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Developing Non-Conformity Process in Case Company

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Abstract

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The purpose of this thesis was to develop a non-conformity process for Maillefer Extrusion Oy, a company specializing in manufacturing machines and lines for the wire, cable, pipe, and tube industry. The study analyses the current non-conformity handling processes and identifies improvements to streamline the process.

The thesis covers various aspects of quality management, cost of quality, non-conformity handling, process modelling, and lean manufacturing principles. The research provides valuable insights and recommendations for future improvements, including employee training, technology upgrades, and business modelling techniques. The thesis achieved the ultimate goal - to contribute to the long-term growth and success of the company by developing a comprehensive non-conformity process aligned with industry best practices and grounded in a thorough understanding of the company's processes.

As an outcome, the thesis has proposed a method for development of a systematic approach to managing non-conformities and missing parts in a manufacturing company. This research provided valuable insights and outcomes that can significantly improve the company's operational efficiency and customer satisfaction. Key outcomes derived from this research include: a systematic approach to non-conformities and missing parts and development of a structured process in line with industry best practices, enabling proactive identification, documentation, and resolution of non-conformity issues.

Keywords: Non-conformance handling, Process modelling, Quality

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Tämän opinnäytetyön tarkoituksena oli kehittää poikkeamaprosessi Maillefer Extrusion Oy:lle, yritykselle, joka erikoistuu kaapeli-, putki- ja putkiteollisuuden koneiden ja linjojen valmistukseen. Tutkimuksen tavoitteena oli analysoida nykyisiä poikkeamien käsittelyprosesseja ja tunnistaa parannuksia prosessin tehostamiseksi.

Opinnäytetyön teoriaosuudessa käydään läpi erilaisia laatujohtamisen, laatukustannusten, poikkeamien käsittelyn, prosessimallinnuksen ja lean-tuotannon periaatteita. Tutkimus tarjosi arvokkaita näkemyksiä ja suosituksia tuleviin parannuksiin, mukaan lukien työntekijöiden koulutus, teknologian päivitykset ja liiketoimintamallinnustekniikat. Opinnäytetyön lopullisena tavoitteena oli edistää yrityksen pitkän aikavälin kasvua ja menestystä kehittämällä kattava poikkeamaprosessi, joka on linjassa alan parhaiden käytäntöjen kanssa ja perustuu perusteelliseen yrityksen prosessien ymmärtämiseen.

Opinnäytetyön tuloksena oli systemaattisen lähestymistavan kehittäminen poikkeamien ja puuttuvien osien hallintaan tuotannossa. Keskeisiä tuloksia tästä tutkimuksesta olivat systemaattinen lähestymistapa poikkeamiin ja puuttuviin osiin: rakenteellisen prosessin kehittäminen alan parhaiden käytäntöjen mukaisesti, mahdollistaen ennakoivan tunnistamisen, dokumentoinnin ja poikkeamaongelmien ratkaisemisen.

Avainsanat: Laatu, poikkeamahallinta, prosessimallinnus

Contents

List of Abbreviations

BPMN: *Business Process Model and Notation*. Graphical representation and modelling language used to depict the steps, participants, and activities of a business process, enabling organizations to better understand, analyse, and optimize their business operations.

CoGQ: *Cost of Good Quality.* Component of the Cost of Quality (CoQ) that refers to the expenses associated with preventing defects and maintaining high quality standards through investments in prevention and appraisal activities, such as quality planning, training, and quality control measures.

CoPQ: *Cost of Poor Quality.* Refers to the total costs incurred by an organization due to poor quality, including the costs of corrective actions, rework, product recalls, warranty claims, and loss of customer goodwill.

CoQ: *Cost of Quality.* Financial measurement that quantifies the total costs associated with ensuring product or service quality, including the expenses related to prevention, appraisal, internal failures, and external failures.

ISO: *International Organization for Standardization.* Non-governmental organization that develops and publishes international standards for various industries, including quality management systems, environmental management systems, and information security management systems.

N-C: *Non-conformity* which refers to a deviation or failure to meet established standards or requirements.

QA: *Quality assurance.* Systematic process to prevent defects and ensure consistent delivery of high-quality products or services that meet specified requirements and customer expectations.

QC: *Quality control*. Refers to the inspection and testing procedures employed to detect and correct defects in products or services, ensuring that they meet the required quality standards and customer expectations.

UML: *Unified Modelling Language.* Graphical language used to visualize, design, and specify software systems, as well as business processes and other non-software systems.

1 Introduction

Nowadays, companies are facing increasing global competition and strive to meet and exceed customer demands. To achieve this, they focus on developing their internal processes and the quality of their suppliers to enable continuous improvement.

Managing a multi-tier chain of subcontracting presents challenges, such as complicated coordination, lack of control over suppliers' processes, and potential quality control issues due to the lack of standardization. Sub-tier suppliers may introduce further quality risks, as companies may not control them directly.

Non-conformance handling is also a significant challenge in chain of subcontracting. Companies may face an increasing number of deviations from product specifications due to the complex supply chain structure, which can lead to potential quality control issues and reputational damage if not addressed efficiently.

To address these challenges, companies need to establish a robust supplier quality management program that includes clear quality requirements, supplier evaluations, and regular audits to ensure compliance. They also need to invest in technology solutions to improve supplier communication and monitoring, such as digital platforms to track supplier performance, providing real-time data to identify and address quality issues proactively.

1.1 Case company

Having discussed the broader challenges and importance of non-conformity handling and business modeling in various industries, it is essential to recognize that these concepts are equally relevant to the case company, Maillefer Extrusion Oy. As a growing organization in the manufacturing sector, Maillefer Corporation

faces unique challenges in managing non-conformities and optimizing its business processes to remain competitive and ensure product quality.

Maillefer Extrusion Oy is a Finland-based company that specializes in manufacturing machines and lines for the wire, cable, pipe, and tube industry. The company is part of the Davis-Standard group, a global company with headquarters in Connecticut, USA, and it has a presence in eight different countries worldwide. Maillefer Extrusion Oy employs around 300 people globally, with its headquarters located in Vantaa, Finland. The company provides comprehensive services to its customers, including the manufacture and sale of complete cable manufacturing lines, as well as individual machines tailored to customers' specific needs. Maillefer Extrusion Oy also offers installation, commissioning, and maintenance services to its clients (Maillefer 2021).

The company has a rich history that dates back to 1900 when it was founded in Switzerland by Charles E. Maillefer. Over the years, the company has undergone several changes in ownership and name, including being part of Nokia and later Nextrom. Maillefer Extrusion Oy has developed a reputation for quality and innovation in the wire and cable industry, with a focus on meeting and exceeding customer demands (Maillefer 2021).

1.2 Objectives and scope of the thesis

The purpose of this thesis is to develop the existing non-conformity handling process of the case company. The thesis aims to build a clear and easily understandable non-conformity management process and provide problem-solving tools to efficiently address various deviations to completion.

The research questions addressed in this thesis are:

- What are the current non-conformity handling processes in the case company?

- What improvements can be made to the existing non-conformity handling process in the case company?

The scope of this thesis is to focus on the non-conformity management process in the case company. The thesis discusses quality management and its challenges in the industry, analyzes the causes of complaints and deviations, and examines the costs of quality and comprehensive quality management in relation to the quality system. Furthermore, the thesis presents and analyzes the applicability of the methods of reducing errors and implementing corrective and preventive measures.

This thesis contributes to the field of quality management by providing insights into the development of non-conformity management process in the manufacturing industry. The findings of this thesis can benefit the case company and other companies facing similar challenges in managing a multi-tier chain of subcontracting.

The limitations of this thesis include the focus on the case company deviation in the production. Therefore, the findings and recommendations of this thesis may not be expanded to other industries or contexts. As the focus is solely on the non-conformities in the production process of the case company, the findings and recommendations presented in this thesis may have a limit to it.

2 Quality

This section provides an overview of the theory of quality management, covering various aspects such as definitions, responsibilities, and cost of quality. It emphasizes the importance of managing quality costs and presents models to classify and measure them. The section also covers non-conformity handling, process modeling, and lean manufacturing principles, along with various problem-solving tools. Case studies of successful implementation of these

practices are presented, highlighting the need for tailoring these methods to suit the unique needs of different industries.

2.1 Quality management

Quality has been defined in various ways by different experts in the field. Juran (1992) described quality as fitness for use, meaning that the product or service meets its intended purpose and satisfies customer needs. Crosby (1979) stated that quality is conformance to requirements, indicating that the product or service fulfills the specifications set by the customer. Deming (1986) viewed quality as a predictable degree of uniformity and dependability, which implies that the product or service consistently meets or exceeds expectations. Garvin (1987) characterized quality by eight dimensions, including aesthetics, conformance, durability, features, performance, reliability, serviceability, and perceived quality. Lastly, the International Organization for Standardization (ISO 9000:2015) defined quality as the degree to which a set of inherent characteristics of an object fulfills requirements.

Though numerous definitions of quality exist, the fundamental concept revolves around fulfilling or surpassing customer expectations. Achieving this goal requires a commitment to continuous improvement, effective communication, and a culture of excellence. Organizations that prioritize quality are more likely to achieve long-term success and gain a competitive advantage in their respective industries.

Responsibility for quality lies with every person in a company, although the responsibility for certain aspects of quality may vary depending on their role. Shopfloor worker who conducts the process are responsible for non-conformance only if:

- Quality criteria are explicit and comprehensible,

- Performance is assessed through received feedback,
- Opportunities are available to adjust performance by implementing corrective actions.

Management holds the responsibility for guaranteeing that quality requirements, feedback, and corrective action provisions are fulfilled, which allows the shopfloor workers achieve quality objectives independently. Nevertheless, organization, communication, and coordination continue to be significant challenges, whether recognized or not. To guide the organization towards the accomplishment of quality goals, management and supervisors must possess a thorough understanding of quality, particularly when addressing critical quality concerns spanning multiple departments. It falls upon management to allocate resources that equip the operator with the responsibility of maintaining quality while carrying out their tasks with precision. (Juran, 1962; Gryna, 2001)

Figure 1 below depicts the prevalent languages within the organization, as described by Gryna (2001).

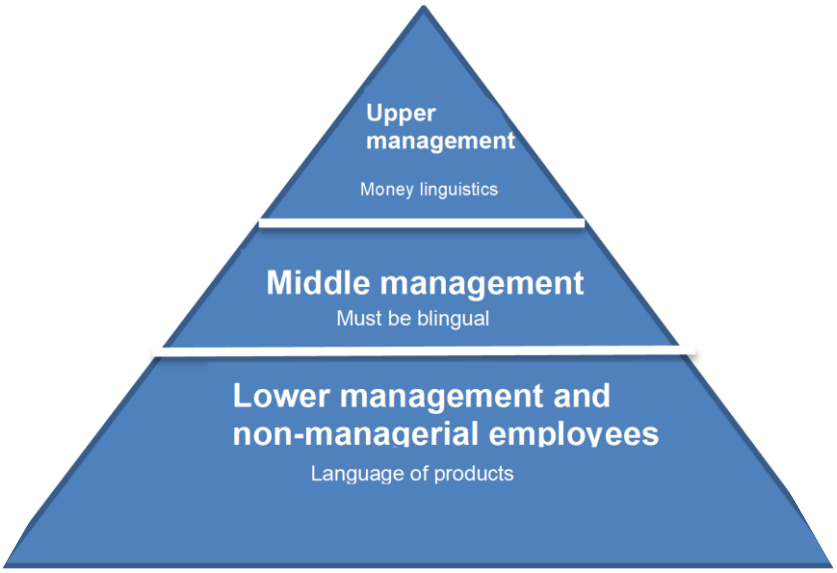

Figure 1 Prevalent languages within the organization (Gryna 2001)

As shown in Figure 1, the different languages prevalent within the organization can have a significant impact on communication and coordination. It is essential for management to recognize these languages and their importance in ensuring effective communication between departments to maintain and improve overall quality.

It is crucial to ensure that quality goals and metrics correspond with each activity based on its location within the company. Nevertheless, distinct sections of the organization might have varying interpretations of quality objectives, affecting the overall clarity and understanding of desired quality targets. To guarantee harmony, top management should convey company-wide quality aspirations in a manner that operators can readily embrace. Typically, this responsibility rests on the shoulders of middle management, which serves as a bridge between senior management and operators and must possess the ability to communicate effectively with both parties. (Gryna, 2001)

Figure 2 provides a visual representation of the Quality Management Framework, illustrating the differences between QA and QC.

Figure 2 illustration from Quality management framework

As shown in Figure 2, the Quality Management Framework emphasizes the distinct roles of QA and QC in maintaining product or service quality. QA takes a preventive approach, encompassing a wide range of activities from design to

delivery, while QC focuses on detecting and correcting defects in the finished product or service. By understanding the differences between these two approaches, organizations can effectively manage quality and ensure customer satisfaction.

Quality assurance (QA) is a proactive approach that focuses on preventing quality problems from occurring by ensuring that specific quality standards are met throughout the entire life cycle of a product or service. It involves a set of processes that establish confidence in the quality conformance based on factual information. According to Whitney, Lind, and Wahl (1998), QA is not just the responsibility of the quality department, but involves the entire organization, from top management to front-line employees. Activities such as process design, training, documentation, and audits are included in QA, which occurs during the development and production process of the product or service.

On the other hand, quality control (QC) is a reactive approach that focuses on detecting and correcting defects or non-conformances in the finished product or service. It involves activities such as inspection, testing, and corrective action. QC primarily falls under the responsibility of quality control inspectors or technicians, who inspect the finished product or service to ensure that it meets the specified quality requirements. QC is a narrow approach that focuses only on the finished product or service and occurs after it has been completed.

The article highlights the difference in the scope of QA and QC. While QA is broad, involving all aspects of the product or service from design to delivery, QC is narrow, focusing only on the finished product or service. The focus of QA is on the prevention of defects or non-conformances in the product or service, whereas the focus of QC is on the detection and correction of defects or non-conformances in the finished product or service. As below table 1 illustrates the comparison the differences between QA and QC.

As below table 1 illustrates the comparison the differences between QA and QC.

Table 1 Comparison of Quality Assurance (QA) and Quality Control (QC). Adopted from (Whitney, Lind, & Wahl, 1998).

Characteristic	Quality Assurance	Quality Control
Definition	A set of processes to ensure that a product or service meets specific quality standards throughout its entire life cycle.	A process that focuses on detecting and correcting defects or non-conformances in the finished product or service.
Objective	Prevents quality problems by focusing on the process used to make the product or deliver the service.	Identifies quality problems by inspecting the finished product or service.
Scope	Broad, involving all aspects of the product or service, from design to delivery.	Narrow, focusing only on the finished product or service.
Responsibility	Involves the entire organization, from top management to front-line employees.	Primarily the responsibility of quality control inspectors or technicians.
Activities	Includes activities such as process design, training, documentation, and audits.	Includes activities such as inspection, testing, and corrective action.
Time of activity	Occurs during the development and production process of the product or service.	Occurs after the product or service has been completed.
Focus	Focuses on prevention of defects or non-conformances in the product or service.	Focuses on detection and correction of defects or non-conformances in the finished product or service.

2.2 Cost of quality

The cost of quality comprises expenses incurred to guarantee that a product or service meets customer demands and expectations. It can be categorized into two types: the cost of conformance and the cost of non-conformance. The cost of conformance includes prevention, appraisal, and internal failure costs, while the cost of non-conformance includes external failure costs. The former aims to prevent defects, while the latter is incurred when a defective product or service is delivered to the customer (Crosby, 1979; Juran & DeFeo, 2010; Feigenbaum, 1991).

Quality-related expenses can arise from various departments and activities within a company, including design, testing, inspection, rework, and warranty work. External expenses, such as customer service and returns, can also be a part of the total cost of quality (Atkinson, Waterhouse, & Wells, 1997).

Managing and measuring quality-related costs is crucial to comprehend the financial impact of quality efforts. Dale and Wan (2002) provide different models to classify and measure CoQ, including the PAF model, activity-based costing, and other approaches. These models help organizations recognize and evaluate the costs associated with quality-related activities.

Overall, CoQ is a fundamental aspect of quality management that allows organizations to understand the costs associated with maintaining product quality and preventing quality failures. Figure 3 illustrates the different cost categories and models that are related to Cost of Quality (CoQ).

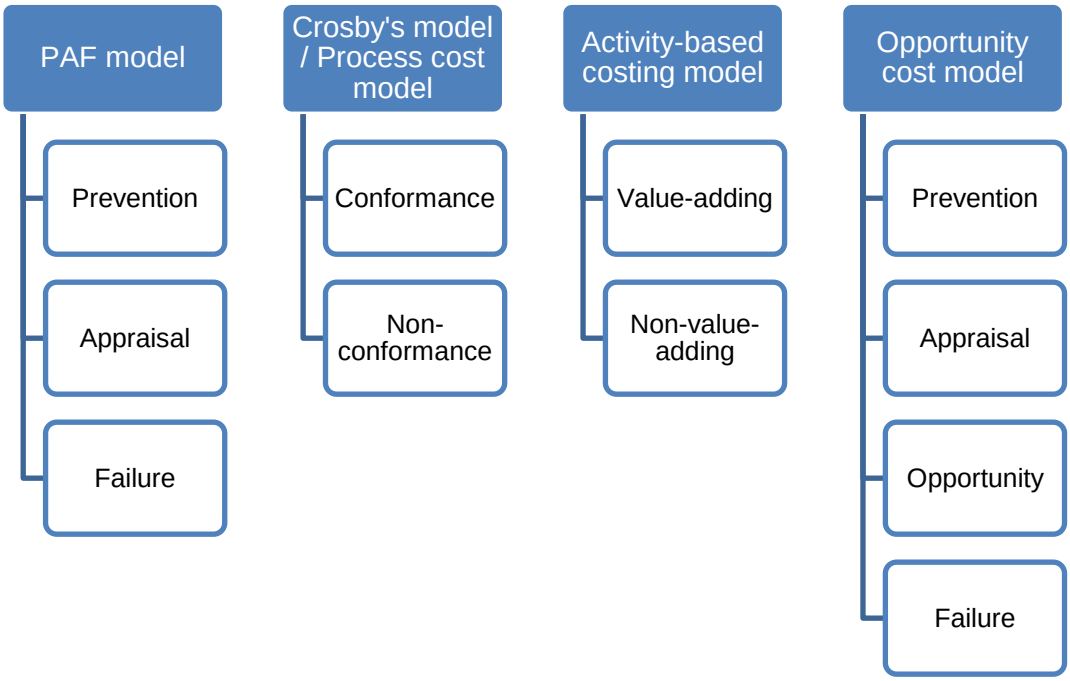

Figure 3 CoQ frameworks and associated cost classifications. Modified from Schiffauerova & Thomson

The simplest way to calculate Cost of Quality (CoQ) is to use the basic equation:

CoQ = CoGQ + CoPQ

Where CoGQ represents the cost of good quality, which includes the cost of prevention activities and the cost of process control, and CoPQ represents the cost of poor quality, which includes the cost of internal and external failures.

According to Juran and DeFeo (2010), the cost of quality can be divided into two main categories: the cost of conformance and the cost of non-conformance. The cost of conformance includes prevention costs, appraisal costs, and internal failure costs, while the cost of non-conformance encompasses external failure costs. The cost of quality can arise from different departments and activities within a company, such as design, testing, inspection, rework, and warranty work.

One widely used model for categorizing CoQ is the Prevention-Appraisal-Failure (PAF) model or Crosby's model, as proposed by Crosby (1979). This model

classifies quality expenses into three categories: prevention costs, appraisal costs, and failure costs. Prevention costs include expenses related to preventing defects from occurring, such as training, quality planning, and process improvement. Appraisal costs involve expenses linked to assessing the compliance of products or services with quality standards, such as inspection, testing, and audits. Failure costs include expenses associated with quality shortcomings, such as rework, waste, downtime, warranty repairs, customer complaints, and lost business opportunities.

Dale and Wan (2002) suggested that managing quality costs across different departments and activities is crucial for effective quality management. Other models for measuring CoQ include activity-based costing and opportunity cost models. These models provide organizations with a foundation for measuring quality costs and identifying areas for improvement.

By managing CoQ effectively, organizations can reduce costs associated with poor quality, increase customer satisfaction, and improve overall performance. Organizations need to monitor quality costs and continuously improve their quality management systems to remain competitive in the marketplace.

Understanding the cost of quality and different models of classification is essential for organizations to improve their quality management systems and reduce costs associated with poor quality. Effective management of quality costs can lead to increased customer satisfaction, reduced waste, and improved overall performance. (Juran & DeFeo, 2010; Crosby, 1979; Dale & Wan, 2002)

2.3 Non-Conformity Handling

This section discusses the importance of non-conformity handling in ensuring product quality, safety, and adherence to regulatory guidelines in various industries. Case studies of successful non-conformity handling practices by

companies such as ABB, BMW Group, and Apple Inc. are presented, highlighting the importance of adopting comprehensive approaches tailored to the unique needs and challenges of each industry.

Non-conformity handling is an essential aspect of quality management systems and risk mitigation in various industries. It involves identifying, documenting, and resolving instances where products, services, or processes do not meet established standards, specifications, or requirements (Hutchins, 2018).

In the manufacturing industry, non-conformity handling is crucial to ensure product quality, safety, and adherence to regulatory guidelines. The International Organization for Standardization (ISO) provides a widely accepted framework for handling non-conformities through the ISO 9001:2015 standard (ISO, 2015). Non-conformities are identified through regular inspections, audits, and performance monitoring. Once detected, they are documented and investigated to determine the root cause. Subsequently, corrective and preventive actions are implemented to prevent recurrence, and the effectiveness of these actions is monitored and reviewed (Hutchins, 2018).

Apple Inc. is an example of a company that relies heavily on outsourcing and has established robust non-conformity handling processes. Apple's Supplier Code of Conduct sets forth strict requirements for its suppliers, ensuring that they follow best practices in labor, health and safety, environment, and management systems (Apple Inc., 2021). Apple conducts regular audits and assessments of its suppliers to identify non-conformities, and when issues are detected, the company requires its suppliers to perform root cause analysis and implement corrective actions promptly. Furthermore, Apple provides support to its suppliers through training and capacity-building programs, encouraging continuous improvement in their performance and adherence to quality standards (Apple Inc., 2021).

In the automobile industry, BMW Group is an example of a company that has implemented effective non-conformity handling procedures. With a commitment

to producing high-quality and safe vehicles, BMW follows strict quality management standards based on ISO 9001:2015 and the International Automotive Task Force's (IATF) 16949 standard (IATF, 2016). The company conducts regular internal and external audits to identify and address non-conformities in its manufacturing processes, ensuring that its suppliers also adhere to these quality standards (IATF, 2016). Advanced root cause analysis and corrective action systems, such as the 8D methodology, are commonly used in the automotive industry to resolve non-conformities and prevent their recurrence (Kumar & Adaveesh, 2017).

Table 2 Benchmarking Non-Conformity Handling Practices in ABB, BMW Group, and Apple Inc.

Company	Industry	Quality Management Standards	Non-Conformity Identification	Root Cause Analysis & Corrective Actions	Supplier Compliance & Monitoring
ABB	Manufacturing	ISO 9001:2015	Regular inspections, audits, and performance monitoring	CAPA system, continuous improvement methodologies	Requires suppliers to adhere to ABB's quality standards
BMW Group	Automobile	ISO 9001:2015, IATF 16949	Internal and external audits, supplier quality standards adherence	8D methodology for root cause analysis and corrective actions	Strict supplier quality standards, regular audits
Apple Inc.	Consumer Electronics	Apple Supplier Code of Conduct	Supplier audits and assessments, product inspections	Timely root cause analysis and corrective actions	Supplier training, capacity-building programs

As shown in Table 2, ABB, BMW Group, and Apple Inc. demonstrate the importance of adopting comprehensive non-conformity handling practices to ensure product quality and compliance with relevant standards across various industries. These companies share common themes, such as adhering to recognized quality management standards, proactively identifying non-conformities through inspections, audits, and performance monitoring, and

employing well-established methodologies for root cause analysis and corrective actions.

Differences in their approaches arise from industry-specific requirements and their reliance on supplier networks. For instance, BMW Group follows the IATF 16949 standard, while Apple Inc. places a strong emphasis on capacity-building and training programs for its suppliers. These differences showcase the importance of tailoring non-conformity handling practices to the unique needs and challenges of each industry.

The successful management of non-conformities and mitigation of potential risks hinge on implementing recognized quality management frameworks, proactively identifying non-conformities, using effective methodologies for root cause analysis and corrective actions, and closely monitoring supplier compliance. The practices of ABB, BMW Group, and Apple Inc. serve as valuable examples for companies across various industries seeking to enhance their non-conformity handling processes.

2.4 Process modelling

Process modeling is a critical tool for organizations seeking to improve their operations by visually representing processes, workflows, and relationships (Dumas, La Rosa, Mendling, & Reijers, 2018). By employing process modeling techniques such as Business Process Model and Notation (BPMN) or Unified Modeling Language (UML), businesses can develop a non-conformance process map that provides a clear understanding of the steps and responsibilities involved in handling deviations (Recker, 2013).

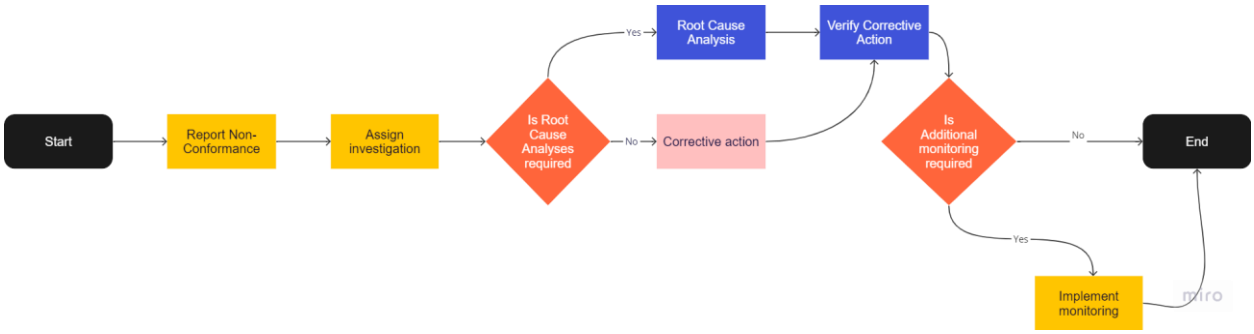

Figure 4. An example of a non-conformance process map utilizing BPMN notation.

Martinsuo and Blomqvist (2010) underscore the importance of process modeling in improving organizational performance. The authors contend that effective process modeling enables organizations to gain a deeper understanding of their operational processes, which in turn facilitates identifying areas for improvement and optimization. Process modeling is described as the systematic representation of processes, including their inputs, outputs, and subprocesses, to ensure alignment with the organization's strategy and customer value creation (Martinsuo & Blomqvist, 2010).

The authors propose a comprehensive approach to process modeling that consists of three key steps: measuring processes, setting objectives, and identifying areas for development (Martinsuo & Blomqvist, 2010). The initial step involves monitoring the inputs, outputs, and functionality of processes using suitable metrics. An effective monitoring system considers process inputs and outputs, the functionality of the process itself concerning objectives, and the requirements of various stakeholders (Martinsuo & Blomqvist, 2010).

The second step in the process modeling approach concentrates on establishing objectives that align with the company's strategy and customer value creation. According to Martinsuo and Blomqvist (2010), determining process objectives involves considering the company's current strategy, discussing customer

expectations, comparing with similar processes, setting performance objectives, and developing process components to achieve these objectives.

The third step, identifying areas for development, necessitates using performance indicators to pinpoint potential areas of process development. Martinsuo and Blomqvist (2010) recommend focusing specifically on value-creating activities and analyzing the process and its components concerning objectives. Typical areas for development include insufficient investments in value-creating activities, waste, and incorrect decisions (Martinsuo & Blomqvist, 2010).

Table 3 Overview of the Process Modelling Approach by Martinsuo and Blomqvist (2010).

Step	Description	Key Points
Measuring Processes	Monitor inputs, outputs, and functionality using suitable metrics	– Stakeholder requirements
Setting Objectives	Establish objectives aligned with company strategy and customer expectations	– Compare with similar processes
		– Set performance objectives
		– Develop process components to achieve objectives
Identifying Areas for Development	Use performance indicators to pinpoint areas of process development	– Focus on value-creating activities
		– Typical development areas:
		– Insufficient investment in value-creating activities
		– Waste
		– Incorrect decisions

2.5 Lean, Problem-solving tools

Lean manufacturing, a production philosophy initially developed by Toyota, focuses on reducing waste, increasing efficiency, and optimizing processes to deliver maximum value to customers (Womack & Jones, 1996). Central to lean manufacturing is the principle of continuous improvement, or kaizen, which emphasizes incremental changes to enhance productivity and quality over time (Imai, 1986).

One of the primary goals of lean manufacturing is to eliminate waste, which is defined as any activity that does not add value to the final product or service (Ohno, 1988). According to Ohno (1988), there are seven types of waste commonly identified in lean manufacturing:

- overproduction
- waiting
- transportation
- over-processing
- inventory
- motion
- defects

By identifying and eliminating these waste sources, organizations can improve efficiency, reduce costs, and enhance customer satisfaction.

Lean manufacturing employs various problem-solving tools and techniques aimed at pinpointing root causes, eliminating waste, and enhancing overall process efficiency. Some key tools include:

- 5 Whys: The 5 Whys is a problem-solving technique that involves repeatedly asking "why" to uncover the root cause of an issue, originally developed by Sakichi Toyoda, the founder of Toyota Industries Corporation. By identifying the underlying cause, rather than just addressing the symptoms, it allows for more effective solutions and has become widely used in quality management through Toyota's Lean Production System. (Ohno, 1988).

- PDCA (Plan-Do-Check-Act) Cycle: Also known as the Deming Cycle, this problem-solving framework involves planning a change, executing it, evaluating the results, and making necessary adjustments (Deming, 1986). The PDCA cycle encourages continuous improvement and learning from experience.

- A3 Problem Solving: A structured approach to problem-solving that uses a single A3-size paper to document the entire process, from problem identification and root cause analysis to proposed countermeasures, implementation, and follow-up (Sobek & Smalley, 2011). The A3 method promotes visual communication, collaboration, and concise documentation.

- Fishbone Diagram (Ishikawa Diagram): A visual tool employed to systematically identify and categorize potential causes of a problem (Mukhopadhyay, 2020). The diagram, resembling a fish skeleton, displays the main problem at the "head" and possible causes branching out along the "bones." This approach helps teams analyze complex problems and uncover root causes.

- Gemba Walk: A practice in which managers and team members visit the workplace (or "gemba") to directly observe processes, detect problems, and engage with employees (Womack & Jones, 1996). Gemba walks foster a culture of continuous improvement, facilitate open communication, and help identify opportunities for process improvement.

These methods are summarized in Table 4 below.

Table 4. Comparison table of the five problem-solving tools.

Problem-Solving Tool	Methodology	Benefits
5 Whys	Iteratively asking "why" until the root cause of a problem is identified.	Simple and easy to use, promotes root cause analysis, and can be applied to various situations.
PDCA Cycle	Plan, Do, Check, and Act steps are followed in a cyclical manner to encourage continuous improvement.	Encourages learning, experimentation, and adaptation; applicable to various problems and contexts.
A3 Problem Solving	A structured approach using an A3-size paper to document the entire problem-solving process.	Visual and concise communication, promotes collaboration, and encourages systematic thinking.
Fishbone Diagram	A visual tool for identifying and categorizing potential causes of a problem in a systematic manner.	Helps analyze complex problems, uncovers root causes, and facilitates team brainstorming.
Gemba Walk	Managers and team members visit the workplace to observe processes, detect problems, and engage with employees.	Enhances understanding of real-world processes, fosters open communication, and drives improvement.

The five problem-solving tools outlined in the table provide the overview of problem-solving techniques within the context of lean manufacturing. Some techniques, such as the 5 Whys and PDCA Cycle, emphasize root cause analysis and ongoing enhancement, while others, like A3 Problem Solving and Fishbone Diagram, offer structured and visual approaches for addressing issues. The Gemba Walk, conversely, accentuates direct observation and employee engagement to identify problems and promote improvement.

These tools can be employed individually or collectively, contingent upon the specific issue and organizational context. By applying these methods within a

lean manufacturing environment, organizations can systematically tackle problems, minimize waste, and boost overall process efficiency. Each tool possesses its distinct advantages, and the selection of the appropriate method(s) relies on the nature of the problem and the intended outcome. In many instances, utilizing a combination of these tools may yield the most thorough and effective problem-solving approach.

3 Current State analysis

The current state analysis is based on observations and discussions with colleagues on the subject. The research method employed is Action Research, which relies on observations and conversations with colleagues as part of a qualitative study focused on participatory and interactive approaches to problem-solving and data collection. Applier Action Research is a qualitative research method that aims to improve practices through active participation and collaboration (Reason & Bradbury, 2001). In Applied Action Research, researchers, together with participants, identify problems, develop and implement improvement suggestions, and evaluate their impacts (Kemmis & McTaggart, 2000). Based on the current state analysis, several areas for development were identified.

Data for the current state analysis (CSA) was gathered through various sources to provide a comprehensive understanding of the existing non-conformity handling process. These sources included the author's observations, discussions with colleagues from engineering, procurement, and production departments, as well as reviewing internal documentation, such as emails, work procedures, and meeting notes. discussion with colleagues were also conducted to gain further insights into the process.

A summary of the primary data sources used for this analysis is provided in the table below:

Table 5. Data sources and purpose for non-conformity handling analysis.

Document Type	**Name**	**Purpose**
Email Correspondence	Supplier Quality Issues	To identify supplier-related quality issues and how they are addressed
Process Description	N-C Handling 2017	To understand the existing non-conformity handling process in the company.
Interview notes	Colleague discussion	To gain insights from various departments on non-conformity handling
Meeting Notes	Project XXX assembly	To gain insights into the handling of non-conformities during assembly.

By utilizing these data sources, the analysis aimed to identify areas of improvement in the current non-conformity handling process and develop recommendations for a more efficient and effective system.

The case company, operating in a competitive market, is currently grappling with significant challenges in managing non-conformities (N-Cs) on the shop floor. These challenges have led to inefficiencies and potential risks. As the company operates within a competitive market, addressing these issues is essential for maintaining product quality, meeting regulatory requirements, and ensuring customer satisfaction.

One of the primary concerns is the lack of a structured, systematic approach to managing N-Cs on the shop floor. The absence of a well-defined process hinders the timely identification, documentation, and resolution of N-Cs, which can negatively impact product quality and operational efficiency. Furthermore, the company's current approach does not align with industry best practices, such as the ISO 9001:2015 standard, which emphasizes proactive N-C handling and continuous improvement.

Another significant challenge faced by the case company is the unclear roles and responsibilities related to N-C coordination and communication. This ambiguity contributes to confusion among employees, delays in addressing N-Cs, and the potential for critical issues to remain unresolved. Implementing well-defined responsibilities and communication channels for N-C handling is essential for prompt and effective resolution, ultimately resulting in high-quality products and customer satisfaction.

Additionally, the company lacks a robust follow-up mechanism to ensure that corrective actions are implemented, and their effectiveness is assessed. This gap increases the likelihood of recurring N-Cs, leading to inefficiencies, wasted resources, and potential regulatory non-compliance.

Apart from addressing N-C handling issues, the organization could significantly benefit from employing process mapping to optimize its processes and resources. Process mapping can help identify bottlenecks and inefficiencies, allowing the organization to make informed decisions for process improvement. In combination with other techniques such as value chain analysis and SWOT analysis, the organization can gain a comprehensive understanding of its operations and better align them with strategic objectives.

By integrating N-C handling with process mapping and other business modeling techniques, the organization can create synergies that not only enhance overall performance but also strengthen risk mitigation. This comprehensive approach will allow the organization to tackle multiple challenges simultaneously, resulting in a more efficient and effective operational structure that supports its long-term growth and success. The issues discussed are summarized in Table 5.

Table 5. Identified Issues and Business Impacts.

Issue	Description	Business Impact
Lack of systematic N-C handling	The company does not have a structured approach to identify, document, and resolve non-conformities.	Poor N-C handling can lead to increased costs due to rework, lost customers, and potential regulatory fines.
Unclear roles and responsibilities	Roles and responsibilities related to N-C coordination and communication are not well-defined.	Insufficient follow-up can lead to recurring issues, wasted resources, and additional costs associated with re-implementation of corrective actions.
Inadequate follow-up mechanism	The company does not consistently assess the effectiveness of corrective actions.	Insufficient follow-up can lead to recurring issues, wasted resources, and additional costs associated with re-implementation of corrective actions.
Missing parts	The company faces issues related to missing parts in the production process.	Missing parts can increase production downtime, lead to higher costs for expedited orders, and negatively impact customer satisfaction, affecting revenue

Out of the identified issues, the lack of systematic non-conformity (N-C) handling and missing parts will be the primary focus. The justification for selecting these two issues is as follows:

Lack of systematic N-C handling: Addressing this issue is crucial because it directly impacts product quality, regulatory compliance, and customer satisfaction. A well-structured N-C handling process will enable the company to proactively identify and resolve issues before they escalate, reducing inefficiencies and potential risks. Furthermore, adopting industry best practices, such as the ISO 9001:2015 standard, will improve the organization's reputation and competitiveness in the market.

Missing parts: Tackling the issue of missing parts is essential for the organization because it can cause delays in the production process, increased costs, and reduced product quality. By implementing measures to prevent and manage missing parts, the company can ensure timely completion of production, optimize resource utilization, and maintain high product quality. This, in turn, will result in enhanced customer satisfaction and a stronger market position.

By focusing on these two issues, the company can make significant improvements in its N-C handling process and overall operational efficiency, ultimately contributing to their long-term growth and success.

In the following chapter, these processes (N-C handling and N-C missing part) will be explored more comprehensively, delving into the root causes and potential solutions for improving N-C handling and addressing the problem of missing parts. This will provide a clearer understanding of the achievements made and the foundation upon which the upcoming chapter's recommendations are based.

4 Process improvement Proposals

This section discusses the process improvement proposals for addressing the identified issues of non-conformity (N-C) handling and missing parts. It comprises an overview of the N-C handling process, a systematic approach to managing missing parts, and strategies to improve communication and collaboration within the organization. This section provides insights into enhancing the company's overall operational efficiency, product quality.

4.1 NC handling process

Effective management of non-conformity parts is crucial for high product quality and customer satisfaction. A well-structured N-C handling process allows companies to proactively identify, communicate, and resolve issues, reducing inefficiencies and risks while adhering to standards like ISO 9001:2015. The current state analysis showed the case company's lack of a systematic N-C handling approach, affecting product quality, regulatory compliance, and customer satisfaction. Implementing a comprehensive N-C handling process aligned with industry best practices, grounded in a thorough understanding of the company's processes, addresses these concerns and contributes to long-term growth and success. A comprehensive overview of each step in this process is provided below.

1. **Detection of Non-Conformities:** The assembly and test teams, warehouse reception personnel, and packing teams play a crucial role in detecting non-conformities (N-Cs) during various stages of the production process. They conduct comprehensive inspections of raw materials, components, sub-assemblies, and finished products to ensure compliance with required specifications and quality standards.
    a. *Part inspection:* Warehouse reception personnel verify the quality and specifications of incoming parts, identifying any deviations or non-conformities through visual and measurement-based checks.

    b. *In-process inspection:* Assembly and test teams perform regular checks during different production phases to identify any issues,

such as incorrect dimensions, faulty welds, or improper assembly.

c. *Final inspection:* Packing teams thoroughly inspect the finished products before packaging, identifying any deviations or non-conformities, such as improperly packaged items, rusted parts, or cosmetic defects.

2. **Reporting Non-Conformities:** When an N-C is identified, the responsible team immediately communicates the issue to the quality coordinator using a pre-established reporting channel. Timely communication of N-Cs enables swift action and reduces the impact on the production schedule and overall efficiency.

3. **Assessment and Disposition of Non-Conformities:** After receiving the N-C report, the quality coordinator analyzes the issue and discusses the most appropriate course of action with shop floor supervisors. Depending on the nature and severity of the N-C, various actions may be taken:
    a. In-house correction: If the defect can be fixed on the shop floor, the quality coordinator instructs the relevant team to perform the necessary adjustments, ensuring the issue is resolved promptly without affecting the production schedule.

    b. External correction: If the issue requires external intervention, the quality coordinator communicates with the supplier, requesting either a repair at the supplier's expense or the provision of a replacement part, depending on the urgency and nature of the defect.

4. **Documentation and Communication with Suppliers:** Once the appropriate course of action has been determined, the quality coordinator documents the N-C details in quality tool and generates a Non-Conformance Report (NCR) to be sent to the supplier, depending on the cause of the N-C.
    a. *Internal issues:* If the N-C is a result of internal documentation or purchasing errors, the quality coordinator records the NCR and informs the responsible person to make necessary corrections, ensuring the supplier receives accurate documentation for future production. The procurement team then communicates the changes to the supplier.

    b. *Supplier-related issues:* If the N-C is due to the supplier's fault, the quality coordinator prepares the NCR to claim the supplier. The NCR should include essential information such as the

purchase order number, project, part description, nature of the deviation, and the required corrective and preventive actions (CAPA) from the supplier.

5. **Submitting a Claim to the Supplier:** The quality coordinator sends the claim to the supplier, adhering to a standardized subject line format, such as "N-C Purchase Order-Project-Ordered Part Description," for easy tracking and follow-up.

6. **Implementing Corrective and Preventive Actions (CAPA):** Once the supplier has acknowledged the claim, they are expected to implement the necessary CAPA to address the non-conformity. The supplier should provide a detailed CAPA report outlining the root cause analysis, the corrective actions taken, and the preventive measures implemented to prevent a recurrence.

7. **Verification of CAPA Implementation:** The quality coordinator reviews the CAPA report provided by the supplier and verifies the effectiveness of the implemented actions. This may involve conducting additional inspections, analyzing production data, or reviewing process changes.

8. **Monitoring Recurring Issues:** The quality coordinator closely monitors N-Cs to identify any recurring patterns or trends. If repetitive N-Cs are observed, the coordinator contacts the supplier's responsible purchaser and works together to develop an action plan to address the issues. The action plan may include additional inspections, process improvements, or supplier audits, ensuring a smooth supply chain and reducing the occurrence of future N-Cs.

9. **Continuous Improvement:** The quality coordinator, in collaboration with other stakeholders, identifies opportunities for continuous improvement in the non-conformity handling process. By analyzing data and trends, the coordinator helps to improve the efficiency and effectiveness of the process, leading to increased product quality and reduced non-conformities.

Based on these 9 points, a process can be mapped and the links between the procedures can be established. The outline of the process can be seen in Figure 5 below.

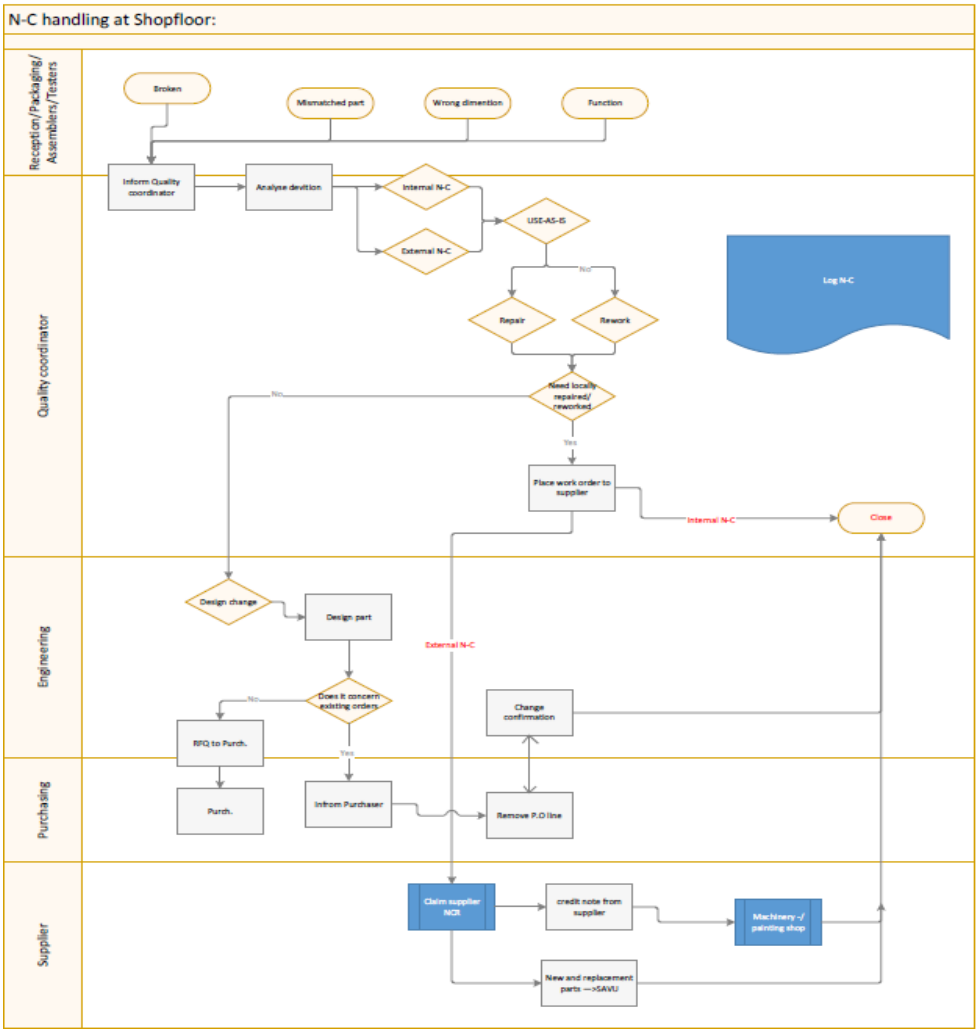

Figure 5. Non-conformities (N-C) handling process map.

4.2 Missing parts handling process

Since 2020, due to global component shortage, the process for handling missing parts is has become especially crucial in maintaining product quality, meeting customer expectations, and ensuring smooth operations. This process involves the detection, reporting, and resolution of instances where parts are missing from deliveries. Currently, this process has not been formalized in the case company. Therefore, to ensure the quality of the products, the process needs to be established. After reviewing the relevant theory and analyzing the current process, the proposed solution looks as follows:

1. **Detection of Missing Parts**: Warehouse reception, assemblers/testers, and packing teams play a critical role in identifying missing parts during the delivery process. As they unpack and verify shipments, they compare the delivered items with the corresponding purchase orders and packing lists.
2. **Reporting Missing Parts:** Once the missing parts are detected, the team should promptly report the issue to the quality coordinator using a designated communication channel. The quality coordinator will then document the issue on quality tool and print the Non-Conformance Report (NCR). This report should include essential information such as the purchase order number, project, part description, and the quantity of missing parts.

3. **Initial Assessment:** Upon receiving the missing parts report, the quality coordinator performs an initial assessment to determine the cause of the missing parts:
    a. ***Internal fault***: If the designated engineer has not specified the correct quantity, the deviation will be documented, and the responsible designer will be contacted to correct the upcoming orders and find a solution for the missing part.
    b. ***External fault*****:** If the supplier is responsible for the missing parts, a claim will be submitted. If the missing part is critical and the supplier is not geographically close, an effort will be made to find the part at a local shop at the supplier's expense.
4. **Submitting a Claim to the Supplier:** The quality coordinator submits a claim to the supplier requesting the delivery of the missing parts. The claim should include details such as the purchase order number, project, part description, and the quantity of missing parts. The subject line of the claim should follow a consistent format, such as "Missing Parts-P. O 12345-ProjectX-Cabinet," for easy tracking and follow-up.
5. **Monitoring and Follow-Up:** After submitting the claim, the quality coordinator should closely monitor the supplier's response and actions. Quality/ Procurement needs to follow up with the supplier to ensure the

prompt delivery of the missing parts and to minimize any disruptions to the production schedule.

6. **Resolution and Verification:** Once the supplier delivers the missing parts, the warehouse team should verify the quantity and quality of the replacement parts with assemblers. The quality coordinator should then update the status of the claim, noting that the issue has been resolved and the missing parts have been received.

By following these steps, the process for handling missing parts effectively addresses any discrepancies in deliveries, ensuring the outsourced automobile manufacturing industry maintains product quality, customer satisfaction, and smooth operations. The process map can be found from Figure 6.

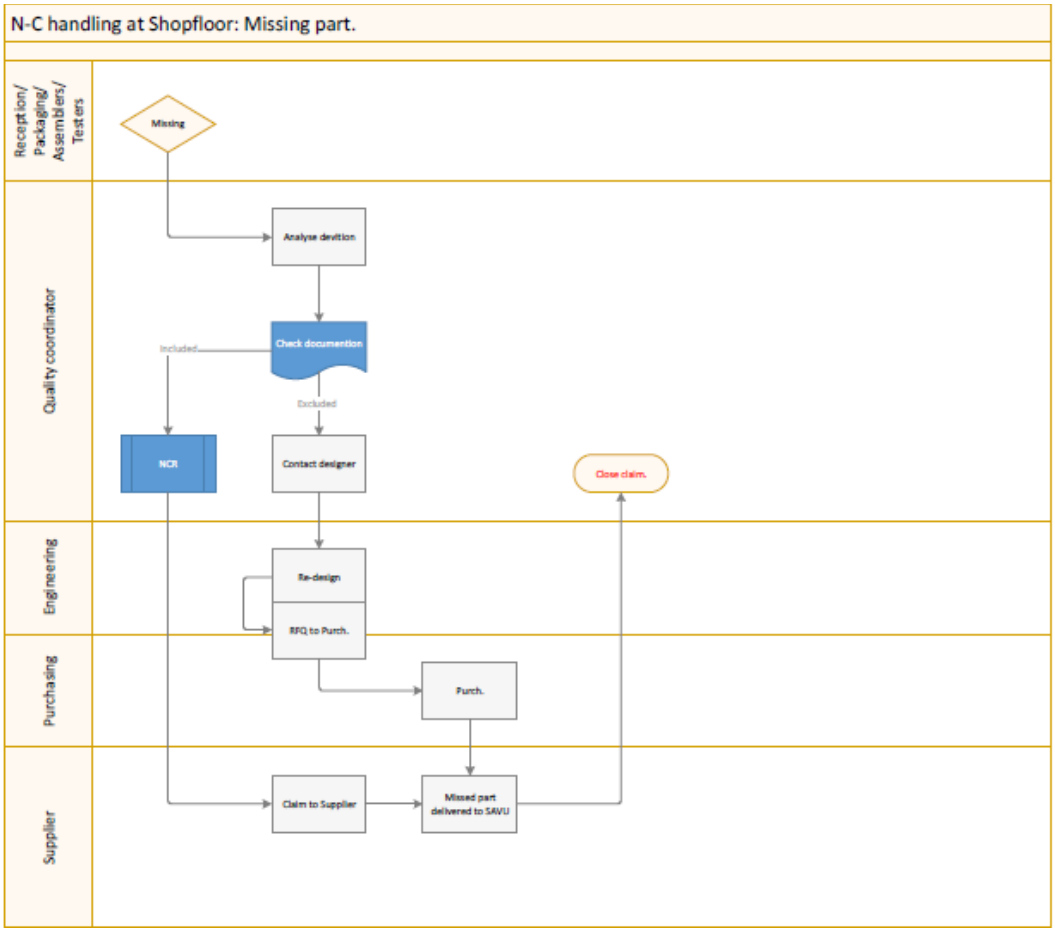

Figure 6. N-C handling process map.

5 Results and analysis

This section presents the results of the thesis and analyses the findings. The thesis research conducted on the company's non-conformity (N-C) handling and missing parts issues has provided valuable insights and outcomes that can significantly improve its operational efficiency and customer satisfaction. The following are some of the key outcomes derived from this research: Systematic way to approach NC & missing parts, risk-managed NC handling, improved communication between departments and upgraded technology and systems.

5.1 Systematic way to approach NC & missing parts

One of the primary outcomes of this research is the development of a systematic approach to managing N-Cs and missing parts. By implementing a structured process that aligns with industry best practices, such as the ISO 9001:2015 standard, the company can proactively identify, document, and resolve N-Cs and missing parts issues. This systematic approach enables the organization to maintain high product quality, comply with regulatory requirements, and ensure customer satisfaction. Finally, it helps in reducing inefficiencies and potential risks, contributing to the overall competitiveness of the organization.

5.2 Risk-managed N-C handling

Another significant outcome of this research is the establishment of a risk-managed N-C handling process. By prioritizing N-Cs based on their potential impact on product quality, regulatory compliance, and customer satisfaction, the company can allocate resources more effectively to address the most critical issues. This risk-based approach allows for timely resolution of N-Cs and minimizes the chances of recurring issues, ultimately resulting in reduced operational risks and improved performance.

5.3 Improved communication between departments

The research has highlighted the importance of clear communication between departments in managing N-Cs and missing parts. By establishing well-defined roles and responsibilities for N-C coordination and communication, the organization can ensure that all relevant stakeholders are informed about the issues and involved in the resolution process. This improved communication fosters a collaborative work environment and accelerates the resolution of N-Cs and missing parts issues, leading to increased operational efficiency and reduced delays in the production process.

5.4 Upgraded technology and systems

Another outcome of this research is the identification of opportunities for technology and systems upgrades to facilitate more effective N-C and missing parts handling. Implementing modern tools and technologies, such as advanced data analytics, automation, and real-time monitoring systems, can provide valuable insights into the root causes of N-Cs and missing parts issues, enabling the organization to address them more efficiently. Also, these technological upgrades can help streamline the production process, reduce manual errors, and optimize resource utilization, leading to improved overall performance.

5.5 Continuous improvement and performance monitoring

The research has underscored the importance of continuous improvement and performance monitoring in N-C and missing parts handling. By regularly assessing the effectiveness of corrective actions and monitoring key performance indicators, the company can identify areas for further improvement and ensure the ongoing optimization of its N-C handling process. This continuous improvement mindset fosters a culture of learning and innovation within the organization, driving long-term success and resilience in the face of market challenges.

6 Conclusion and recommendations

This research has provided a comprehensive understanding of the current state of non-conformity (N-C) handling and missing parts issues within the organization. By systematically analysing the existing challenges and developing targeted recommendations, the company can effectively address these concerns and improve its overall operational efficiency and customer satisfaction. The key outcomes of this research include the implementation of a systematic approach to N-C handling and missing parts management, risk-based N-C handling strategies, enhanced interdepartmental communication, and the promotion of a continuous improvement culture.

The findings from the current state analysis serve as a solid foundation for future research and development efforts within the organization. There are several additional areas identified during the analysis that warrant further investigation and potential improvement. These areas include employee training and development, technology upgrades, and more effective business modelling techniques such as process mapping and value chain analysis.

Future research should explore employee training for effective N-C handling and missing parts management, focusing on best practices, critical skills, and competencies. Additionally, examining the impact of technology on organizational processes could offer insights into potential system upgrades and integration to improve overall performance.

Further research into business modelling techniques could help optimize processes, identify bottlenecks, and align operations with strategic objectives. Assessing the effectiveness of improvements in N-C handling and missing parts management could enhance overall performance. This commitment to research and improvement will contribute to the company's long-term growth, success, and competitiveness.

References

ABB. (2021). Quality management. ABB. Retrieved March 23, 2023 from https://global.abb/group/en/about/corporate-strategy/quality-management

Apple Inc. (2021). Supplier responsibility: 2021 progress report. Apple Inc. Retrieved March 23, 2023 from https://www.apple.com/supplier-responsibility/pdf/Apple_SR_2021_Progress_Report.pdf

Atkinson, A. A., Waterhouse, J. H., & Wells, R. B. (1997). A stakeholder approach to strategic performance measurement. MIT Sloan Management Review, 38(3), 25-37.

BMW Group. (2021). Sustainable value report 2021. BMW Group. Retrieved March 23, 2023 from https://www.bmwgroup.com/content/dam/grpw/websites/bmwgroup_com/responsibility/downloads/en/2022/svr/BMW-Group_Sustainable-Value-Report_2021.pdf

Crosby, P. B. (1979). Quality is Free: The Art of Making Quality Certain. McGraw-Hill.

Dale, B. G., & Wan, G. (2002). Setting up a quality costing system. Business Process ManagementJournal,8,104–116.

Deming, W. E. (1986). Out of the crisis. Cambridge: MIT Press.

Dumas, M., La Rosa, M., Mendling, J., & Reijers, H. A. (2018). Fundamentals of Business Process Management. Springer.

Feigenbaum, A. V. (1991). Total quality control (3rd ed.). New York: McGraw-Hill.

Garvin, D. A. (1987). Competing on the Eight Dimensions of Quality. Harvard Business Review, 65(6), 101-109.

Hutchins, G. (2018). ISO 31000: 2018 enterprise risk management. Greg Hutchins.

IATF. (2016). IATF 16949:2016 - Quality management system for organizations in the automotive industry. International Automotive Task Force.

Imai, M. (1986) Kaizen: The Key to Japan's Competitive Success. McGraw-Hill Education, New York.

International Organization for Standardization. (2015). ISO 9000:2015 Quality management systems - Fundamentals and vocabulary. Retrieved March 5, 2023, from https://www.iso.org/standard/45481.html

ISO. (2015). ISO 9001:2015 - Quality management systems - Requirements. International Organization for Standardization. Retrieved March 5, 2023, from https://www.iso.org/obp/ui/#iso:std:iso:9001:ed-5:v1:en

Juran, J. M., & De Feo, J. A. (2010). Juran's quality handbook: the complete guide to performance excellence. McGraw-Hill Education.

Juran, J. M., & Juran, J. M. (1992). Juran on quality by design: the new steps for planning quality into goods and services. Simon and Schuster.

Kemmis, S., & McTaggart, R. (2000). Participatory Action Research. In N. K. Denzin & Y. S. Lincoln (Eds.), Handbook of Qualitative Research (2nd ed., pp. 567-605). Thousand Oaks, CA: Sage

Kumar, T. S. M., & Adaveesh, B. (2017). Application of “8D methodology” for the root cause analysis and reduction of valve spring rejection in a valve spring manufacturing company: A case study. Indian J. Sci. Technol, 10(11), 1-11.

Maillefer. Yrityksen sisäinen Intranet-tiedosto. 2021.

Martinsuo, M., & Blomqvist, M. (2010). Process modeling for improved performance.

Mukhopadhyay, M. (2020). Total quality management in education. SAGE Publications Pvt. Limited.

Ohno, T. (1988). Toyota production system: beyond large-scale production. crc Press.

Reason, P., & Bradbury, H. (Eds.). (2001). Handbook of Action Research: Participative Inquiry and Practice. Thousand Oaks, CA: Sage Publications.

Recker, J. (2013). Empirical investigation of the usefulness of gateway constructs in process models. European Journal of Information Systems, 22(6), 673-689.

Schiffauerova, A., & Thomson, V. (2006). A review of research on cost of quality models and best practices. International Journal of Quality & Reliability Management, 23(5), 647-669.

Sobek II, D. K., & Smalley, A. (2011). Understanding A3 thinking: a critical component of Toyota's PDCA management system. CRC Press.

Womack, J. P., & Jones, D. T. (1996). Lean thinking: Banish waste and create wealth in your corporation. Free Press.