah's (2015) proposed model for project selection, prioritisation and classification. Lastly, and not as frequently mentioned, is the safety criterion; however, according to Salah (2015), some companies base their improvement project selection on health and safety issues among others.

It is evident that a wide variety of factors can be used for assessing and prioritising improvement projects. Notwithstanding, Pande et al. (2000) (in Salah, 2015) argue that companies not should use too many criteria and suggest a selection of five to eight attributes that are most relevant to the company.

2.4 Theoretical Framework

Based on the previously presented theory, a theoretical framework has been created to explain a holistic strategy that can be used for selecting the most effective and strategic quality improvements based on data from field returns; see Figure 2.11. Quality Management serves as a foundational brick for prioritising the most critical NCs for improvement projects. In addition, the theoretical framework consists of three elements that are deemed necessary based on the literature, namely, *formal processes for quality improvements; data embedded in every decision, interaction, and process;* and *risk assessment and strategic prioritisation.* These elements are necessary to ensure that the most essential NCs are acknowledged and thus trigger the most strategic quality improvement projects.

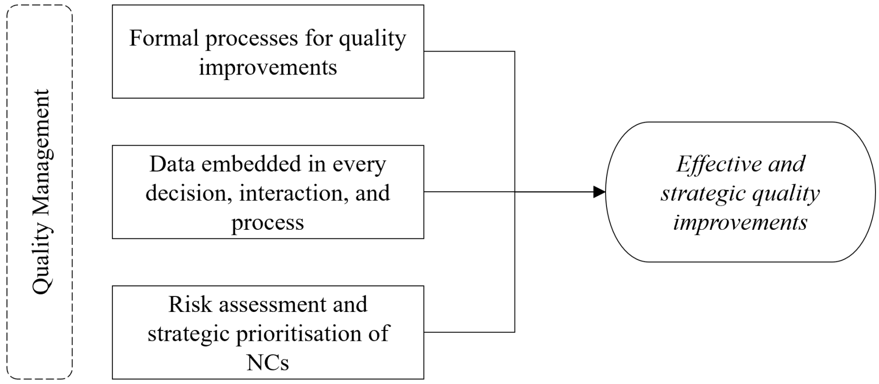

Figure 2.11: Theoretical framework for creating a holistic strategy for quality improvements from NCs.

First and foremost, it is vital to establish formal processes for quality improvements to ensure the effective realisation of improvement projects. The literature suggests that the improvement work should be management-led, data-driven, conducted in cross-functional teams, and adopt a high level of customer focus to assure that the improvement activities and their corresponding corrective actions are aligned with the company's strategic objectives (McAdam et al., 2000). Moreover, in the immensely complex case of NCs arising in the field, using actual data is emphasised as essential within the organisational processes, interactions among the employees, and indeed in all decisions taken to improve NCs. However, integrating and having access to relevant data is often insufficient (Gazzola et al., 2017). To ensure that the company's resources are allocated to the most value-added tasks, it is of utmost importance to have standardised methods and decision criteria aligned with the overall strategy and goals (Salah, 2015), which leads into the third and last part. By formulating and establishing criteria specific to the company, it will be possible to prioritise the most critical improvement projects (Donauer et al., 2015). In addition, it is paramount to perform a thorough risk assessment based on scientific knowledge and data such that all the potential risks of the improvement project are reviewed (Williams et al., 2006).

3
Method

In this chapter, the method of the thesis is provided. The chapter elaborates on the research strategy and design chosen for this study, the different methods used for data collection and analysis, and the quality of the research, including discussions regarding trustworthiness and ethics.

3.1 Research Strategy

The research strategy of the thesis is qualitative, which allows a more in-depth analysis of the research questions (Bell et al., 2019) and supports the exploratory type of purpose outlined for this thesis. Further, the thesis adopts an abductive approach towards the relationship between theory and empirical data. The abductive approach was applied by starting from the case company's observed problem and then through iterative reasoning between theory and empirical data, ending up with suggesting a prioritisation model upon which NCs should be evaluated when selecting improvement efforts. The primary sources for finding literature for this study has been through the database hosted by Chalmers Library as well as the search engine Google Scholar. To obtain relevant and applicable search results, the keywords *Nonconformities*, *Field returns*, and *Improvement project prioritisation* among a few were used.

3.2 Research Design

The research design is an embedded single case study. It examines a manufacturing company and how its field return data can be utilised to facilitate the prioritisation and selection of improvement efforts. The case study includes several groups within one organisation and is thus characterised as a *single embedded* case study (Yin, 2018). The choice of conducting a case study for this thesis is also justified by Bell et al. (2019), as they highlight its appropriateness when conducting a detailed analysis of a specific subject.

Company X was sampled grounded on its excellent reputation in assisting in a previous master thesis conducted in collaboration with the company. Further, the subject of the case study was sampled based on the aspiration to find a research topic that can provide theoretical and empirical insights. Bell et al. (2019) verify the appropriateness of the sampling strategy by emphasising the importance of choosing case studies from where the opportunity to learn is the greatest. This case study has contributed to learning opportunities, such as what attributes NCs should be evaluated against to facilitate the prioritisation and selection of essential quality improvements, what methods should be used such that the knowledge gained from NCs can be utilised to facilitate fact-based decision making, and how the improvement suggestions can be visualised and communicated to transfer the knowledge in the case company. Despite the great learning outcomes typical for case studies, previous research evaluating case studies and their usefulness for theoretical generalisations have been critical towards its use due to the lack of external validity (Bell et al., 2019). Further, since the purpose of the thesis has been to create a framework based on the case company and its internal processes, the results might not be directly applicable in other contexts without adaptions. Thanks to the awareness of the thesis's limitations, the lack of external validity alone do not motivate a selection of another research design.

The thesis and its final recommendation are based on data gathered from various sources such as interviews, observations, focus groups, secondary data, a survey, and existing theory on the subject, which is discussed in the following sub-chapter. The research started with the initial research scope provided by the case company, followed by a planning phase to establish the purpose and research questions. After that, an iterative process of data collection, literature study, and data compilation and analysis was performed. Once the analysis was saturated, the iterative data collection and analysis process stopped, and final conclusions and recommendations could be drawn. The research design is illustrated in Figure 3.1.

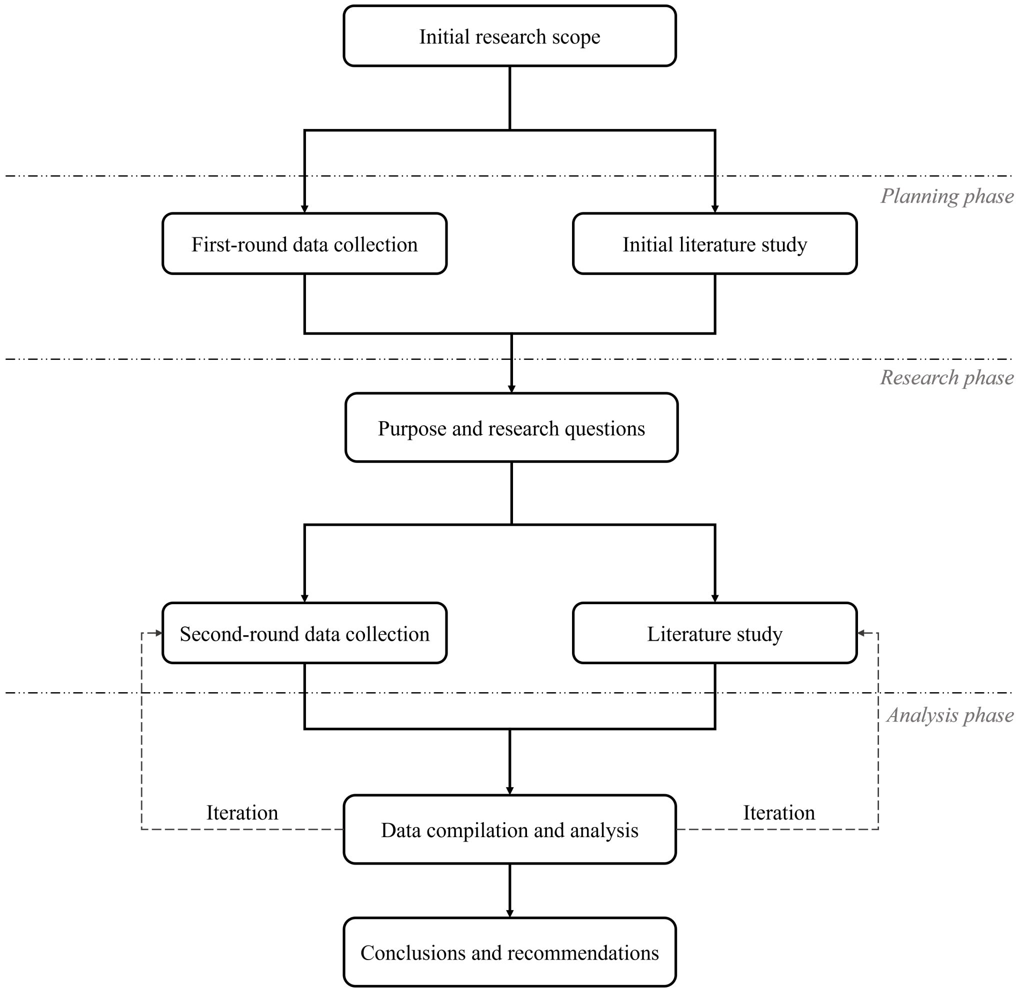

Figure 3.1: The research design of the study.

3.3 Data Collection

This chapter includes descriptions of the data collection methods chosen for the study. In total, 14 individuals participated in one or more interviews and focus groups, which is displayed in Table 3.1. Despite the interviews and focus groups, data was also collected through observations and a survey. These methods are excluded from the table to not transgress the anonymity and because the survey respondents were anonymous to the researchers.

Table 3.1: Summary of the participants in the study

Participant	**Department**	**Interview round 1**	**Interview round 2**	**Focus group 1**	**Focus group 2**
I_1	Quality	✓	✓	✓	
I_2	Quality	✓	✓	✓	
I_3	Quality	✓	✓		✓
I_4	Quality	✓	✓	✓	
I_5	Quality		✓		✓
I_6	Quality			✓	
I_7	Product Management	✓			✓
I_8	Product Management	✓			
I_9	Product Management	✓			
I_{10}	Product Management	✓			✓
I_{11}	Product Management	✓		✓	
I_{12}	Product Management	✓			
I_{13}	Project Management	✓			
I_{14}	Engineering & Development	✓			

All participants are employees at Company X, and the majority belong to either the quality or Product Management department. Four of the Quality department representatives are employed as failure analysis (FA) engineers, and among them, different levels of seniority are present. The remaining two participants have the roles of manager and product reliability engineer, respectively. Participants belonging to the Product Management department have roles that range between manager, product manager, and product engineer. Despite the quality and Product Management departments, one employee from the Engineering and Development department and one from the Project Management department participated in the study.

The sampling strategy used for the interviews was a combination of purposive and convenience sampling. The first mentioned ensured that people with relevant knowledge and insight for the research were chosen. This approach was chosen since, according to Bell et al. (2019), purposive sampling is suitable for qualitative studies and has a strong focus on the research objective. In the initial stage of the study, a relatively small sample of individuals belonging to different groups within the Quality- as well as individuals within the Product Management department that, according to company representatives, were deemed relevant to the study was interviewed. This enabled the researchers to quickly gain an understanding of the targeted process and current state. Thereafter, a snowball approach, which is one kind of convenience sampling, was undertaken as the research direction evolved. The sampling was thus sequential, where the researchers conducted added samples as the study progressed to ensure a sufficient sample size to answer the research questions. Moreover, the sampling process brings challenges regarding how to deal with bias. It is tough to remove bias completely, primarily when the sample selection is influenced by personal judgements (Bell et al., 2019), which was the case in this study where company representatives recommended individuals they believed to have relevant knowledge or ideas to the research. To encounter and minimise bias, several individuals with similar expertise were interviewed.

Furthermore, for both focus groups, a purposive sampling strategy was used to ensure that the limited number of people that participate is suitable with regard to the research questions of the study. Therefore, both individuals belonging to the Quality- and Product Management departments were chosen. In this way, different opinions can be challenged and discussed with employees from the two departments. According to Bell et al. (2019), there is no particular preferable number of participants when arranging focus groups. However, the authors highlight that a typical group size is around six to ten individuals. Bell et al. (2019) further suggest that smaller groups are favourable to use when the topic is complex, and the participants are likely to be very active in the discussion and have a lot to say on the matter. Moreover, it might be easier to stimulate discussions when the group size is relatively small. Therefore, due to the complexity of the subject, the number of participants was decided to be around five. However, to achieve as many perspectives as possible, it was decided to perform the same focus group on two occasions.

3.3.1 Interviews

To gain insight and understanding of the current state and problem, unstructured conversation-inspiring interviews were conducted to avoid presumptions and expectations at the beginning of the study. This strategy is supported by Bell et al. (2019), who further suggests that when a thorough understanding of interviewees' world views and when the research topic is relatively general, unstructured interviews are appropriate to use. Moreover, by starting with open and unstructured interviews, the direction and emphasis of the study can be adjusted as unknown topics or issues arise in the course of interviews (Bell et al., 2019). This strategy enabled the researchers to obtain a preunderstanding of the organisational context as well as the percieved problem. When the scope and focus of the research were narrowed to a specific purpose, and research questions were decided, semi-structured interviews were carried out. This approach was deemed suitable because it allows for both flexibility and comparability (Bell et al., 2019). Semi-structured interviews usually follow an interview guide; however, the interviewer does not need to strictly follow the guidelines, meaning that they can change the order and wording of questions as well as ask follow-up questions for further insight into the interviewee's answers. Further elaboration and going off track are encouraged in qualitative research since it reveals deeper information, and the interviewees can elaborate on topics they believe is essential.

The interviews were performed in two rounds. The first round focused on mapping the problem, whereas the second aimed to complement the findings from the focus groups described later in Chapter 3.3.2. The interview guides can be found in Appendix A. The duration of all interviews ranged between 30 minutes and one hour and the interviews were recorded, if deemed necessary and as long as the interviewee was comfortable and provided consent. This allowed the researchers to listen to the answers again to ensure that the study used the correct information. Moreover, it eases the interviewing since it enables the interviewers to entirely concentrate on what is said and come up with follow-up questions that enrich the interview rather than taking notes which might distract both the interviewer and the interviewee (Bell et al., 2019).

3.3.2 Focus Groups

The primary source of data used were obtained through the use of focus groups; this data constituted the foundational bricks for the analysis of the study as well as the development of a prioritisation model. These were were held on two occasions and designed and performed according to the Affinity and Interrelationship Method (AIM). The purpose of the focus groups was to identify different opinions and suggestions on what attributes should be considered before escalating a quality issue from the failure analysis process, their relative importance, how they could be measured, and what information is needed to perform the evaluation. Moreover, according to Allen (2017), the main objective of using focus groups is to elicit a wide variety of perspectives on a particular topic from a homogeneous group consistent with the purpose of the focus groups. Another reason for using focus groups is that the method enables descriptive and elaborate data that goes beyond simple explanations (Allen, 2017). Bell et al. (2019) build on the arguments provided by Allen (2017) and state that the dynamics of group discussions foster new ways of thinking about business problems as well as the environment facilitate creative ideas to solve the targeted problem. This is mainly because focus groups open up for debate and allow the participants to challenge each other's views (Bell et al., 2019). Moreover, the involvement of employees, that potentially will be affected by the outcome of the study, in the development of the solution may enhance motivation to use new procedures or tools and minimise resistance to change. Thus, the focus groups also aimed to strengthen the feeling of ownership over the model and increase buy-ins to the final recommendation and solution.

3.3.3 Participant Observation

Participant observation is a research method that enables the researcher to be involved and gain insight that is troublesome in other methods such as interviews or surveys (Kawulich, 2005). The researchers have the opportunity to observe events that are not brought up during interviews, either because the participant is unwilling or unable to share the information verbally. Nonetheless, events expressed during interviews can also be observed to enhance understanding of processes and minimise misinterpretations which, in turn, improves the quality of the data collection (Kawulich, 2005). Participant observations also enhance validity since the context of the research area can more easily be understood. Kawulich (2005) further stresses that nonverbal expression of feelings, interactions, way of communicating, and time spent on various activities can be recognised during observations. The method also allows the researchers to have an open mind about the phenomenon under study that is not influenced by a participant's view (Bell et al., 2019). In other words, participant observations aid in achieving a holistic understanding of the research topic (Kawulich, 2005).

Moreover, it is relevant to acknowledge that participant observations can have different meanings, where the degree of participation and role that the researcher adopts vary (Bell et al., 2019). In this study, the researchers had a similar role to the *observer-as-participant* role in Gold's (1958, as cited in Bell et al., 2019) classification of participant-observer roles. More specifically, during the first occasion the researchers mainly observed the participants performing their work tasks but interrupted with questions for further explanations. During the second occasion, the meeting, where interactions between individuals were of interest, the researchers merely observed not to influence the participants' behaviours.

Two occasions of participant observation were performed. One included observing the daily work of two FA engineers to gain more insight into the field return process of NCs. The other session was a failure analysis meeting between several departments and groups within the case company. The participants in the observations were sampled by using a convenient approach, which was selected for two different reasons. First, not all individuals work with relevant tasks to the research on a daily basis, making it challenging to arrange an observation session. For example, individuals in the Product Management department who are responsible for product improvements and updates do not spend much time daily or weekly on specific improvements raised by the FA engineers or the Quality department. Second, it was deemed most fruitful to observe the work process of failure analysis since the research is somewhat focused around that particular process. In addition, the internal quarterly failure analysis meeting which aims to share currently existing findings and trends from filed returns with the organisation was deemed relevant and chosen for observation.

3.3.4 Survey

An online questionnaire was used to collect data on opinions of the quarterly failure analysis meeting. The purpose was to gain insight into what employees think about the meeting, such as its content, usefulness, structure, participant coverage, etc. Surveys are beneficial to use as a research method when it is of interest to obtain information about a large sample of individuals relatively quickly (Ponto, 2015), and since 34 employees attended the meeting, it was deemed as a suitable method to use. The questionnaire was designed to allow the respondents to answer each area of interest in two ways, one mandatory with answer options and one optional where the respondent could elaborate more in a text box. This design was chosen to increase the number of responses as the questions with answer options are the only mandatory and quick to go through. However, it might have impacted the result for the optional questions as they are both time consuming and easy to skip. Notwithstanding, the risk of non-response was deemed significantly higher if all questions were to be mandatory. Moreover, to avoid non-responses to the greatest extent possible, a limited number of questions were selected to reduce the time spent answering the survey. The questions included in the survey can be found in Appendix B.

In total, there were eight answers to the survey, four from the Engineering and Development department, three from the Quality department, and one from the Product Management- respectively Operations department. The low number of responses may result in non-response bias. Many departments are underrepresented which implies that it will be difficult to estimate the characteristics and opinions of the whole population.

3.4 Data Analysis

The data analysis was divided into two parts. The first part synthesised and interpreted the data gathered from both the empirical data and the theory on how the data from field returns can trigger the most essential quality improvements. Moreover, data reduction was conducted to facilitate and improve the interpretations of the gathered data. Further, a thematic analysis was performed of the data collected majorly from the interviews, observations, focus groups and literature and was essential to accomplish trustworthy interpretations (Bell et al., 2019). Additionally, the first part of the data analysis included interpretations of the secondary data, more thoroughly described in Chapter 3.4.1. The purpose of the first part of the data analysis was to explore found theories in the literature, seek patterns within the empirical data, and map interpretations of both the theoretical and practical findings.

The second part of the data analysis was the creation of the prioritisation model. The model was created based upon the patterns and interpretations found in the first part of the analysis and provided a suggestion on how the gap in the literature and identified practical issues could be formalised into a solution.

3.4.1 Secondary Data

Secondary data, already gathered or created by the case company in the course of their business, were analysed to understand the current state. Primarily, processes used within the area of field returns were investigated, but also quality policies and other internal documentation that appealed relevant to the study were explored. This has helped the development of the future state, as well as ensured that the solution and final recommendation are linked to the overall quality objectives of the company. Moreover, secondary analysis enables longitudinal analysis of trends over time (Bell et al., 2019) which was useful when the current state was evaluated since data stretching back several years was used.

3.5 Research Quality

In this sub-chapter, the research quality of the thesis is evaluated. Since the study was qualitative, trustworthiness is recommended by Bell et al. (2019) as the only evaluation criterion. However, trustworthiness can be divided into four sub-criteria, namely, *credibility, dependability, confirmability*, and *transferability.* First of all, the study's credibility, described as the alignment of the researcher's and interviewees' views of the subject (Bell et al., 2019), was ensured by collecting data through interviews from several individuals in the Quality- as well as Product Management department. Secondly, the dependability, the verification that the chosen methodology and processes were conducted appropriately (Bell et al., 2019), was assured by storing the recordings from interviews and continuously documenting the findings. In the same way, the confirmability of the study, i.e. the objective assessment of the thesis (Bell et al., 2019), was also ensured by storing recordings of interviews where consent was provided. The recordings could confirm that the interviewees' statements were understood correctly and were not influenced by any of the researchers. Lastly, transferability is described by Bell et al. (2019) as the possibility to replicate the study and this is a typical deficiency among single case studies. However, in this study, it was assured by good and clear descriptions of the study, its context and its limitations such that other organisations can take this into consideration when trying to adopt the findings in another company or context.

The thesis included an online survey, as described in section 3.3.4, that were sent out to 34 employees at the case company. However, only eight responses were received, which might imply non-response bias and thus limit the study's credibility (Berg, 2005). Nevertheless, some of the findings from the survey were used in the empirical results. Still, in those cases, they were used as complementary findings to the derived results from the observation and interviews and therefore deemed acceptable to use without limiting the study's credibility.

3.6 Ethical Considerations

Bell et al. (2019) propose four ethical principles that should be considered in business research: *harm to participants, lack of informed consent, invasion of privacy*, and *deception.* These were acknowledged and treated as an integral part of the entire research process to ensure that ethics were not negotiated. The first principle, harm to participants, includes physical harm, emotional harm, and professional harm that may negatively impact the individual´s career prospects or self-esteem (Bell et al., 2019). The participants are anonymised in the report to avoid transgression of harm since there is no additional value in presenting personal details. It is particularly important that the interviewees are not identified nor identifiable due to the study's small sample size. Therefore, in circumstances where a title leaves only a few possible alternatives, these were disguised. Instead, without compromising the quality nor the ethics of the study, the individuals were only connected to their department.

The second principle, to ensure informed consent, was acknowledged by informing the participants about the study and how their answers will be used for them to make an informed decision on whether they would like to participate or not. Moreover, in cases recordings were used, the researchers informed this, and the interviewee had the opportunity to refuse the interview to be recorded. To ensure that informed consent not only was a one-off consideration, the interviewees were also granted the guarantee that they at any time, even after the interview, can withdraw their statements. The third principle regarding the invasion of privacy is somewhat linked to informed consent since it ensures understanding of what involvement in the study might entail (Bell et al., 2019). Moreover, it is essential to acknowledge that privacy is individual and that sensitive topics may vary from person to person, and a humble approach is thus preferable. Despite this, as aforementioned, the participants were kept anonymous. The fourth principle, preventing deception, is also connected to informed consent and was ensured by honesty about the objective and goal of the study.

4
Current State of Affairs

To understand the current state of the case company, relevant internal processes for the research need to be outlined and described in more detail. The data is gathered from internal documentation together with interviews and observations. Firstly, the process of field returns is explained, followed by the different possible paths and improvement processes that cases of nonconformity may initiate.

4.1 The Process of Field Returns

Field returns are an integral part of most organisations that involve product purchases (Blischke, 1995). From a customer's point of view, the process of field returns assures that a faulty product can be repaired or replaced by the providing company without additional cost during a specified timeframe from the purchase. Similarly, from the providing company's perspective, the warranty period acts as a protection so that the customer cannot expect total replacement too long after the purchase. Further, the process of field returns can also add value to the company. The returns can be rich in feedback on problems in the product's performance and, if utilised efficiently, help organisations to improve in favour of value creation (Klapalova, 2019). However, for the organisation to use the information provided by the field return, a thorough failure analysis is required to determine the root cause of the failure (Gazzola et al., 2017).

The process of field returns at Company X is like most return processes initiated by a customer complaint about a malfunctioning product. These customer complaints are often first handled by the sales personnel, who, through a Return Material Authorisation (RMA) process, approve the return of a product. Simultaneously additional information needed for the failure analysis is added to a global Customer Relationship Management (CRM) system. Once information about the customer complaint is forwarded to the FA engineers, the product is physically transported to a designated product analysis laboratory which, in this case, is the one in Gothenburg. Once the product is received and registered in the failure analysis (FA) database, the product and its belonging safety documents are examined to ensure that it has been cleaned from potentially dangerous substances. The FA engineers follow test routines in a pre-set sequential order, only skipping or neglecting tests when the failure is recognised from previously received products. If no NC is found, the case is resolved in the FA database, the customer request is closed. In cases where a NC is found, it is logged in the FA database, and further data analysis is conducted to identify critical measures. When it is deemed necessary to address the NC either the

Engineering Change Request- (ECR) or Corrective and Preventive Action (CAPA) process is initiated, depending on whether the issue is product- or process related. However, there is currently no formal process used to assess the severity or priority of the NC cases. The entire process of how Company X currently handles the field returns is visualised as a flowchart in Figure 4.1.

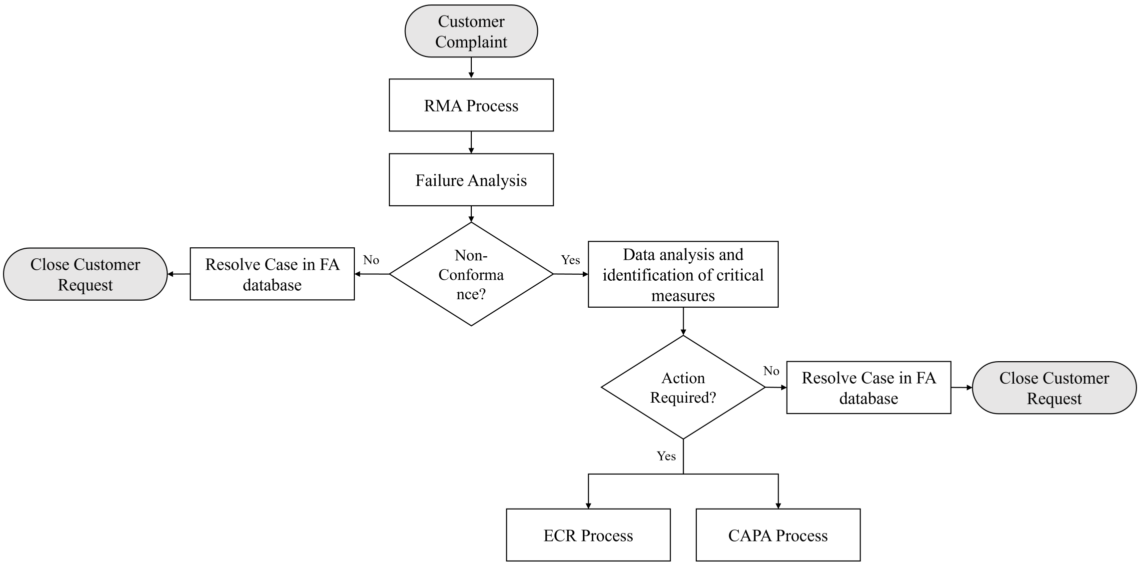

Figure 4.1: The internal process of field returns

Recently, Company X has set up quarterly failure analysis meetings, a technical forum where failures found in the field and production are described and discussed with concerned stakeholders. The meeting aims to share current findings and trends in the product analysis laboratory with the company, facilitate fact-based decision making, and highlight potential risks and concerns. In addition, the Quality department strives to contribute to continuous improvements of the company by highlighting known failures in existing and new designs to ensure it meets customers' current and future expectations. The meetings are hosted by the Quality department and include representation from Product Management, Engineering, Operations, Technical Service and Support, and Supplier Quality. However, the representative depends on the agenda for the meeting, such as which products or subjects will be discussed.

The meeting includes a presentation of how Company X is performing in connection to their Key Performance Indicators (KPIs) and a segment where the FA Engineers escalate the most severe quality issue, which has appeared from the field or within the production during the last quarter. The KPIs are displayed in Table 4.1 and divided into four categories: warranty cost, concession cost, customer claims, and field return rate. The field return rate is in turn divided into two KPIs: all products, and new products, where the target for new products is tougher in order to develop more reliable products year by year.

Table 4.1: Key Performance Indicators (KPIs) of Company X

Key Performance Indicator	Measurement variables
Warranty Cost	Percentage of Net Sales
Concession Cost	Percentage of Net Sales
Customer Claims	ppm of Total Number of Order Lines
Field Return Rate - All Products	ppm of Total Number of Shipped Units
Field Return Rate - New Products	ppm of Total Number of Shipped Units

Furthermore, the FA engineers currently experience that their improvement suggestions become neglected due to a higher focus on the costs and resources required to conduct the product changes in the Product Management department rather than focusing on the severity of the NCs and their customer impact. On the other hand, the Product Management team experience that the improvement suggestions were too poorly motivated to justify changes. As there is no formal description of how the handover of improvement suggestions should be performed between the FA engineers and the Product Management, nor an explanation on when NCs should be escalated, company representatives see it as critical to review this step in the current process. This concern, related to the evaluation and handover, is thus the basis for conducting this thesis. Nevertheless, the case company requests standardised routines that can be applied to assess the severity and priority of NCs. Thus, the different processes for NC cases are described in the next sub-chapters.

4.1.1 Engineering Change Request Process

To describe the process of engineering changes, the concept of Engineering Change Management (ECM) has to be outlined. ECM has grown in prominence and gained more attention in both practice and academia with the increasing market competition, demanding higher product quality and performance at a lower price than before. In addition, product life cycles are becoming shorter, putting pressure on companies to develop products in a shorter period of time. Engineering changes (EC) can be described and defined in a vast variety of ways and on different levels of abstraction (Jarratt et al., 2011). However, at the simplest level, ECs refer to changes made to existing products or components. In this thesis, the definitions by Huang et al. (2003) and Jarratt et al. (2005), as stated below, will be used but modified.

"Engineering changes (ECs) are the changes and/or modifications in dimensions, fits, forms, functions, materials, etc. of products or constituent components after the product design is released." (Huang et al., 2003, p. 481)

"An engineering change is an alteration made to parts, drawings or software that have already been released during the product design process. The change can be of any size or type; the change can involve any number of people and take any length of time." (Jarratt et al., 2005, p. 268)

These definitions concern changes made after the design process has finished. However, due to the scope and focus of this thesis, the timing of changes will be slightly different. This thesis will concentrate on the changes initiated after product development and customer delivery, specifically those occurring from field failures. Moreover, Jarratt et al. (2011) distinguish between EC and ECM and explain their relationship as *"Engineering Change refers to making alterations to a product and Engineering Change Management to the organising and controlling of this process."* (p.105).

In literature, there are attempts to describe a generic Engineering Change process (Jarratt et al, 2005, 2011); however, as depicted in the article by Pikosz and Malmqvist (1998), the process is highly influenced by organisational-, market-, and product issues related to the company which make it challenging to create a one-fits-all process. For example, a company that manufactures safety-critical products may prioritise quality over speed and low costs, while the other way around can be true in another company. Nevertheless, it is acknowledged that, at a higher level, the processes appear similar (Pikosz & Malmqvist, 1998). The generic EC process proposed by Jarratt et al. (2005) is shown in Figure 4.2.

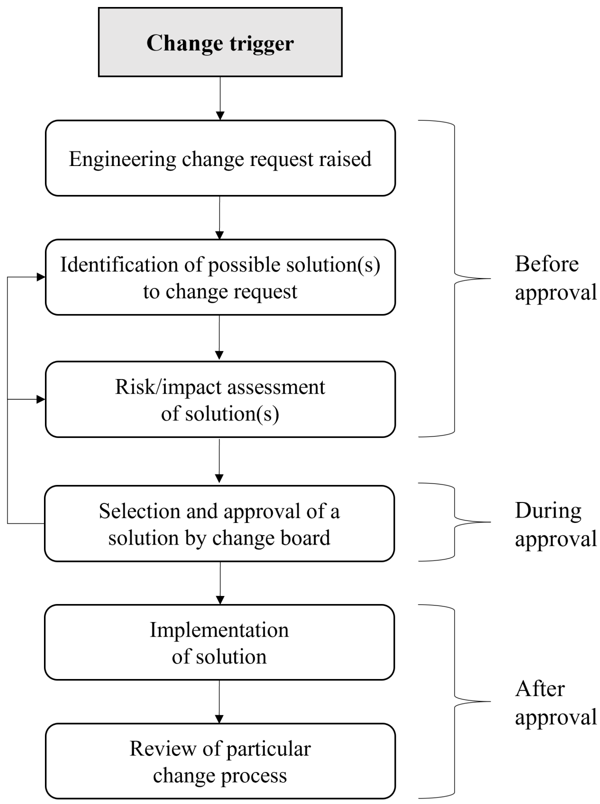

Figure 4.2: A model of a generic engineering change process (adapted from Jarratt et al., 2005)

Before the first step, a trigger or cause of a certain change must start the process, which, at a fundamental level, can be of two kinds of reasons. The first is to remove errors from the product, which can be referred to as emergent, while the second is to improve the product to meet new customer requirements and is referred to as initiated change (Eckert et al., 2004). After a trigger has started the process, the first step in the generic model by Jarratt et al. (2005) concerns the creation of an Engineering Change Request (ECR) where the reason, priority, type and other relevant information about the change need to be included. Usually, an ECR can be raised by any employee in an organisation. During the second step, possible solutions to the change request are identified. Then, the impact of risks associated with implementing the different solutions needs to be assessed where factors such as the impact on design and production schedules, supplier relationships, or budget could be considered. However, exact steps on how to assess risks are absent. In the fourth step, the Engineering Change Board consisting of individuals from key functions connected to the product, review the proposed change and solution and decides whether it can be approved or not. Before approval is given, a cost-benefit analysis of the change should be performed to estimate the potential impact on the company as a whole. After the approval, the implementation phase can begin. However, the timing of implementation may vary due to different conditions, for example, the nature of change or when during the product life-cycle the change occurs. Safety or compliance issues are examples of issues with high priority decision making. In the sixth and last step, a review of the change should be made by the company. This step is essential for the learning part, where it is possible to prevent problems from happening again in future change processes. Nevertheless, according to Jarratt et al. (2011), far from all companies perform such a review process.

The engineering change request (ECR) process of Company X, illustrated in Figure 4.3, is initiated in cases where the design of a product or documentation needs to be improved. However, due to the goal and nature of this study, only emergent changes, as described by Eckert et al. (2004), will be considered since the focus is devoted to NCs from field failures. After a need is discovered, an ECR is created, followed by a technical assessment to ascertain the feasibility of the change required. Any employee in the company can raise an ECRs, however, the focus in this thesis is on those created as a response to field failures. Moreover, according to internal documentation, the ECR should include the scope of the change, the underlying motivation, how to realise it, and the deadline for implementation.

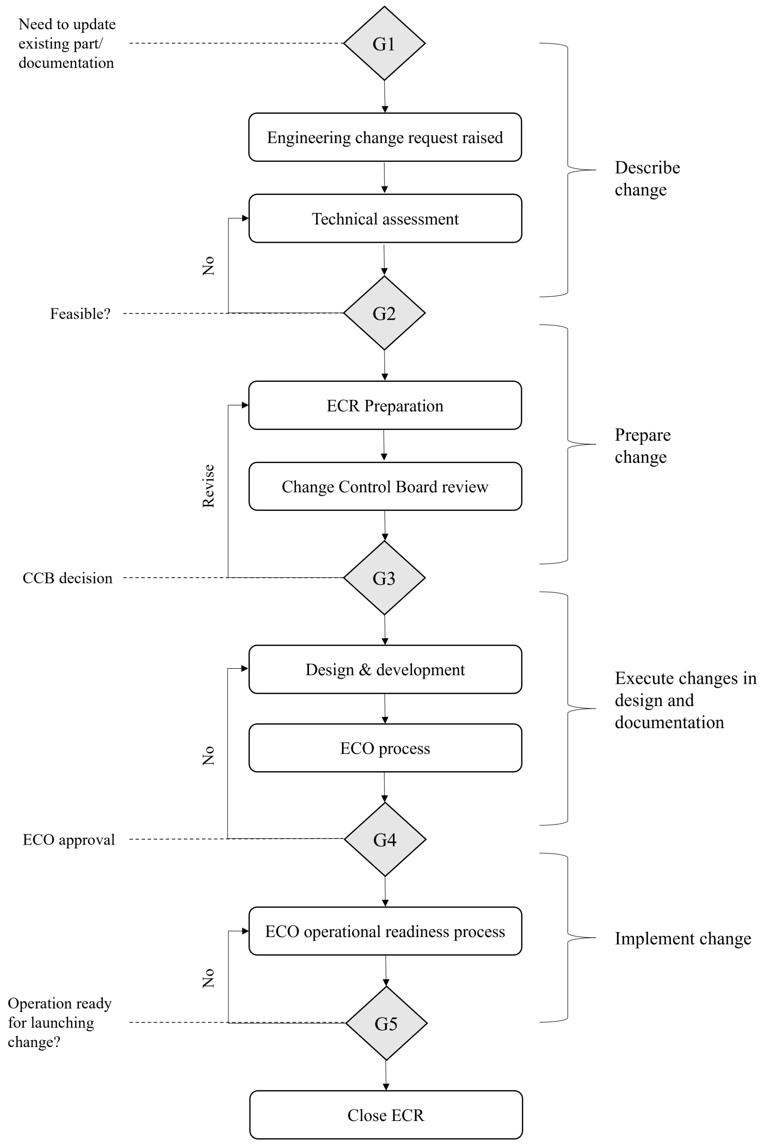

Figure 4.3: The ECR process of the case company (internal documentation)

The second step, the technical assessment, aims at evaluating whether the proposed change is technically feasible and relevant for the engineering change process. This evaluation is based on a thorough checklist. Once the feasibility has been determined, five outcomes are possible in the second gate. The ECR can be accepted, rejected, set on hold to await suitable implementation, moved to new product development (NPD) if the change is deemed too complex, or revised if the necessary information is missing. Product Management assesses ECRs and prioritises them to ensure that no more ECRs are pursued and allowed to pass each gate than can be managed by the team. Once an ECR is accepted, the preparation phase can start, followed by a decision made by the Change Control Board (CCB), where the same alternatives are available as in gate 2 and can be found in Table 4.2. The purpose of the CCB review is to ensure that only feasible and value-adding changes are implemented and prioritise ECRs according to the severity or added value. The priority is set on a 1-3 scale; however, what this decision is based on is not documented. Nevertheless, one of the product managers [I_7] explained that this priority is subjectively determined by the product manager responsible for the concerned product. For an ECR to be accepted at this stage, it needs to generate a positive business case, meaning that the benefits associated with the change need to outweigh the cost and effort. Nevertheless, if the CCB requires more information before a decision can be made, the ECR can be revised, and the preparation phase must be performed again.

Table 4.2: Possible decision alternatives in gate 2 and 3

Decision	**Explanation**
Approve the ECR	Based on the ECR proposal, the severity or value adding capabilities justifies further work on the ECR
Reject the ECR	Based on the ECR proposal, the severity or value adding capabilities did not justify further work on the ECR
Place ECR on hold	The ECR proposal is feasible, but the effort for running it alone cannot be justified. The ECR is therefore put on hold until it can be implemented together with another ECR related to the same part/document. ECR can also be put on hold if the available resources cannot handle the change at this point.
Initiate a NPD project	A NPD project should be initiated if any of the following conditions are not met: • The change must affect an **existing** process or part specified on **existing documentation**. • The change must be **non-complex**, i.e. not involving extensive work in multiple disciplines (e.g. hardware and software). • The **risks** (economic, safety, quality, timing etc.) associated with implementing the change **should be low**.
Revise ECR	The ECR proposal was not complete or insufficiently made.

Once the ECR is accepted, the change in design and documentation can be executed. Once the design and plan are approved, the implementation can start and ultimately, the product update can be launched. The process stops by closing the ECR. Notwithstanding, it is important to note that at each decision-point, displayed by gates, it can be decided to go back and perform the previous steps again until approval can be made.

Challenges

Jarratt et al. (2011) stress that personnel and organisational challenges associated with engineering changes need to be acknowledged. One common cause of poorly operating change processes is often drawn to communication between teams. In a study of 100 companies in the UK, it was found that over 80 per cent of the respondents identified poor communication as a barrier to effective ECM (Huang & Mak, 1999). Another organisational and cultural related challenge is the lack of decision discipline, which results from eighter making decisions without a sufficient basis of information or postponing necessary decisions (Fricke et al., 2000). The reason behind postponing decisions may vary; however, Fricke et al. (2000) highlight three common causes in their study (p. 172):

- *"Initiating changes is seen as an unpleasant task."*
- *"Waiting for someone else's change in order to use it as a reason for one's own change, which means shifting responsibility."*
- *"Be a hero by saving the project in the last minute. Therefore, you do not initiate changes, but wait till there is big trouble and you have the solution already at hand."*

Another prominent challenge regards the attitudes towards engineering change (Jarratt et al., 2011). Engineering changes often receive a negative connotation in companies as they are viewed as error correction rather than product improvement. In other words, the cause of the change impacts the perception and attitude towards the change, where changes arising from mistakes usually are unpleasant, and changes occurring from innovation are seen as something positive. Consequently, the latter case is often more likely to gain acceptance and thus be implemented (Eckert et al., 2004). Pikosz and Malmqvist (1998) support this and emphasise that ECs trigger irritation as it means that something that has already been designed needs to be redesigned, which may signal that the initial work was not good enough. Subsequently, the ECs often have a lower status than completely new and creative design ideas.

4.1.2 Corrective and Preventive Action Process

To ensure continued customer satisfaction, organisations need to correct found NCs and implement tools that prevent potential problems (Tashi et al., 2016). Therefore, it is required for organisations to establish a process which can identify both current and future NCs suggest appropriate actions to be taken, i.e., implement a corrective and preventive action (CAPA) system. Over the recent years, CAPA systems have become a critical component for successful continuous improvements (Tashi et al., 2016). Effective implementation of a CAPA system has provided organisations within different contexts with a reliable source of quality data (Majanoja et al., 2017). Further, organisations can also recognise trends and patterns by monitoring the incoming data about quality issues entered into a CAPA process, which can be addressed through corrective or preventive actions (Majanoja et al., 2017).

Most organisations make their adoptions and create a CAPA process that facilitates their specific needs, defining the process's purpose and classifying NCs differently (Tashi et al., 2016). Company X has an established CAPA system; see Figure 4.4 . Their process is an effective tool for handling products and process NCs. Further, NCs are, according to the case company, defined as any deviation from what is assessed as normal and includes malfunctioning products, findings from audits, improper handling of chemicals, sales orders that are missing vital information, and incorrect stock quantity. However, this thesis focuses on malfunctioning products already delivered to customers. A NCs found in Company X enters the CAPA process through a corrective action request. In the request, the CAPA initiator is expected to include sufficient information about the NC and whether a product hold is necessary.

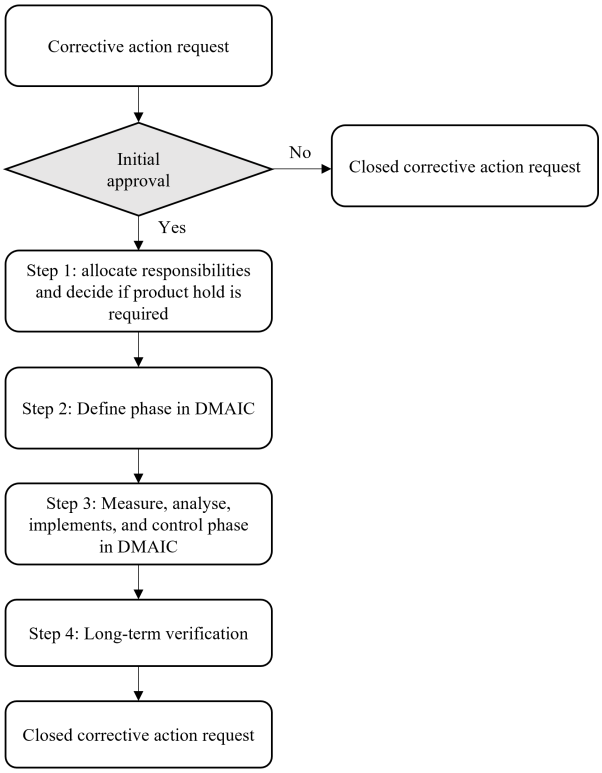

Figure 4.4: The corrective and preventive action process of the case company (internal documentation)

A CAPA process can trigger two types of actions: *corrective and preventive* (Tashi et al., 2016). In literature, corrective actions are defined as actions taken to remove the root cause of a current NC. In contrast, preventive actions are defined as actions taken to eliminate the cause of potential NCs (Motschman & Moore, 1999). These definitions are similar to the ones adopted by Company X:

- Corrective actions are taken when - "The NC has occurred and been observed"
- Preventive actions are taken when - "The NC has not been observed, but a resolution is needed to prevent it from occurring".

When the CAPA process at Company X is initiated through a corrective action request, a decision point is reached. This decision point refers to whether to move forward with the corrective action request or not. If the request is disapproved, the NC is logged without any actions taken. However, if the request is deemed severe, it will continue the CAPA process, divided into four steps. The first step determines who will be responsible for coordinating the CAPA and leading the DMAIC problem-solving process. This first step further includes deciding whether or not a product hold is required. A product hold can be issued if the severity of the NC requires that all products within the supply chain must be located, isolated and if the production process must be stopped. After the first step of the CAPA process, the DMAIC is started, and the NC firstly enters the define phase, in which the type of CAPA is defined. At company X, there can be three types of CAPAs:

1. *Process- or department CAPAs*, which are used for NCs in processes
2. *Product CAPAs*, which are used for NCs related to products
3. *Safety CAPAs*, which are used for investigating occupational health or safety issues of the NC.

The third step in Company X's CAPA process includes the rest of the DMAIC, i.e., the measure-, analyse, implement-, and control phase. At the end of this step, the following should be assured:

- That proper investigation of possible root causes has been carried out
- That the actual root cause of the NC is identified
- That the implemented action plan will eliminate all future NCs
- That the control methods implemented are sufficient to control the NC and will be alarming if it occurs again.

The fourth and last step of Company X's CAPA process is long term verification. In this step, the CAPA owner and CAPA initiator confirm whether the expected long-term improvements are obtained through the implemented action plan. If this cannot be verified, the CAPA returns to the second step, i.e., the measure, analyse, implement, and control step. However, if the implementation of the action plan is deemed adequate, the long-term improvements are documented, and the corrective action request can be closed.

5
Empirical Findings

In this chapter the empirical findings are presented. First, the key attributes for prioritising NCs are summarised and thematised into two dimensions. Subsequently, empirical data concerning the data and information sharing between different organisational teams are presented where focus has been devoted to the collaboration between the Quality- and the Product Management team. Lastly, attitudes towards correcting NCs and the employees' opinions on the impact of the corporate culture are displayed.

5.1 Key Attrributes for Prioritisation

From the empirical data, two dimensions of important attributes when prioritising improvement efforts from NCs could be identified, namely: *The Company-specific dimension*, and *The Risk dimension.* The first includes attributes that are deemed critical for Company X and the latter is inspired by the FMEA approach and include associated risk attributes. These dimensions and respective identified attributes are described in more depth in the following two sub-chapters.

5.1.1 The Company-Specific Dimension

The first and most frequently mentioned attribute that should be considered when prioritising quality improvements, according to the research participants, is the customer impact. The customer perspective was brought up in almost all interviews and both focus groups, and there was no significant difference in opinions between different functions or roles regarding this aspect. Thus, it can be argued that there is a common agreement between the Quality and Product Management departments that the impact on the customers should be considered in the prioritisation of NCs. During the focus groups, the participants were asked to rank the attributes proposed by themselves. The result of the ranking exercise displayed that customer focus and -impact respectively received the highest score by all participants and they were determined as the most important aspects in the two focus groups. As one of the participants expressed *"without our customers we will not have a business so we need to consider the impact on them as well"* [I_{11}]. It was also mentioned [e.g., I_1, I_4, & I_7] that the company can be better at considering the customer's point of view when deciding upon quality improvements.

Moreover, the possibility of measuring the customer impact has been discussed in the interviews and focus groups. Customer impact, in this context, concerns the degree of impact or disruption on the customer's operations and business which can be of safety, functional, and financial nature. The participants in the focus groups mentioned that some type of evaluation based on a predefined scale with set values could be suitable for measuring the customer impact. One participant from the Product Management department [I_{10}] explained that different types of issues can have almost no to very severe effects where the customer needs to shut down their operation as a result of the problem leading to massive economic losses. Another Product Management representative [I_7] and three from the Quality department [I_1, I_4, & I_5] highlighted the importance of corporate image, trust, and customer loyalty and explained that these measures could be affected negatively by neglecting the customer impact. However, two of the FA engineers [I_1 & I_2] expressed a concern that they do not always have access to this type of information to perform an evaluation. As one of the engineers said *"We only receive the faulty product, we do not know how it was integrated to the customer's system or what impact the failure had on the customer. It is the customer care team who has the direct contact with the customers and possibly know how severe the consequences are"* [I_1].

Business impact was the second identified aspect. Many employees that participated in the study, especially those working in the Product Management team [e.g., I_7, I_9, I_{10}, & I_{12}], emphasised the importance of establishing a business case for the NCs to evaluate their respective impact on the business. By acknowledging the business impact, a more holistic judgement is possible according to the participants [e.g., I_8 & I_{10}]. On this subject, cost was the most frequently discussed attribute. Cost of investment on the improvement project connected to a particular NC together with cost of poor quality and cost of lost opportunity were the discussed cost elements that should be evaluated to gain a holistic perspective. However, the feasibility of performing this type of cost analysis this early on in a potential improvement initiative has been questioned. Two of the FA engineers [I_1 & I_2] explained that they are lacking the information and knowledge required for performing this type of analysis and it would be time consuming as they would need to access information from various individuals. Despite cost, it was brought up in some interviews and in the second focus group [I_2, I_7, & I_{10}] that the type of customer could be considered as well. According to the participants, Company X has strategic and important customers who are critical to the business. It was explained by a product management participant [I_{10}] that a strategic customer could be one connected to a new or specific industry where Company X would like to expand its business and that a key customer often is a customer that brings in a significant share of the revenue. For this factor, it was suggested to use a list of, for example, Company X's twenty most important customers.

Furthermore, another attribute identified during two interviews [I_4 & I_7] and both focus groups was the risk of propagation. This attribute includes the probability that a particular NC will affect several components, products, or product families. During the focus groups, it was discussed that a NC affecting several components or products might have a more complex solution, as the solution must apply to and solve the found NC for all the affected parts. However, it was also discussed that a solution addressing several products or components might have a more robust business case.

In addition to the propagation, several employees from the Quality- and the Product Management department [e.g., I_1, I_4, I_7, & I_{10}] mentioned that NCs with a known solution might be less complex to address since it requires fewer resources. This is mainly due to some foundational groundwork in suggesting a feasible solution is already conducted and thus not requiring resources from the Product Development department. The same participants emphasised that suggested improvements for such NCs are more likely to be addressed.

In the interviews with employees from the Quality department [I_1, I_2, & I_4], the time to failure was discussed. The interviewees described that the FA engineers, for each NC, select how long the product has been in use from a drop-down menu in the FA database. They further discussed that NCs arising during the first months of its use, or NCs identified upon delivery, so-called out-of-box failures, are deemed more severe and vital to address. From a customer perspective, such NCs indicate a quality issue in the quality design or manufacturing. Additionally, one of the interviewees [I_4] discussed time to failure as a measure of the product reliability and thus argued for the importance of predicting and considering the time to failure when selecting and prioritising quality improvement initiatives.

The last identified attribute thematised to the company-specific dimension was the product lifecycle. This attribute was discussed by one participant from the Product Management department [I_7] and by two of the interviewees from the Quality department [I_1 & I_2] in their interviews and in both focus groups. Employees from both departments emphasised that new products often have a more considerable amount of NCs, and several of the participants from the Product Management department [I_7, I_{10}, & I_{11}] mentioned that NCs connected to new products are given a higher priority both due to that the KPIs for new products are tougher. Further, the same interviewees discussed that new products are seen as more strategically important to address since they probably have many years left on the market and a higher sales volume.

5.1.2 The Risk Dimension

The risk dimension was the second dimension of attributes identified during the interviews and focus groups. When the interviewees discussed risk, the most commonly mentioned attribute was the severity of the failure and whether or not the failure was affecting the safety. In interviews and focus groups, participants from both Quality- and Product Management department [e.g., I_1, I_2, I_5, I_7, & I_{11}] described that safety is non-negotiable due to company policies, and hence, product safety is one of the essential attributes to consider when prioritising quality improvements. Further, as one of the employees at the Quality department [I_4] elaborated upon the severity of specific NCs, the importance of considering the functional impact on the complete system of products was emphasised. The interviewee mentioned that NCs may have a minor or major functional impact as well as temporary or permanent impact on the complete system of products and thus differ in the degree of severity.

Moreover, all participants in the focus groups discussed the impact of frequency on the risk dimension. In their interviews, two of the FA engineers [I_1 & I_2] mentioned that the frequency of recurrent failures with identical root causes is the attribute they base most of their current prioritisation. In addition, participants from the Product Management department [e.g., I_7, I_{10}, & I_{11}] justified the importance of receiving a sufficient amount of the same NC before making decisions about quality improvements. However, as one of the product managers [I_7] emphasised, the frequency of occurrence should preferably be measured in contrast to the number of sold products and displayed over time in order to identify trends and patterns of an increased amount of NCs.

Lastly, the detectability and its impact on the risk dimension were highlighted by one of the employees at the Quality department [I_4]. In particular, it was emphasised that the possibility of detecting the NC in quality controls should be considered when assessing the risk correlated to the NC such that it can be used as a basis for selection and prioritisation of quality improvements. For example, it was discussed that NCs, which are easily detected in quality controls, are more easily addressed as they only require a few changes in the production process. In contrast, as an NC is impossible to detect through quality control, its quality must be improved through more comprehensive corrective actions.

5.2 Data and Information Sharing between Functions

The forums for data and information sharing between the Product Management and the Quality department have been discussed in interviews and observed through participant observation. From interviews, the following communication channels between the functions were mentioned:

- The ECR database, including both creation of an ECR and updates
- The quarterly Failure Analysis Meetings (FA meetings)
- Informal communication either through emails, chats in the hallway, or short subject-specific meetings organised by either the project managers or FA engineers when deemed necessary

The above mentioned communication channels were appreciated among the interviewees, however, several respondents [I_7, I_9, & I_{10}] discussed improvement suggestions that could enhance the existing communication between the departments. Many of the suggestions concerned the newly implemented quarterly FA meeting and the communication through the ECR database. In the interviews, employees from both the Quality- and Product Management department [e.g., I_1, I_2, I_7, & I_8] discussed the limitations of using the ECR database as a single source of communication regarding created ECRs. As one interviewee from the Product Management department stated *"No matter how well written the ECR is, it becomes flat when only communicated through a database"* [I_7]. The same interviewee proposed that the ECR creator favourably could schedule a meeting with concerned stakeholders when creating the ECR to describe the found failure, its causes, the improvement suggestion, and elaborate on why action is deemed necessary. Further, employees from the Quality department [I_1, I_2, & I_4] discussed the limited information or thin arguments provided when an ECR is rejected. Regarding the FA meetings, most interviewees seemed to appreciate the meetings and emphasised the great potential of the forum to improve communication between the departments. The raised concerns and recommendations mainly involved the content of the meeting and who was invited to participate. For example, one interviewee from the Product Management department [I_{10}] suggested that the information provided regarding the failures should give a more holistic view of the problem and include to what degree the suggested improvements addresses the cause of failure. The same respondent further requested more global collaboration between the different laboratories. Another interviewee from the Product Management department [I_8] emphasised the need to communicate all necessary data regarding the field returns as the product managers themselves do not utilise the database containing the field return data.

The observation of the FA meeting depicted a great engagement from the participants in the topics presented. Further, the meeting participants were asked to provide their opinion about the forum in a survey. The answers from the survey showed that, in general, the content and meeting format was appreciated, that the purpose of the meeting was fulfilled, and that the technical degree of difficulty was on an appropriate level, see Figure 5.1, 5.2, and 5.3.

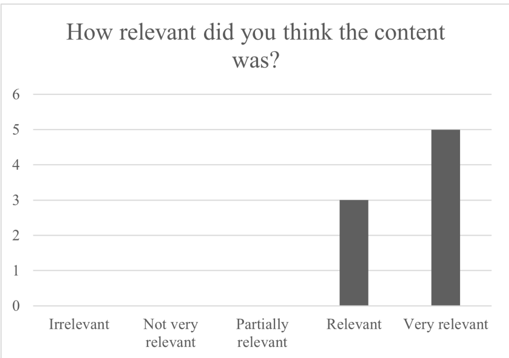

Figure 5.1: Result of the relevance of the content (n=8).

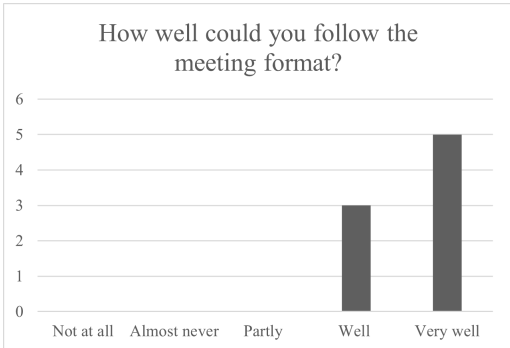

Figure 5.2: Result of the meeting format (n=8).

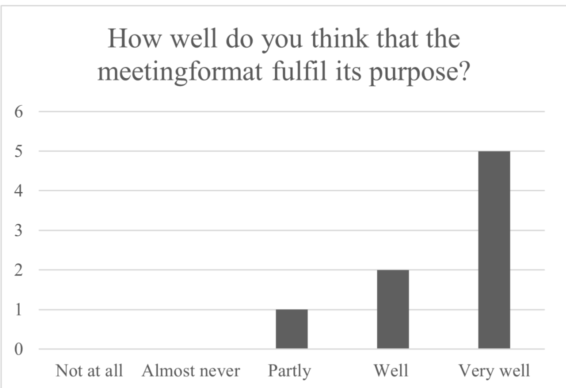

Figure 5.3: Result of the fulfilment of the purpose (n=8).

Further, the survey received positive comments such as "Good content, only applies that it reaches the right people and that it starts quality-improving measures" and *"Interesting to know what team of persons working on a specific problem"*. Besides the great feedback and positive comments, the survey also contributed with some general feedback from different respondents. One respondent from the Product Management department mentioned that the meeting lack a common thread and that the possible consequences of found failures are insufficiently described. Another respondent from the Quality department requested that the meeting starts with a follow-up discussion on the previous session to avoid losing focus on expected actions. A third respondent from the Product Management department criticised some of the visualisations used during the meeting, as they were too difficult to read due to clutter and not deemed relevant for the technical level of the meeting.

5.3 Attitudes and Corporate Culture

During the interviews, the company culture was discussed. One interviewee explained that at the highest level, the company is divided into three business areas which almost can be compared to organisational silos [I_4]. Each business area has their own way of doing things, and it was expressed by one of the Quality department participants [I_1] that suggestions for product improvements may be evaluated differently depending on the involved business area. Moving down one level, the company is divided into several departments and groups. The departments under investigation, the Quality- and Product Management departments, have both expressed that there is a difference of opinion about the interpretation of the escalation of NCs from the field. The FA engineers expressed that they experience that many of their suggestions (ECRs) are being neglected while some of the product management representatives had a different point of view. One participant from product management explained that the different departments have different kinds of knowledge. They said that *"the Quality department, particularly the failure analysis engineers, has much knowledge about the technical part and also, naturally, puts a lot of focus on the technical aspects when it comes to improvement suggestions. The Product Management department, on the other hand, has more knowledge connected to the business and financials and needs to look at every case from a holistic perspective as there are many variables to consider"* [I_{11}]. The same interviewee confirmed that they were aware of the concern expressed by the FA engineers and explained that the product managers sometimes accept ECRs to avoid destroying the motivation for creating ECRs even though they might not be justified based on their evaluation.

6

Analysis

In this chapter, the empirical data and literature are combined and analysed which serves as a foundation for identifying key attributes for prioritisation of NCs and developing a model for improvement project prioritisation.

6.1 Key Attrributes for Prioritisation

There are similarities between both the literature and the empirical findings regarding the attributes or criteria to take into account before initiating improvement projects. The financial impact was a highly mentioned criterion in the literature (e.g., Antony, 2004; Banuelas et al., 2006; Salah, 2015). Likewise, the empirical result revealed the importance of considering the cost as a business impact. The alternative cost of neglecting the issue, the cost of lost opportunity and cost of poor quality were mentioned. However, the impact on the revenue stream was not explicitly discussed. It is evident that this aspect is important as well since the goal of any enterprise is to maximise the profit which is dependent on both the cost- and the revenue stream. The literature has a more nuanced contribution to the criterion of the financial impact where, for example, Jiang and Klein (1999) suggest considering the benefit/cost ratio, rate of return, contribution of profitability, growth rate, and payback period to capture the whole picture. However, as stated in the empirical findings, it would be challenging for the FA engineers to perform such comprehensive cost analysis at this stage of the process as they do not possess the required knowledge.

Another similarity that could be found in both the literature and the empirical data was the customer focus. The literature (e.g., Antony, 2004; Donauer et al., 2015; Zhou et al., 2016) emphasises customer satisfaction and the ability to meet customer needs whereas the interviewees from the case company discussed customer impact, more specifically, to what degree the issue is damaging the customer's operation and its economic consequences. In addition, the raised concern of deteriorated brand image and thus decreased customer loyalty as a result of neglecting NCs is supported by the literature (Karunaratna & Kumara, 2018). To ensure that the customer perspective is acknowledged, the number of customer complaints that can be related to a specific NC will be included in the prioritisation model, see Table 6.1.

Table 6.1: List of attributes essential for the prioritisation of NCs.

Dimension	Attribute	Description
Risk	Occurrence of NCs	Failure frequency
	Severity	Potential impact of a given NC if delivered to and used bythe customer
	Detectability	The probability to detect the NC
Company-specific	Customer complaint	The number of customer complaints that can be related to a specific NC
	Propagation	The risk that other components, products, or product families will be affected by the NC
	Time to failure	Estimated time in service

Moreover, the literature stresses the importance of aligning the improvement projects with the company strategy (e.g., Antony, 2004; Antony & Banuelas, 2002). This was also discussed during interviews and focus groups, where the participants emphasised the importance of focusing on quality improving activities to be aligned with the company's goal of high quality. However, the discussion focused on the importance of not neglecting or delaying corrective actions rather than on prioritising NCs based upon their strategic alignment. As mentioned earlier, the company's strategy is highly focused on the quality and reliability of its products, which may be impacted by neglecting or delaying corrective actions. In addition, some participants from the Quality department expressed concern regarding the ignored quality issues and thus the company's reputation.

Except the importance of establishing a strategic link, the literature (e.g., Banuelas et al., 2006; Donauer et al., 2015; Jiang & Klein, 1999; Salah, 2015) and interviewees agree that the risk associated with the project should be assessed. Therefore, the proposed model presented in the subsequent chapter is inspired by the FMEA methodology and include the associated attributes of *severity, occurrence,* and *detectability.* Severity and the impact on safety has the highest priority for the company and cannot be negotiated under any circumstances. In the context of Company X, more specific due to the characteristics of its offered products, a NC may imply severe consequences from a safety perspective. It is thus understandable that this attribute got the highest priority.

Some discrepancies between the empirical data and literature could also be identified. The theory (i.e., Antony & Banuelas, 2002; Banuelas et al., 2006; Gošnik & Hohnjec, 2009) emphasised the learning and growth opportunities that come with an improvement project. However, due to the nature of the improvements in this case, which mostly are of correctional type, it is rather unlikely that a major product- or process innovation would emerge. Therefore, this criterion will not be included in the model. Moreover, technical feasibility was brought up in the literature (e.g., Antony, 2004; Banuelas et al., 2006; Salah, 2015) and during some interviews but this criterion was also deemed difficult to assess at this stage of the process. Success probability were not discussed during any of the interviews or focus groups but highlighted as an appropriate criterion in the literature (Antony, 2004; Goldstein, 2001; Salah, 2015). In general, the feasibility of the project implies a greater possibility for success, notwithstanding, in this context, feasibility and success probability have almost the same meaning, and is as previously explained, challenging to evaluate at this stage of the process.

Furthermore, the risk that a particular NC will affect several products was stressed by the company representatives but not found in the literature. This is most certainly because of the context and the type of products Company X offers. For the company, many products share the same components, and in some cases the NC and associated problem may spread to several products. As discussed in the empirical findings, these circumstances, when the risk of propagation is high, may have different implications dependent on the particular NC. Sometimes it entails a more robust business case when a single correction can solve the problem on several products. However, in cases when the product architecture or requirements differ from product to product a single solution might not be sufficient. Even though a high risk of propagation sometimes requires more effort it is severe and should be given a high priority in the evaluation. Another attribute that was absent in the literature is time to failure and the same motivation regarding the context is applicable here. The offered products' reliability is emphasised as highly important to the company which is displayed by their quality goals. It is therefore critical to correct the NCs that is associated with short time to failure and this attribute is thus included in the model. The importance of time to failure is also motivated by the potential costs since shorter time to failure may imply that the warranty is still valid. Lastly, the product life-cycle was also deemed important to consider since new products that probably have many years left on the market are more strategic to improve than old products that have a much lower sales volume and that even may be exchanged by newer generations. However, the products that Company X offers vary a lot in how many years they are available on the market before they are removed or exchanged. In other words, it is extremely difficult to know how many years a particular product has left and therefore it is impossible to perform an accurate evaluation based on this attribute. Nevertheless, a new product, which is up to five years from launch, has a greater chance of being relevant longer.

6.2 The Prioritisation Model

A customised prioritisation model is created to facilitate decision making and assist Company X in prioritising which NCs that should be addressed. The model together with the already established product- and process improvement processes aim to contribute to effective and strategic quality improvements as displayed in Section 2.4 and Figure 2.11.

The prioritisation model is a weighted multi-attribute model which includes influences of Pareto- and FMEA analysis as well as the attributes presented in Table 6.1. Since the company possess knowledge and previous experience in utilising the FMEA as a tool for risk assessments the implementation of the model is deemed to be smooth. The combination of tools is justified in the literature, as Marriott et al. (2013) emphasise that FMEA alone is not sufficient to distinguish between contributing and wasteful quality improving activities. Moreover, Pareto analysis has previously been successfully combined with FMEA and to facilitate the decision making process (Görener & Toker, 2013; Donauer et al., 2015). The model is customised to suit the company's way of working and available data, see Figure 6.1.

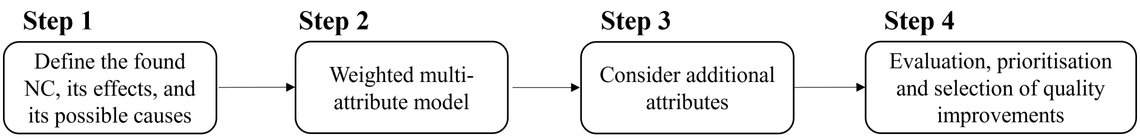

Figure 6.1: The prioritisation model.

The first step of the process includes defining the found NCs, its effects and possible root causes. This is something the FA Engineers already do in their failure analysis process, and thus, that information can be reused in this step. The second step is to create the weighted multi-attribute model, which process steps are displayed in Figure 6.2.

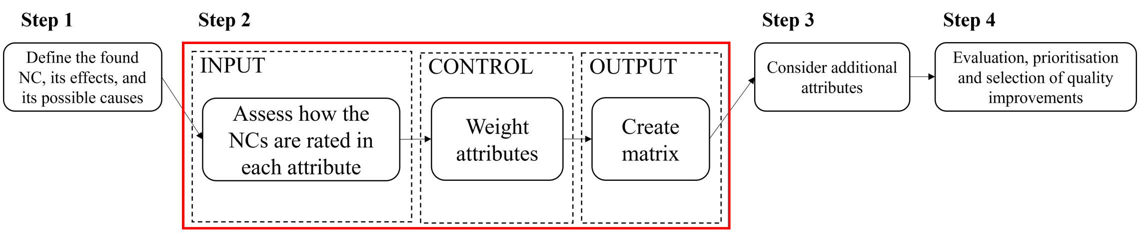

Figure 6.2: The prioritisation model – Step 2.

The initial step of the weighted multi-attribute model includes assessing and rating the previously defined NCs in each of the six selected attributes described in table 6.1, namely *occurrence of NCs, severity, detectability, customer complaint, propagation*, and *time to failure*.

The attributes are divided into two dimensions in the analysis: *the risk level dimension* and *the company-specific dimension*. The three attributes common within

FMEA are chosen within the risk dimension, i.e., occurrence, severity, and detectability. In contrast, more company-specific attributes, namely, customer complaints, propagation, and time to failure are selected for the company-specific dimension. Among these, mainly the customer complaint attribute is inspired by Pareto analysis. This is since the attribute determines the share of defects in a specific part or component, which can be solved by addressing the NC. The chosen attributes are mutually exclusive, implying that they cannot be satisfied simultaneously. However, the attributes are not collectively exhaustive but based upon the empirical findings, deemed to capture the essential aspects needed to prioritise and select effective and strategic NCs to address.

In Table 6.2, each of the attributes and their ratings are described. The first attribute in the risk level dimension is the occurrence of NCs, which is defined as the failure frequency of a part and component with a specific NC. This attribute is rated with the number of NCs received. As discussed in Chapter 6.1, the occurrence of a NC is an essential indicator on the magnitude of the failure. Further, the second attribute in the risk level dimension, severity, addresses the potential impact of a specific NC if delivered to and used by the customer. The attribute is rated on a scale from 1 to 10. One implies that the NC is not having any significant impact upon occurrence, while ten means that the NC is causing severe safety issues with high customer impact. However, as previously stated, safety issues is according to policies at the case company deemed critical and should thus always be addressed with suitable corrective actions. The third and last attribute in the risk level dimension, detectability, is related to the effectiveness of internal quality inspections in production. It is defined as the probability of detecting the NC before delivered to the customer and is similar to severity ranked on a scale from 1 to 10, where one implies that the NC is always detectable when it occurs, while ten means that it is impossible to detect the failure during an inspection.

The first attribute in the company-specific dimension is the customer complaint attribute, which addresses the number of customer complaints referred to a specific NC. It is a quantitative measure calculated in Equation 6.1. This implies that the attribute gets a value from 0 to 1, where a value close to zero denotes that the specific NC is responsible for only a small proportion of failures for the part or component. In contrast, a value close to one shows that most of the NCs related to the specific part or component is due to the investigated NC.

$$\frac{\text{Number of complaints on the part or component due to a specific NC}}{\text{Number of complaints on the part or component}} \tag{6.1}$$

The second attribute in the company-specific dimension is the risk of propagation, i.e., the possibility that other components, products, or product families will be affected by the same NC. The attribute is rated on a scale from 1 to 10, where 1 implies that there is no risk for propagation and 10 implies that an entire product family is affected by the NC. The third and last attribute connected to the company-specific dimension is the time to failure. This attribute is defined as the estimated time in service. The attribute is also rated on a scale from 1 to 10, where the ratings are based upon categories already used in the FA database.

Table 6.2: List of attributes for the weighted multi-attribute model

Attributes		**Type of data**	**Descriptions**	**Ratings**
			Risk level dimension	
X1	Occurrence of NCs	Quantitative data	Failure frequency	Number of received parts or components with a specific NC
X2	Severity	Qualitative data	Potential impact of a given NC if delivered to and used by the customer	Rating from 1-10 ***10* -** Impact on Safety ***9* -** Major functional impact (permanent) ... ***7*** - Major functional impact (temporary) ... ***5*** - Minor functional impact (permanent) ... ***3* -** Minor functional impact (temporary) ... ***1*** - No Significant Impact
X3	Detectability	Qualitative data	The probability to detect the NC	Rating from 1-10 ***10*** - Low detectability (impossible to detect without destructive testing) ... ***5*** - Moderate detectability (possible but not easy to detect) ... ***1*** - High detectability (always detectable)

Table 6.2: (Continued)

Attributes		Type of data	Descriptions	Ratings
Company-specific dimension				
Y1	Customer complaint	Quantitative data	The occurrences of customer complaints that can be related to a specific NC	$\frac{\text{Number of complaints on the part or component due to a specific NC}}{\text{Number of complaints on the part or component}}$
Y2	Propagation	Qualitative data	The risk that other components, products, or product families will be affected by the NC	Rating from 1-10 ***10*** - A product family is affected by the NC ... ***5*** - Other products can be affected by the NC ... ***1*** - No risk of propagation
Y3	Time to failure	Quantitative data	Estimated time in service	Rating from 1-10 ***10*** - Out of box failure ***9*** - Less than 1 month ***8*** - 1-3 months ***7*** - 3-6 months ***6*** - 6-12 months ***5*** - 1-2 years ***4*** - 2-3 years ***3*** - 3-5 years ***2*** - 5-10 years ***1*** - 10 + years

When the NCs are assessed according to the attributes, the ratings and gathered data is scaled in order for the single attributes to fit in the multi-attribute model. The ratings are scaled by Equation 6.2 and 6.3, which gives the attributes a value between 0 and 1.

$$x_i = \frac{x_j - x_{min}}{x_{max} - x_{min}} \tag{6.2}$$

$$y_i = \frac{y_j - y_{min}}{y_{max} - _{min}} \tag{6.3}$$

When the attributes are scaled they are also weighted towards each other. It is suggested by Donauer et al. (2015) to use an average weighting of the risk level attributes and in a three-step approach set the full weight to each of the company-specific attributes. Thus three 2x2 matrices will be generated. The suggested weighting strategy is described in Table 6.3. However, the weightings are flexible, and it is possible to change if deemed necessary. Further, as mentioned in several studies (see e.g., Sutrisno et al., 2013; Donauer et al., 2015), the severity and impact on the safety of the NCs are of high importance when selecting improvement efforts. Thus, it could be useful to also adopt a weighting strategy, which gives the severity superior influence. Moreover, in cases where it is not deemed possible to assess a NC according to a company-specific attribute, it is possible to skip that attribute and only plot the matrices giving value to the decision making process.

Table 6.3: Strategies to set weights

Description of the weighting strategy		**vi**	**wi**
a	High number of customer complaints	$v_i = \frac{1}{n} = \frac{1}{3}$, for n=3 as in this case.	$w_1 = 1; w_2 = 0; w_3 = 0$
b	High risk of propagation	$v_i = \frac{1}{n} = \frac{1}{3}$, for n=3 as in this case.	$w_1 = 0; w_2 = 1; w_3 = 0$
c	Low time to failure	$v_i = \frac{1}{n} = \frac{1}{3}$, for n=3 as in this case.	$w_1 = 0; w_2 = 0; w_3 = 1$

Lastly, the 2x2 matrices can be plotted, see examples in Figure 6.3 – 6.5.

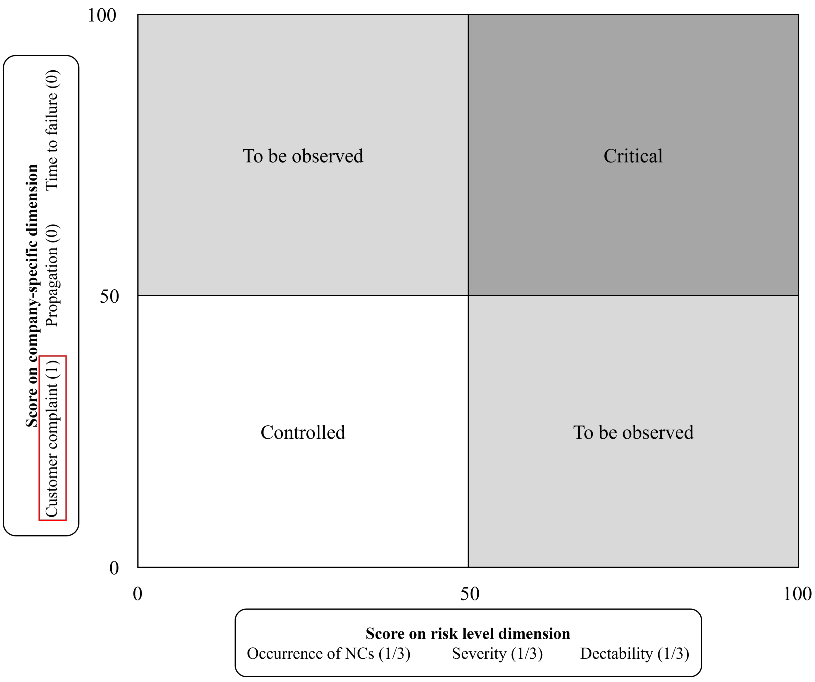

Figure 6.3: Matrix of weighting strategy a - x-axis with average weights and full weight to customer complaint at y-axis.

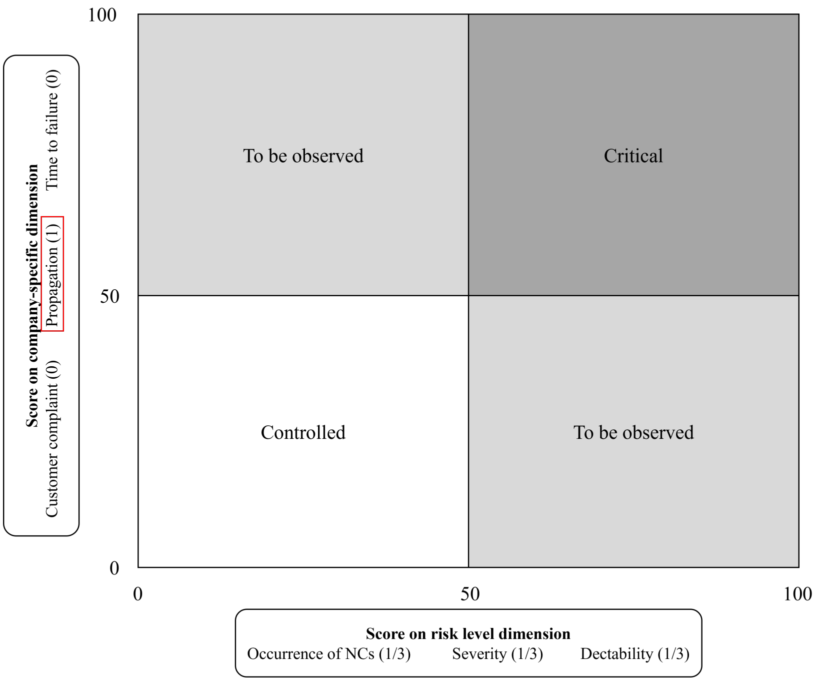

Figure 6.4: Matrix of weighting strategy b - x-axis with average weights and full weight to propagation at y-axis.

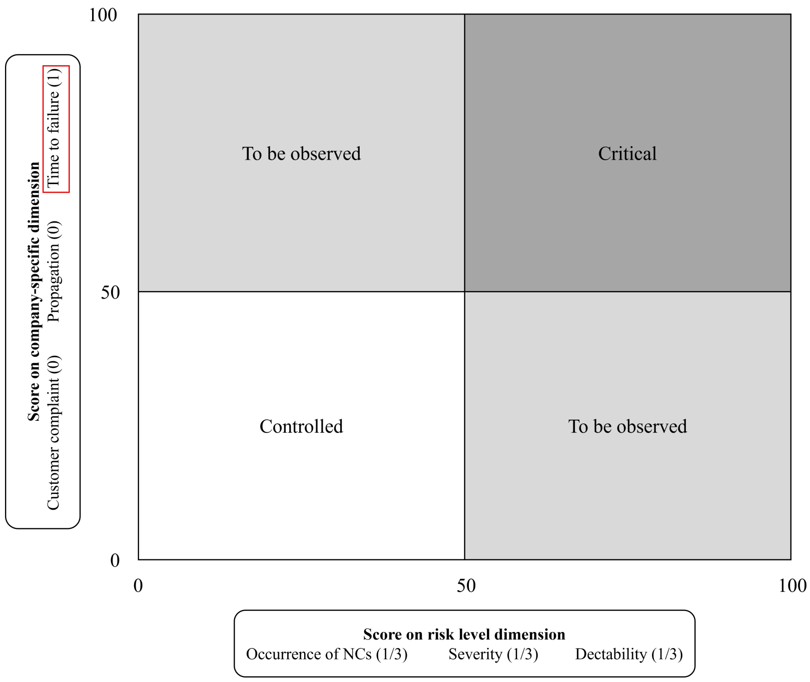

Figure 6.5: Matrix of weighting strategy c - x-axis with average weights and full weight to time to failure at y-axis.

In addition to plotting the 2x2 matrixes, it is suggested by Donauer et al. (2015) to conduct a profile analysis on the NCs. This implies adding each of the six attributes at the corners of a hexagon and plotting the specific profile of the NC. In the hexagon the value ranges from 0 in the centre of the hexagon to 100 at the outer line, see Figure 6.6. The profile analysis of a NC is conducted by entering the values from the 2x2 matrices such that a new shape is been created. From each shape it will be possible to accumulate information about the NC and the importance of addressing the failure will be more easily visualised.

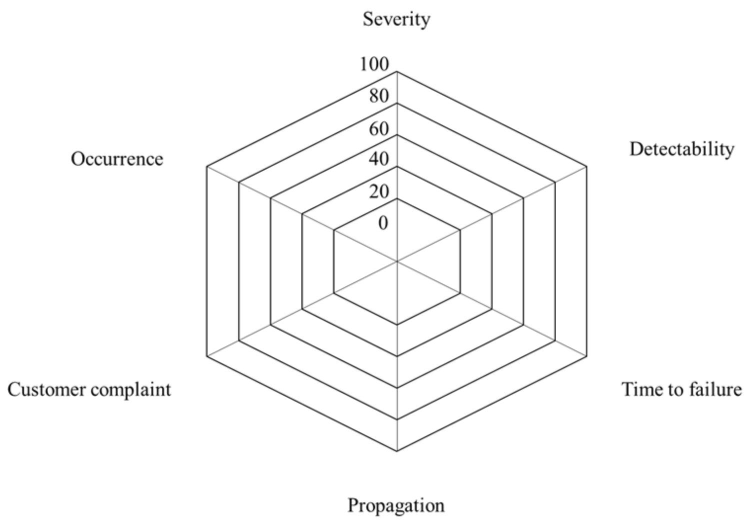

Figure 6.6: Shape profile, to be filled in.

The third step of the prioritisation model in Figure 6.1 is to consider some additional attributes, which were deemed valuable in the prioritisation and selection of NCs, but only available in a format which did not fit in the weighted multi-attribute model. The prioritisation model will consider these attributes by pondering on the below questions.

1. *Is the non-conforming component troublesome for the customer to replace? If yes, how problematic is the replacement?*

This question considers the impact of replacement, which is an attribute essential for Company X, since some replacements, as emphasised in the empirical findings, require more resources and thus have a greater impact on the customer's business. Replacements of NCs, which have a large impact on the customer business, such as requiring the customer to interrupt their business to replace the component are deemed more severe and such NCs may be more important to address than others that are easily replaced by a new component.

2. *Is there a known feasible solution to the NC?*

The second question revolves around the complexity of a NC, more specifically the assessed complexity and to some extent probability of success. If there exists a known feasible solution to the specific NC, it is deemed to be somewhat easier and relevant to address the issue, since it will be more resource-efficient as the Product Management department does not need to spend time and resources on coming up with a feasible solution.

3. *Is the NC affecting a key customer or a strategically important customer?*

The third question is considering the customer type and is indicating whether or not the NC is affecting a strategically important customer. To assist the FA engineers in this decision, a list of twenty customers should be provided, ten key customers based upon the sales volume, and ten strategically important customers in for example new market segments.

4. *Is the affected product classified as a new product?*

The fourth question to be evaluated is whether or not the product affected by the NC is classified as a new product. If so, as emphasised in the empirical findings and motivated in Chapter 6.1, the NCs should be given high importance.

The fourth and last step of the priority model is to summarise all analysis and assessments and make a final decision, on whether or not the NCs should be addressed, see 6.4. In this step it is important to consider all inputs provided and an overall assessment.

Table 6.4: Evaluation table, summarising the results from step 2 and 3 in the prioritisation model.

Evaluation point	Result		
	Controlled	To be observed	Critical
Step 2			
Matrix of weighting - Strategy a			
Matrix of weighting - Strategy b			
Matrix of weighting - Strategy c			
Step 3			
Impact of replacement on the customer?	☐ Low	☐ Moderate	☐ High
Known feasible solution?	☐ No ☐ Yes		
Strategically important customers?	☐ No ☐ Yes		
New product?	☐ No ☐ Yes		

6.2.1 Strengths and limitations of the prioritisation model

There are several potential strengths of the suggested model. Firstly, it facilitates objective decision making, as the assessment of the attributes is based upon weighted multi-attributes. Moreover, even though the model includes qualitative assessments, the structuring of the assessments provides an objective way of rating and comparing the attributes. Secondly, the prioritisation model and its 2x2 matrices allow the case company to monitor NCs overtime in an objective way. Thus, it will be easier for the organisation to make more fact-based decisions and prioritisations over time. Thirdly, the 2x2 matrices and the profiling are constricted by easy to read graphs, which illustrate what NCs to address. As already established in the theory, the 2x2 matrices are emphasised to be an intuitive way of identifying critical NCs and its presentation style is an already established approach within the quality-related business discussions. Fourthly, the easy visualisations and clearly depicted need for changes conveyed by the model address some of the identified challenges of ECRs, such as the negative connotation towards ECs and the need for sufficient information to base the decision making on. Lastly, the prioritisation model is flexible such that it can be easily adapted by the case company if over time other attributes are deemed more important, or if new weighting is needed.

Although the prioritisation model is constructed based upon reliable knowledge and data gathered through the existing theory and the empirical findings at Company X, there are some limitations. The first significant limitation is that a model is an offline tool, which continually requires manual handling and updates. However, as emphasised by Donauer et al. (2015), which have constructed a similar model, it is deemed possible to upgrade the model to operate by itself as an online tool. Notwithstanding, such an upgrade may limit the model's flexibility, as the algorithms may be more complicated to change. Secondly, there are some limitations related to the data quality upon which the assessments are made. For example, for the suggested improvement efforts to generate an accurate prioritisation, it is deemed crucial to ensure that the data used is of high quality.

6.3 Presentation and Communication of Data

As aforementioned, the above-suggested priority model can be used to assess whether a specific NC should be escalated or not. However, for the model to be useful and fulfil its purpose, the data in the model must be presented easily accessible way. For example, it is essential that the presentation of the data gathered from the model transfers the knowledge and create a shared understanding of the current situation.

Two sets of complementing frameworks are identified from the data visualisation theory, i.e., *Knaflic's visualisation framework* (2015) and H*egarty's principles of effective graphics* (2011). Both frameworks highlight the importance of understanding the context and adapting the visualisations to the context it will be used (Knaflic, 2015; Hegarty, 2011). The authors further stress that the visualisations must be relevant and understandable such that the audience can extract and interpret the communicated data. As previously mentioned in the empirical findings, the content and visualisations in the FA meeting were criticised in the survey. Some of the survey respondents stated that the content and visuals were on a too-high technical level for the audience to extract and interpret the provided information. This is an easy mistake (Knaflic, 2015), as the FA engineers and the entire Quality department responsible for the presentations at the FA meetings are employees with high technical competence compared to some of the recipients. To address this, it is emphasised by Knaflic (2015) to define the audience, their previous knowledge and desired tone before selecting what visuals to include in the meeting.

Moreover, Knaflic (2015) and Hegarty (2011) agree on the importance of focusing the audience's attention on the most important parts of the data (Knaflic, 2015; Hegarty, 2011). This implies that the presenter needs to take the limitations in working memory and attention span of the audience into consideration when creating the presentation. Knaflic's visualisation framework (2015) emphasised that this can be ensured by clearly defining the visualisation's purpose and establishing what message the visualisations should convey. Compared to adapting the information to the audience, the attention was not criticised by survey respondents. Additionally, both frameworks highlight the importance of avoiding clutter or inappropriate types of visualisation (Knaflic, 2015; Hegarty, 2011). In the survey about the FA meeting, one respondent experienced that some of the included visualisations were too detailed and difficult to read and thus were not contributing to the audience's understanding. To address this, Knaflic (2015) suggests avoiding using too advanced visuals, as they might mislead the audience, require too much brainpower from the audience, and thus lose focus on the essential information to be communicated.

In addition to the principles mentioned above, Knaflic's visualisation framework (2015) emphasises that the presenter should preferably think like a designer when constructing the visuals. As described by the author, this implies that the presenter should think about how the audience will utilise the visualisation to create a common understanding among the audience. Moreover, Knaflic (2015) also stresses the importance of visuals telling a story about the data to further enhance the recipients' understanding. In the survey, this was criticised by one of the respondents as the meeting did not provide a holistic view of the current situation. The respondent further expressed that it was hard to utilise the information shared since the information sharing and visuals were missing the common thread between the found failure mode and its consequences.

By utilising the suggestions in the literature on how to visualise and present information, it is possible to summarise and synthesise the information such that knowledge can be created and prioritisations of quality improvements can be conducted (Knaflic, 2015; Mandinach et al., 2006). Further, the literature on compelling data visualisations emphasises that an improved way of sharing information can enable better communication and increase the trust in the communicated information (Hegarty, 2011; Knaflic, 2015). In the case of Company X, the purpose of the FA meeting is appreciated, and many of the participants agree on the usefulness of the communication channel. However, for the information to be of most value to the organisation, the departments must adopt the same terminology and start to see the identified failure modes and suggested solutions from the same holistic perspective. By improving the format of the FA meetings and the including enhanced visualisations according to the feedback provided through the survey and the essential principles emphasised in the literature, a more common understanding among the departments can be achieved and thus an enhanced attitude towards each other.

The visualisations used in the prioritisation models are constructed based upon the existing theory on how data most efficiently should be communicated and are adapted to fulfil all aspects of the two presented frameworks: Knaflic's visualisation framework (2015) and Hegarty's principles of effective graphics (2011). For example, the 2x2 matrix shows only the relevant information for the recipients, i.e., whether it is deemed critical to addressing the NC. Further, the 2x2 matrix is easy to apprehend due to its simplicity, which is adapted to the recipients such that they can extract and interpret the knowledge shared. The shape profiling, which is also a graphic used within the model, is also used and adapted to highlight the essential characteristics of specific NCs and provide a holistic picture of how the NC is rated in all attributes simultaneously. However, the shape profiling is not entirely following the *Principle of Compatibility* (Hegarty, 2011), as two profilings on occasions might not differ enough to be comparable.

Moreover, by working with the suggested prioritisation model and the simple 2x2 matrices, it will be easier for Company X to enhance bettered presentation and communication of the available data. The model can also address the significant challenge of attitudes toward engineering changes emphasised by Jarratt et al. (2011). The authors describe that changes characterised by corrective actions to a found NC often receive a negative connotation compared to innovative ideas that contribute to product development. With enhanced communication through the simple 2x2 matrices and more clearly substantiated improvement suggestions by considering all identified attributes in the prioritisation model, the need for change is prominent and thus more relevant for the final decision-maker.

7
Discussion

In this chapter, the research questions are discussed and answered.

7.1 Research Question 1

What attributes should NCs from field returns be evaluated against to facilitate the prioritisation and selection of improvement efforts?

The literature on prioritisation of improvement projects display the wide spectra of criteria that improvement projects may be evaluated against to ensure that the right improvements are being realised (e.g. Salah, 2015). However, it might be overwhelming to consider every possible aspect and it is thus suggested to pick a few to concentrate on (Pande et al., 2000) (in Antony & Banuelas, 2002). These do not need to be collectively exhaustive but should be mutually exclusive (Donauer et al., 2015). Having too many criteria or attributes to take into account may be confusing, and the most important ones may lose their power in the prioritisation. Nevertheless, when choosing attributes, data availability is crucial to ensure accurate prioritisation (e.g. Goldstein, 2000; Salah, 2015; Gošnik & Hohnjec, 2009).

Moreover, when prioritising and deciding upon improvement projects it is critical to consider the goals and strategy of the company (Pikosz & Malmqvist, 1998; Salah, 2015) and thus determine attributes that are relevant to a specific context. In the context of NCs and based on the literature (Donauer et. al., 2015) and results of this study it seems that the attributes included in the FMEA method i.e. severity, occurrence, and detectability are suitable to assess the risk associated with different NCs. In addition to risk, it is suggested to include attributes that the company deem important for its business and goals. Together, a comprehensive evaluation and prioritisation among NCs can be made to facilitate the realisation of the most critical improvement projects.

7.2 Research Question 2

What methods or tools should be used to facilitate the prioritisation and selection of improvement efforts of NCs from field returns?

As many projects fail due to insufficient or subjective project selections, it is deemed critical for organisations to choose the most appropriate methods for prioritising and selecting quality improvements (Salah, 2015). As previously emphasised, the literature on the topic presents a wide range of methods applicable to the prioritisation and selection of what NCs to address (Kirkham et al., 2014; Larson, 2003; Pyzdek, 2003; Donauer et al., 2015); however, it is of great importance to select and adopt the methodologies such that they become valuable for organisational evaluations (Donauer et al., 2015). For Company X, it is suggested to use a weighted prioritisation model based on an integration of Pareto- and FMEA analysis similar to a model proposed by Donauer et al. (2015). It is deemed appropriate to adopt a model influenced by FMEA since the case company possesses knowledge of how to utilise it as a tool for risk assessments. Further, Pareto- and FMEA were successfully combined by Donauer et al. (2015) in a similar context, and thus the combination of tools was deemed appropriate. The suggested method is to use an objective weighted multi-attribute evaluation and visualise the findings in intuitive 2x2 matrices closely following the upcoming trends of visual management.

The close connection between FMEA and the prioritisation model is mainly due to the model utilising the commonly defined variables *occurrence, severity, and detectability* (Can, 2018). These attributes shed light on the potential risks of neglecting to address the NCs, and can, in this specific adaption, be utilised to achieve a refined selection and prioritisation of improvement efforts. The inspiration for Pareto analysis recognised in the prioritisation model is mainly in the company-specific attribute *customer complaint*, which assesses the share of defects in a certain component or part that can be solved by addressing the NC. As suggested in the theory of Pareto analysis, some defects contribute to more poor quality than others (Powell & Sammut-Bonnici, 2014), and thus the selection of improvement efforts should be influenced by this mindset.

The prioritisation model suggested in this thesis enables Company X to identify, select, and prioritise improvement efforts through an objective and fact-based evaluation process of the NCs. The prioritisation model allows the company to observe non-critical NCs over time and prioritise the most critical improvement activity among several competing improvement projects. Moreover, the model addresses the current challenge of negative connotations towards engineering changes and product improvements, as the ability to, in a fact-based way, argue for its relevance is prominent.

Due to the many potential benefits identified with adopting the prioritisation model and selecting the most critical NCs to address, it is suggested to apply a weighted multi-attribute model influenced by the two commonly used quality tools, Pareto- and FMEA analysis.

7.3 Research Question 3

How should the suggested prioritisation of NCs be visualised and communicated to transfer knowledge between organisational functions?

The literature on effective visualisations and how they can be used to communicate and transfer important information and knowledge throughout the organisation highlights several essential aspects. For example, several frameworks emphasise the extensive need for understandable graphs that are adopted and deemed to be on an appropriate level for the specific audience (Knaflic, 2015; Hegarty, 2011). Thus, before creating the visualisations, defining the audience, its knowledge, and the desired tone between the audience and the presenter is suggested. Further, when communicating the prioritisation of NCs, it is recommended to ensure that the visualisations used provide substantiated arguments and a holistic picture of the situation.

Further, the theory about effective visualisations emphasises focusing attention on the most important message to be conveyed (Knaflic, 2015; Hegarty, 2011). Along the same line, both frameworks highlight the importance of simple visualisations and avoiding clutter. When communicating and visualising the prioritisation, it is thus recommended to use simple visuals to enable the audience to absorb the communicated information and knowledge. Based on the literature, it is also suggested to "think like a designer" (Knaflic, 2015) when structuring the visualisation such that it is adapted to how the presenter would like the audience to use the communicated knowledge.

8 Conclusions and Recommondations

To continuously become better, it is important to focus on quality improvements. However, it is not possible or sound to perform every identified improvement area. Resources are scarce and organisations need to prioritise the improvements that bring the most value to the organisation and its customers. This Master's thesis aimed to assess how NCs arising in the field can be prioritised to ensure that the most severe and important ones are addressed. The thesis further aimed to foster the communication and knowledge sharing between organisational functions to achieve a joint agreement on how future NCs should be evaluated and treated. The findings in this report display that there is no silver bullet when it comes to the prioritisation of NCs but argues that it is important to have a customised method that suits the specific company. More specifically, companies who aim to incorporate a formal method for prioritising quality improvements should first determine what attributes that are deemed critical. This will ensure that the improvements that are prioritised also is in line with the company's strategy and goals. When the attributes are established, a suitable method can be developed as the one presented in Chapter 6.2. Lastly, to assure that knowledge are successfully transferred between different organisational departments, that potentially have different lingos, it is recommended to visualise the prioritisation and evaluation in a clear and tangible way.

In this thesis, a case study was performed on a single case company and a customised prioritisation model was developed. The model is inspired by the FMEA method and Pareto analysis and the output is displayed in a visually appealing 2x2 matrix which is based on occurrence, severity, and detectability on one axis, and customer complaint, propagation, and time to failure on the other. Further, it is recommended for the case company to test the model on prior cases to ensure validity before eventual implementation.

8.1 Future Research

This thesis has contributed with a prioritisation model that can be used by manufacturing companies to determine the most critical NCs. However, to validate the findings more research on the subject is needed. For example, the model could be applied in other manufacturing companies to evaluate the generalisability. Moreover, other company-specific attributes identified but not used in this case study could be included in other studies to investigate the applicability of additional attributes. The proposed model in this thesis is delimitated to only assess the priority of NCs and it would be of interest to conduct studies on how to prioritise the corrective action alternatives after the selection of critical NCs. Lastly, the literature on NCs in the context of field returns in general is limited and more research should preferably be performed to further investigate the potential of field return data.

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A

Appendix A: Interview Templates

A.1 Appendix A1: Template for the Quality department

Background

- Would you like to introduce what you work with? The role, responsibility, etc.
- How long have you been working at Company X?
- What is quality for you?
- In what ways do you work with quality?

Current applications

- How does Company X work with improvement efforts as a result of field failures?
- Could you please describe the entire process from receiving a customer complaint and how you work from there?
- How do you assess the severity or importance of a specific product failure?
- The product management department is responsible for further action of escalated field failures. From your experience, how do you believe the communication and collaboration is working today?
  - Do you often agree on what quality improvements that should be realised?

Potential

- Do you experience any flaws in the current way of working with quality improvements from field failures, i.e. from identified issue to implementation of a product or process change?
- How can the current way of working with quality improvements from field failures, but also the collaboration between the departments, be improved to ease or improve your work?
- Do you know if there have been any previous attempts to improve the current way of working, and if so, why it did not work?

Ending

- Is there anything additional you would like to discuss that you think would be of interest in this study before ending this interview?
- Do you know any person with relevant knowledge that would be of interest for our research?

A.2 Appendix A2: Template for the Product Management department

Background

- Would you like to introduce what you work with? The role, responsibility, etc.
- How long have you been working at Company X?
- What is quality for you?
- In what ways do you work with quality?

Current applications

- How does Company X work with improvement efforts as a result of field failures?
- Please describe the Engineering Change Request (ECR) process.
- How do you assess the business potential of an ECR?
- How do you assess the severity/importance/priority of an ECR?
- Do you experience any difficulties in assessing the severity/importance/priority of ECRs?
- When rejecting ECRs, how is the feedback received by the creator?
  - Do you and the ECR creator often agree on what quality improvements that should be realised?
- From your experience, how do you believe the communication and collaboration between the product management and quality department is working today with respect of working with quality issues from the field?

Potential

- Do you experience any flaws in the current way of working with quality improvements from field failures, i.e. from identified issue to implementation of a product or process change?
- How can the current way of working with quality improvements from field failures, but also the collaboration between the departments, be improved to ease or improve your work?
- Do you know if there have been any previous attempts to improve the current way of working, and if so, why it did not work?

Ending

- Is there anything additional you would like to discuss that you think would be of interest in this study before ending this interview?
- Do you know any person with relevant knowledge that would be of interest for our research?

B

Appendix B: Survey Questions

1. Is the content presented at the meeting relevant for its purpose according to you?
   (a) Is it anything regarding the content you would like to bring forward?
2. Were you able to follow the meeting structure?
   (a) Is it anything regarding the meeting structure you would like to bring forward?
3. What are your impression on the technical level on the meeting? Was it hard to understand something due to the technical level being too complicated?
4. Is it anything else you would like to bring forward?

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