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Improving the Standardization of the Raw Material Incoming Inspection Process through Digitalization

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Abstract

In manufacturing, the quality of the finished products is closely dependent on the quality of the sourced raw materials. As the volume of sourced raw materials increases, companies become more reliant on their suppliers for consistent product quality, making effective incoming quality inspection essential. Traditional quality control processes often lack standardization and traceability, leading to inefficiencies and an increased risk of non-conforming materials entering production. Digitalization has enabled process improvements by integrating digital technologies into industrial operations. This thesis presents a solution proposal to standardize the incoming raw material quality inspection process through digitalization. Furthermore, it explores how the successful implementation and adaptation of a digitalized process can be supported.

Conducted as a case study, this study synthesizes insights from a literature review and internal interviews, development workshops, and pilot testing within the case organization. The findings indicate that the proposed digital solution positively impacts process execution. Pilot testing demonstrated that the solution enhances compliance with operating procedures, supports raw material quality assurance, and improves process traceability. While the solution is tailored to the case organization, its core principles can also be adapted by other manufacturing organizations. Additionally, the study highlights that successful implementation of a digitalized process depends on critical success factors such as effective change management.

Keywords supplier quality management, digitalization, process development, business process re-engineering

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Tiivistelmä

Valmistavassa teollisuudessa tuotteiden laatu on vahvasti riippuvainen hankittujen raaka-aineiden laadusta. Hankittujen raaka-aineiden volyymien kasvaessa, yritykset ovat entistä riippuvaisempia toimittajistaan tuotteiden tasaisen laadun varmistamisesta, tehden tehokkaasta saapuvan raaka-aineiden laadun varmistamisesta tärkeää. Perinteisissä laadunvarmistusprosesseissa usein puuttuu standardisointi sekä jäljitettävyys, joka johtaa tehottomuuteen ja kasvattaa riskiä siitä, että vaatimustenvastaista materiaalia pääsee tuotantoon. Digitalisointi on mahdollistanut teollisten operaatioiden kehitystä integroimalla digitaalisia teknologioita niihin. Tämä diplomityö esittää ratkaisuehdotuksen raaka-aineiden vastaanottotarkastuksen standardisointiin digitalisointia hyödyntäen. Lisäksi diplomityö tutkii, kuinka digitalisoidun prosessin käyttöönottoa ja siihen sopeutumista voidaan tukea.

Tapaustutkimusmenetelmän avulla työssä on hyödynnetty niin kirjallisuuskatsausta kuin sisäisiä haastatteluita, kehitystyöpajoja sekä pilottitestausta tapaustutkimusyrityksessä. Tulokset osoittavat digitalisoidun ratkaisun positiivisesti vaikuttavan prosessin suorittamiseen. Pilottitestaus osoitti ratkaisun parantavan operatiivisten toimintatapojen noudattamista, raaka-aineiden laadunvarmistusta sekä edistävän prosessin jäljitettävyyttä. Vaikka ratkaisu on räätälöity tapaustutkimusyritykselle, sen keskeisiä periaatteita voidaan soveltaa myös muissa valmistavan teollisuuden yrityksessä. Lisäksi diplomityö korostaa, kuinka digitaalisen prosessin onnistunut käyttöönotto edellyttää kriittisten menestystekijöiden kuten toimivaa muutoksenhallinnan toteutumista.

Avainsanat toimittajan laadunhallinta, digitalisointi, prosessikehitys, liiketoimintaprosessin uudistaminen

Preface

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Helsinki, 23 April 2025

Linnea Loimu

Contents

Abbreviations

AI	Artificial Intelligence
BPR	Business Process Re-engineering
ERP	Enterprise Resource Planning
MES	Manufacturing Execution System
PDM	Product Data Management
PDCA	Plan, Do, Check, Act
QA	Quality Assurance
QC	Quality Control
QM	Quality Management
RACI	Responsible, Accountable, Consulted, Informed
SQM	Supplier Quality Management

1 Introduction

1.1 Background

When purchasing raw materials and parts in the manufacturing industry, the quality of the finished product depends not only on the company's capabilities but also on its supplier's the performance and quality standards. Efficiently managing the quality of purchased raw materials and collaboratively improving their quality is critical to maintaining a high-quality level of the end product. Due to this, the importance of quality in supply chain management has increased, and businesses are increasingly relying on their suppliers to continuously improve their process and product quality (Liker and Choi, 2004). Challenges for managing supplier quality include variability in raw materials, inconsistency in performance, and misaligned quality standards. Thus, continuous monitoring and assessing supplier performance are necessary when addressing the challenges. Similarly, companies and their suppliers often have differing systems and priorities, which can negatively affect collaboration when aiming for certain finished product quality. Therefore, to achieve the desired level of quality, companies must continuously review the requirements of materials and systematically control the supplied quality with an approach tailored based on the strategy and type of partnership used with the supplier (Burt, 1989).

Digitalization, considered the fourth industrial revolution, has enhanced process improvements in industrial operations by integrating digital technologies (Fitzgerald et al., 2014). Technologies such as Enterprise Resource Planning (ERP), Manufacturing Execution System (MES), and Product Data Management (PDM) systems have been rapidly developed to support production-related data management and traceability. These technologies have improved productivity, enhanced value creation, and simplified and standardized processes (Martinsuo and Blomqvist, 2010). Still, the benefits of digital technologies can be undermined without properly following a process development framework. Automating an outdated process can lead to suboptimal outcomes. Thus, before implementing digital solutions, the objectives of the project need to be clearly defined, and the current process needs to be analyzed. (Martinsuo and Blomqvist, 2010; Fasna and Gunatilake, 2019.)

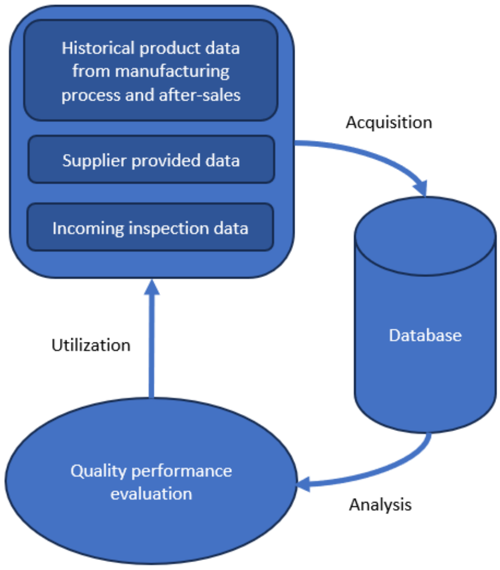

Figure 1: The data flow of quality management (modified from (Li et al., 2019)).

Despite the widespread adoption of digital technologies, significant challenges remain. Product quality data is often scattered in different systems and stored in digital and paper formats. This hinders the efficient monitoring and analysis of the data and reduces the efficiency and accuracy of traceability. As a result, companies struggle to comprehensively analyze the quality data, which limits their ability to get a holistic view of product performance and supplier reliability. (Li et al., 2019.) This thesis introduces a digitalized quality control process to address the inefficiencies in the current quality management practices. The proposed solution presented in Figure 1 aims to increase visibility and traceability by introducing a centralized database that combines data from multiple sources. In the database, product quality data is analyzed to evaluate the performance of raw material deliveries. Later, the data is utilized to review the supplier over an extended period and determine the requirements for the material and strategy used with that supplier as Burt (1989) stated.

1.2 Research Context

This thesis was conducted for a multinational manufacturing organization at its local plant in Finland. The company will be referred to as the case organization in this thesis. The thesis topic was initiated due to an identified need to improve the incoming inspection process for raw materials. The company has encountered challenges with the quality of supplied raw materials, revealing inadequacies in the current process.

Deviations in raw material quality directly impact the finished products as they can disrupt the production flow and reduce the quality of finished products. Thus, detecting non-conforming materials early in the process when they are still at the supplier site or during incoming inspection minimizes costs as issues identified first in production are more expensive and time-consuming to resolve. Additionally, the later the defect is detected, the risk that material has been consumed in other products increases. To mitigate these risks, a proactive framework for ensuring the quality of sourced material is critical to total quality management.

This thesis aims to enhance the quality control process of sourced materials by developing a digitalized tool to ensure process standardization (and thus the traceability and compliance of the quality requirements of the supplied material). There exist frameworks for managing sourced raw materials, but there are shortcomings in their compliance. This can lead to risky practices since if some non-conforming material in products is discovered late in the production process, significant project delays and additional costs may occur. Continuously monitoring material quality with the tool can help detect non-conforming materials before production. Furthermore, by enabling digital material traceability with the tool, resources allocated to manual traceability processes can be redirected, for example, to other quality improvement efforts. In addition to addressing the quality control challenges, this thesis investigates how business process re-engineering projects, such as digitalized solutions, can be effectively implemented to enhance organizational performance. The thesis context and objectives can be formulated into the following research questions:

RQ1: How can digitalization improve standardization and traceability of raw material incoming quality inspection process in manufacturing?

RQ2: How can successful implementation and adoption of a digitalized quality control process be supported?

1.3 Thesis Structure

The thesis is divided into seven chapters. After this introduction, which presents the background of the thesis topic, motivates the research and introduces the research context and questions, Chapter 2 provides the literature review conducted to build the theoretical background and foundation for the study. The chapter covers topics such as supplier quality management and digitalization of quality in manufacturing. It also presents frameworks for business process transformations, change management, and digital transformation success factors.

Chapter 3 describes the research methodology used in the study and provides the reasoning for conducting the research. The chapter also presents the data collection and data analysis methods used for conducting the study.

Chapter 4 presents the case organization's incoming inspection process based on the findings of the secondary data is presented. Chapter 5 analyzes the current state of the process, focusing on challenges in the current process and identifying requirements for the solution proposal.

Finally, Chapter 6 describes and evaluates the solution proposal, while Chapter 7 concludes the key findings of the thesis and considers its impact and future recommendations for the case organization.

2 Theoretical Background

2.1 Supplier Quality Management

Supplier Quality Management (SQM) is essential for improving internal quality performance as manufacturing outsourcing increases the product quality dependence on suppliers. Still, managing the quality of supplied products can become difficult due to the suppliers' increasing production scale and complexity. Nowadays, when outsourcing materials and semi-finished goods from suppliers, it is not uncommon to find final product quality incidents to be traced back to supplier quality defects. (Lee and Li, 2018.) For this reason, implementing supplier quality management within the operations is essential for ensuring final product quality.

The overall concept of quality is important when discussing supplier quality management. Juran and De Feo (2010) describe quality as fitness for purpose as every good produced must be fit for its purpose. This means that the product must meet the customer's requirements and be efficient for superior business performance. Similarly, according to American Society for Quality (2024c), quality can be either described as the characteristics of a product that bear its ability to satisfy stated or implied needs or as a product free of deficiencies.

Next, topics such as supplier quality control processes and methods for managing supplier relationships are shortly discussed. Still, as this thesis aims to develop a process control system rather than improve the product quality of the case company, these topics will be discussed shortly.

2.1.1 Supplier Quality Control Processes

When improving the quality of the manufactured product, having the right quality of the purchased materials is often the quickest and easiest way (Burt, 1989). The quality produced by the supplier includes the supplier's ability to deliver goods that satisfy customers' needs. Therefore, supplier quality management can be defined as the system in which quality is used to manage suppliers proactively and collaboratively. (American Society for Quality, 2024d.) According to Burt (1989), there are three activities that each have a critical impact on the quality of the product when ensuring the high quality of the purchased materials:

- determination of what material is required - including its quality, quantity, and timeliness
- selection of a source capable of providing the right quality at the right price
- management of a contract that ensures timely receipt of acceptable quality goods

To enable these activities, the atmosphere of the organization must be characterized by teamwork and requires defined roles and responsibilities of the system (Burt, 1989).

According to Burt (1989), the number of quality-related problems with purchased goods is closely connected to how the material requisitions in cooperation went through with the stakeholders. When the purchasing department has not accepted requisitions for materials until they have, in collaboration, provided precise specifications for that specific material, the number of quality-related problems with purchased goods has significantly decreased. The requirements for the materials must be reviewed when developing a new source of supply. Burt (1989) recommends that new sources of supply are pre-qualified to ensure that they have the capabilities from various departments, including technical, physical, financial, and attitudinal capabilities, to meet the customer's quality and quantity requisitions. Having a close partnership and communication with the supplier from the beginning is an invaluable resource, which can later enhance the quality of the sourced material and the overall operational success.

Figure 2: Relationships in Quality Management, Quality Assurance, and Quality Control

Quality control (QC) is one aspect of quality management (QM) and a fundamental aspect for ensuring that the product meets the requirements specified in the design phase and customer expectations. Product integrity, safety, and performance can be maintained with adequate quality control processes. Management and control of incoming raw materials serve as the foundation for ensuring the total quality of the end product. Before further discussing quality control, quality management, and its other functions besides quality control are clearly to be defined. These and their relationships are also presented in Figure 2.

According to Juran and De Feo (2010), the functions can be described as:

Quality Management (QM) is the comprehensive set of functions utilized for determining and achieving quality and preventing non-conformities within the organization. It consists of quality assurance and quality control.

Quality Assurance (QA) includes all planned and systematic activities implemented within the quality system that can be demonstrated to provide confidence that a product will fulfill requirements for quality. Typically, QA activities and responsibilities cover all of the quality systems.

Quality Control (QC) refers to the operational processes and activities that are used to ensure the quality of a product or process by ensuring that specified quality requirements are met. QC is a subset of the QA activities.

Managing the quality of materials sourced directly from suppliers is critical for maintaining a high quality of the end product. (Burt, 1989) state that many purchased material-related quality problems arise from unclear requirements. Therefore, systematically reviewing the requirements in cooperation with internal stakeholders, including quality assurance, purchasing, and manufacturing, can help identify and eliminate issues. Also, involving the supplier in this process can help identify the problems. When updating the requirements, it is often also beneficial to visit and audit the supplier's facility to understand their operations and needs. Similarly, for the supplier to better understand the buyer's needs for the material, return visits help the supplier to understand how their product will be used. These visits will not only improve quality performance but also communication and cooperation.

The methods for controlling the supplier's quality depend on the strategy and type of partnership with the supplier. According to Burt (1989), there are various methods for ensuring the quality of purchased material, including physical inspection, certification programs, and monitoring the supplier's process control data. Similarly, Lee and Li (2018) outlines that the three primary methods the buyer uses are direct investment, incentives, and inspection. When direct investments focus on improving incoming quality by investing in suppliers to improve processes or products, incentives are used to motivate the supplier by encouraging supplier to quality-improvement efforts and inspection to control the supplied quality by inspecting incoming units. These are further discussed in Section 2.1.2.

2.1.2 Methods for Managing Supplier Relationship

Managing the quality of the sourced material to be within the requirements is critical for maintaining the overall product quality. An inspection-based quality control system enables the buyer to identify defects upon delivery, thereby controlling the quality outgoing to subsequent processes. Detecting non-conformity units immediately upon delivery helps the buyer to hold suppliers responsible for defects. Without incoming inspection, the defective materials can more easily end up in end products and reach customers. This causes additional costs and expensive consequences for the company. Also, due to a lack of visibility, it might be difficult to trace the sourced material unit, making it difficult to hold the supplier responsible for the defect. Still, when manufacturing outsourcing increases, inspecting each unit received from the suppliers becomes more challenging. Thus, the buyer becomes more reliant on suppliers for product quality. Also, according to (Lee and Li, 2018), quality defects are frequently traced to the supplier's inadequate processes and procedures, which emphasize that the request for cooperative relationships, direct investments in supplier quality improvement projects, and appropriate incentive contracts are needed.

Based on these different methods for controlling the supplier quality, (Lee and Li, 2018) identifies three strategic approaches for the buyer. First, the investment-based strategy focuses on the buyer's investment effort. This strategy is to be used when the buyer's and supplier's efforts are strongly substitutable. When using this strategy, quality improvement can, for instance, be achieved through a supplier assistance program, which is an especially effective method in situations where the supplier lacks quality standards and management know-how.

Secondly, according to (Lee and Li, 2018), the inspection-based strategy is to be used when the efforts are strongly complementary. When both parties exert great effort to improve the quality, an inspection-based strategy with mutual defection can be replaced with a collaboration-based strategy. Thirdly, (Lee and Li, 2018) identifies an integrative strategy where investment, incentives, and inspection-based methods are used in cooperation for gaining additive efforts. Effective supplier quality management often requires coordination between the different strategies, and the weighting between different strategies differs based on the relationship and interests between buyer and supplier efforts.

Ensuring the quality of incoming raw materials is not just about implementing quality control measures for the materials but also involves effective management of the supplier relationship. A strong, collaborative relationship with the core suppliers can enhance the quality of purchased materials and improve overall operational excellence. When increasing the amount of purchased materials, according to Liker and Choi (2004), companies increasingly rely on their suppliers to reduce costs, improve quality, and develop new processes and products to keep up with their rivals. Therefore, companies should turn their arms-length relationships with suppliers into close partnerships, which can be a more challenging process than the companies imagine.

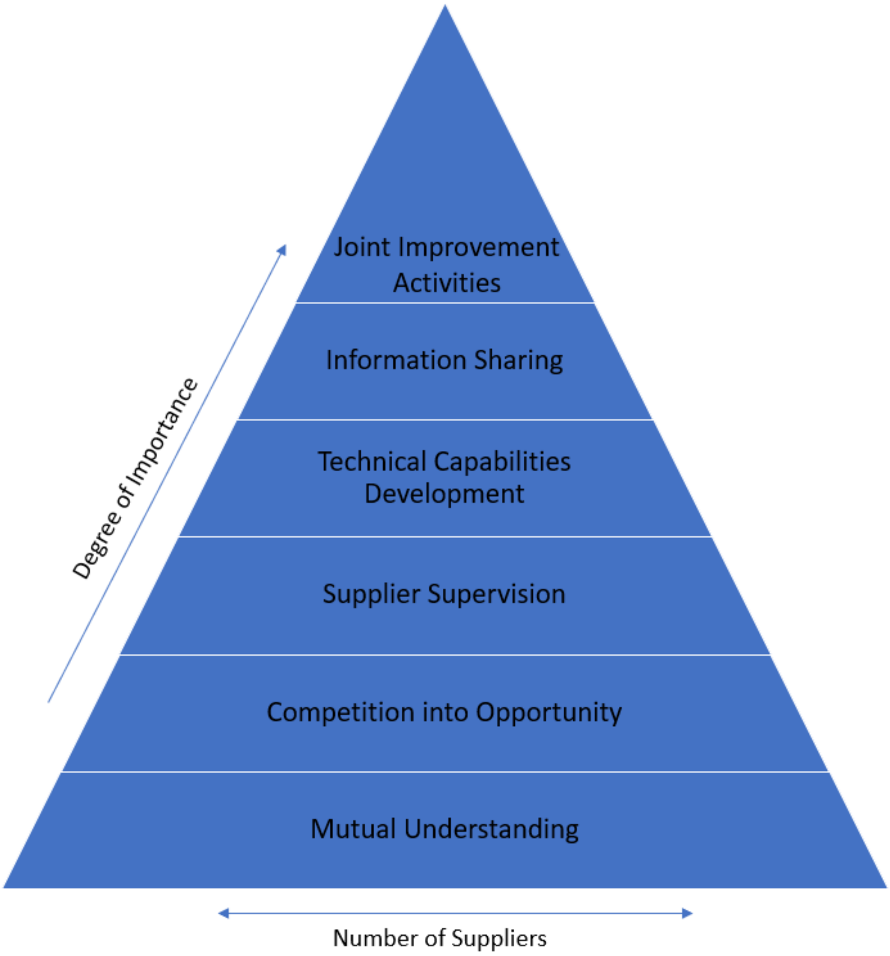

Figure 3: The Supplier-Partnering Hierarchy adapted to Liker and Choi (2004)

Liker and Choi (2004) introduce the supplier-partnering hierarchy, which consists of six steps, with one leading to another for building a collaborative relationship with the supplier. The six steps in the supplier-partnering hierarchy include topics described in Figure 3. These steps help the company build a relationship with the supplier so that the supplier can meet the high standards set by the company. These six steps are needed as a system is used to build the relationship successfully.

The first step is to understand the supplier's ways of working. Liker and Choi (2004) state that the company should try to learn as much as possible about the supplier as they trust that a good foundation for a partnership is that the company knows as much about their supplier as the supplier knows about themselves. Therefore, the company's executives should visit the supplier to get a picture of how the supplier works and to study the organization. By understanding the supplier, companies can handle orders concerning the suppliers' capabilities and commit to co-prosperity. In addition to the company getting a better understanding of the supplier, the supplier also understands that with the company's support, it can improve its operations. This first step process is quite time-consuming, but it is prone to be valuable for both the supplier and the manufacturer due to many examples.

The second step of the hierarchy includes turning supplier rivalry into opportunity. The company should always have two to three suppliers for each raw material and never depend on a single source for anything (Liker and Choi, 2004). This helps spark competition between vendors, especially when there is none, but only with the support of their existing suppliers. It also ensures that there are always other possible suppliers if some supplier does not fulfill requirements. Still, this kind of competition between suppliers should be especially encouraged during the product development stage as it allows the company an opportunity to promote the suppliers' production philosophies and systems in cooperation.

Supervising the supplier's work, setting targets, and monitoring their performance is the third step in the hierarchy. According to Liker and Choi (2004), the company can, for instance, send their supplier monthly reports where the supplier's performance is monitored and constant feedback is given. To enable continuous improvement, it is important that the supplier takes every problem seriously and uses problem-solving methods to try to solve the problem. This also leads to the fourth hierarchy step: developing the supplier's technical capabilities. Suppose the supplier is not capable of using problem-solving methods to uncover root causes. In that case, the manufacturer will facilitate the supplier with expertise in finding the root cause, but the supplier's engineers must execute the changes. Later, when the supplier can use these methods, the company should expect the supplier to be able to identify solutions to problems in product development and manufacturing (Liker and Choi, 2004).

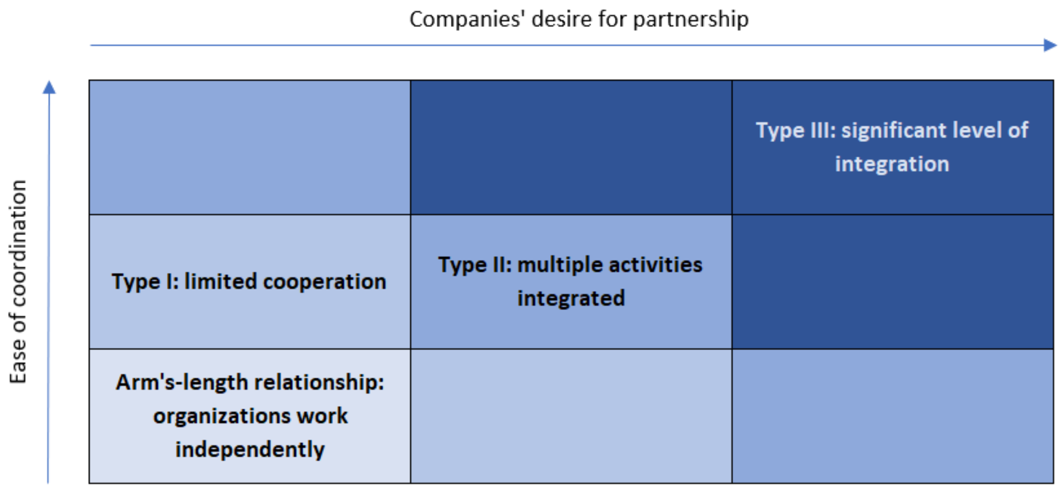

Figure 4: The Propensity-to-Partner Matrix for analyzing the suitable type of partnership according to Lambert and Knemeyer (2004)

The company should share information with the supplier intensively but selectively. The information with the supplier should be structured, for instance, by having a rigid format for information sharing with the supplier and having a clear agenda, time, and place for these meetings (Liker and Choi, 2004). Lambert and Knemeyer (2004) introduce a partnership model for helping companies build relationships with their suppliers on the right foot. For determining how deep the relationship with the supplier should be developed, Lambert and Knemeyer (2004) have determined a so-called propensity-to-partner matrix for showing how the scores indicate which type of association would be the best. The matrix discussed is described in Figure 4 where the axes of the matrix are "companies' desire for the partnership" and "ease of coordination."

Both axes are measured by giving the supplier points on facilitators, including corporate culture, compatibility of management philosophy and techniques, sense of mutuality, symmetry between the parties, and physical proximity. Gaining points from different facilitators adds points to the total score, and based on the matrix, the higher the score is, the more recommended the prescription for a stronger partnership is. The different types of relationships entail varying levels of managerial complexity and resource use. Where in Type I relationships, the organizations recognize each other as partners and coordinate activities and planning on a limited basis; in Type II relationships, they integrate activities involving multiple divisions and functions; and respectively, in Type III partnerships, they share a significant level of integration while viewing each other as an extension of itself. Similarly, in an arms-length relationship, the organizations work independently. (Lambert and Knemeyer, 2004.)

Lastly, the company should allow their supplier to continuously learn, improve, and enhance during the relationship (Liker and Choi, 2004). By allowing the supplier to learn and improve their operations continuously and sharing data on demand and supply, the supplier can more easily adapt their supply chain to stay competitive. Lee et al. (2004) state that the supply chain must have agility, adaptability, and alignment to enable good performance. When building a collaborative relationship with a supplier, as Liker and Choi (2004) state, agility, to ensure that external disruptions such as changes in short-term demand and supply can be handled smoothly, can be built by promoting the flow of information with the supplier, and by drawing up contingency plans and developing crisis management system (Lee et al., 2004). Similarly, for enabling adaptability to the supply chain, using intermediaries for developing fresh suppliers and creating flexible product designs is important (Lee et al., 2004). This is also supported by the second step of Liker and Choi (2004)'s supplier-partnering hierarchy. Lastly, keeping up transparent information exchange and knowledge with the suppliers, sharing risk with the supplier, and laying down roles, tasks, and responsibilities for suppliers are methods for alignment as by creating incentives for better performance (Lee et al., 2004) (Liker and Choi, 2004).

2.2 Digital Transformation of Quality in Manufacturing

Digitalization refers to the process of digitizing, including the transformation of analog data into a digital form (Parviainen et al., 2017). Similarly, Henriette et al. (2015) state that digitalization is the ability to turn existing products and services into digital variants and thus offer advantages over tangible products. Also, Henriette et al. (2016)

determines digitalization to be a change process that begins with adopting digital technology and evolves into an organizational transformation and value creation.

According to Parviainen et al. (2017), digitalization is one of the major business trends. Therefore, Markovitch and Willmott (2014) state that companies must accelerate the digitalization of their business processes to meet customer expectations. This includes automating existing processes and reinventing the entire business process (Parviainen et al., 2017; Markovitch and Willmott, 2014). This often includes cutting the steps required within the process, developing automated decision-making, redesigning operating models and roles, and adjusting data models to enable better decision-making and performance tracking. Altogether, digitalization requires combining old ways of working with new skills. (Markovitch and Willmott, 2014.)

From a manufacturing quality perspective, digital transformation refers to using advanced digital technologies to enhance processes used to ensure quality. According to (American Society for Quality, 2024a), the digitalization of quality, also referred to as Quality 4.0, is using digital technologies to enable significant business improvements within the quality field. Similarly, (Jacob, 2017) define the digital transformation of quality to include the digitalization of quality management but, more importantly, the impact of digitalization on quality technology, processes, and people. The digitalization of quality does not replace traditional quality methods but instead can be seen as an improvement on top of the traditional methods (Jacob, 2017; Parviainen et al., 2017).

As digital transformation improves the current ways of working, it refers to changes at several organizational levels. According to Parviainen et al. (2017), the changes in different levels of the organization can be referred to as:

- Process level: adopting new digital tools and streamlining processes by reducing manual steps
- Organisational level: offering new services, discarding obsolete practices, and offering existing services in new ways
- Business domain level: changing roles and value chains in ecosystems
- Society level: changing society structures (type of work, means of influencing decision making)

The benefits of digitalization are significant when the process is executed as planned. Digitalization can improve compliance by standardizing processes and enable a better real-time view of operations and results by providing structured insights into the operational data. Additionally, digitalization can enhance the business process efficiency, quality, and consistency by improving project accuracy and eliminating non-value-adding manual steps in the current process. (Parviainen et al., 2017.)

When replacing manual and paper processes with software-driven processes, data from the processes can be automatically collected and further used for a better understanding of the performance of the process and the risks related to it. Similarly, when data from the process activities is available in real-time and more accessible, creating up-to-date dashboards and reports of the process performance becomes more efficient. This allows the organization to better understand changes occurring within the process, enabling addressing problems before they become critical. (Markovitch and Willmott, 2014.)

With these digital tools, for instance, in supply chain activities, the quality-related issues with purchased goods can be identified and dealt with more rapidly Markovitch and Willmott (2014). Still, organizations need to recognize that migrating large-scale processes into a digital form takes a long time to deliver impact. In some cases, the digitalized solutions may not work. Therefore, when reinventing processes, everything related to the existing process should be challenged, and during the rebuilding, methodologies such as Lean and Agile should be exploited. (Markovitch and Willmott, 2014.)

Despite being ranked as one of the significant trends in business, companies are still struggling to understand digitalization's impact on the markets and the benefits it brings. This might be influenced by the fact that earlier, multiple companies have failed to efficiently implement digitalized solutions as a part of their continuous improvement processes. According to Parviainen et al. (2017), this has been due to the companies lacking overall digitalization strategy, other competing priorities, and inadequate technical skills.

To enable the successful execution of a digital transformation, the organization must develop and implement the right digital strategies and organizational change Parviainen et al. (2017). Markovitch and Willmott (2014) state that the digitalization process should start by designing the future state for each process without considering the current constraints. Other success factors presented by Markovitch and Willmott (2014) include having a skilled and motivated cross-functional team working with the digitalization project and strong managerial-level support. These success factors are further discussed in Section 2.4.

2.3 Standardizing Processes by Re-engineering

Business Process Re-engineering (BPR) aims to improve organizational performance by analyzing an organization's business processes and suggesting required alterations for improving performance and reaching strategic goals (Fasna and Gunatilake, 2019). Similarly, Gunasekaran and Kobu (2002) state that business process design and BPR depend on linking production procedures to business goals and objectives. Also, Martinsuo and Blomqvist (2010) state that understanding and developing activities as processes can be efficiently used to implement strategy, promote efficiency, and enhance cross-functional cooperation.

Process development activity, such as BPR, is often associated with productivity improvement and eliminating non-value-adding process activities. This process also often involves adopting new information systems to support it. For that reason, the key characteristics of process management include systems thinking, goal orientation, focus on value-adding activities, and effective use of the feedback provided within the process in modifying the operations. Therefore, process management and improving process productivity also emphasize sharing good practices and standardizing and automatizing process activities. (Martinsuo and Blomqvist, 2010.)

Regardless of the terminology used for describing the process improvement event, the process's focus and goal remain the same. For this reason, in this thesis, process development, business process re-engineering, and business process design are viewed as similar approaches and are considered synonymous and used interchangeably when describing improving organizational performance. That is, according to Martinsuo and Blomqvist (2010); Fasna and Gunatilake (2019), typically, the phases of business process re-engineering consist of the same steps, including:

- defining the project scope and objectives
- current process analysis and process re-modeling
- piloting and improvement
- process launch
- implementation and monitoring

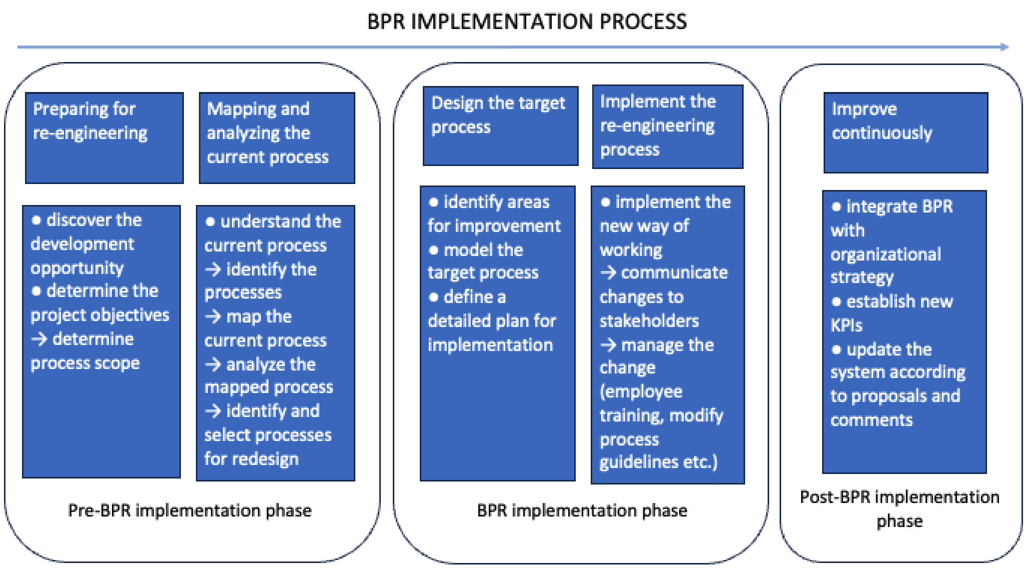

Figure 5: Framework for implementing BPR modified from Fasna and Gunatilake (2019) and Martinsuo and Blomqvist (2010)

To successfully enable a BPR implementation, these key activities should be followed to redesign the business process. Fasna and Gunatilake (2019) state that one of the main reasons an improved business process fails is the lack of proper implementation methodology. Similarly, Gunasekaran and Kobu (2002) state that carrying the BPR without following any framework and thus not understanding the way it is done, the most likely outcome of the new process would be continuing less than satisfactory current practice and automating the outdated current process. For these reasons, when leading a BPR implementation project, the steps presented in Figure 5 are highly recommended to be followed.

The BPR process starts with a pre-BPR implementation consisting of two key steps: preparing for re-engineering and mapping and analyzing the current process (Fasna and Gunatilake, 2019). Before starting the actual development process, the first step includes discovering the development opportunity and preparing for the re-engineering of the business process. After discovering the development opportunity, the project vision and the scope of the development project can be defined. The objectives of the company for the project must be clearly defined to be able to specify these characteristics. Similarly, during this process step, active managerial commitment and a project team for driving the BPR project are recommended to be gathered. (Fasna and Gunatilake, 2019; Martinsuo and Blomqvist, 2010.)

After clearly defining the project's objectives, scope, and expectations, the actual process development process can begin. In the second step of the pre-BPR, mapping and analyzing the current (AS IS) process, the existing stage of the process is mapped and analyzed. First, as much reliable data regarding the current process as possible is to be obtained. This way, an idea of the current efficiency, quality, and performance of the current process is gathered, which can be used as a baseline for improvement, and the existing process is identified and understood. (Martinsuo and Blomqvist, 2010; Fasna and Gunatilake, 2019.) During this process step, it is important to gain an unbiased understanding of the process and to form a solution only based on the data gathered during the BPR project. It is also useful to gather both general measurement data about the process and data illustrating the functionality of the process. Similarly, it is recommended to use multiple data collection methods such as interviews, group work, data mining on past performance, and field observations to analyze the current process. (Martinsuo and Blomqvist, 2010.)

When the current process has been identified and understood, the current process is to be mapped and analyzed. According to Martinsuo and Blomqvist (2010), the most commonly used methods for detailed process descriptions in process mapping include flowcharts, process flow diagrams, task matrices, and textual instructions. When mapping the existing process, the most important goal is finding areas for improvement. For this reason, the current and target processes are kept separately, even if the process description may be chaotic when mapping the current process, and the current activities and outputs may not meet the ideals. After mapping the current process, the current performance of the process is compared to the process objectives. This is a good way to identify development needs, find non-value-adding activities, and determine the performance baseline. (Fasna and Gunatilake, 2019; Martinsuo and Blomqvist, 2010.)

The pre-BPR implementation is followed by the BPR implementation phase, which consists of two elements: designing the target (TO BE) process and implementing the re-engineering process. In the first step of the BPR implementation phase, the areas for process development are to be analyzed, and the target process is to be modeled. Often, process redefinition deals only with a limited part of the process, and sub-processes are identified as poorly performing and have no value added during the previous step. When considering these, the target process is to be described so that the process can reach its performance objectives. Similarly, when describing the target process, it is vital to ensure it is feasible and simple. Also, the modeled target process is reviewed with the project team to ensure the process has been defined according to good practices and meets its objectives. If some activity, resource, or system in the target process is found not to add value, it should be removed. (Martinsuo and Blomqvist, 2010.)

After reviewing the target process, the process is piloted where it can be observed while making final corrections and adjustments to the process model. This is recommended before the extended implementation such as during the piloting stage. It can still be observed whether good data is obtained on the revised process being worthwhile and solving the problems that the company had with the earlier process (Martinsuo and Blomqvist, 2010). During this phase, the new way of working must be determined and informed to all stakeholders. This includes training and instructing all impacted personnel, making the needs and benefits of the change clear for employees, finding a way to deal with non-conformities from the new process, and modifying process guidelines targeted at different stakeholders. The process will not be implemented until the organization in question and the process customers are fully involved in. Therefore, a key characteristic for ensuring smooth implementation is open communication. (Fasna and Gunatilake, 2019; Martinsuo and Blomqvist, 2010; Povey, 1998.)

The last phase of the development process is the post-BPR implementation. During this phase, a new measurement and managerial system is set to establish and ensure the successful deployment of the new process. Also, new proposals and comments related to the updated system are received, and in the spirit of continuous improvement, these are used to develop the system further. Thus, feedback on the new process is continuously gathered and analyzed for improvement. (Martinsuo and Blomqvist, 2010.)

To ensure that the business process re-engineering has succeeded, Martinsuo and Blomqvist (2010) has listed perspectives as good practices to be considered and taken into account when modeling processes. The list of good practices to be considered is as follows:

- the process is a clear, logical entity
- the process should be described in a consistent and straightforward manner

- once the process is described, everyone should follow the process
- the process should be managed so that it achieves its objectives

Also, for the re-engineered process, there is a need for a good monitoring system that considers the process inputs and outputs and the functionality of the process in relation to the objectives. A monitoring system and its indicators are used to portray the actual performance of the process. For the organization to benefit from the re-engineered process as much as possible, the monitoring system should consider the different stakeholders' requirements and provide reliable and easily understandable data that is as automated as possible to highlight clear ideas of improvement from the process. (Martinsuo and Blomqvist, 2010.)

For the business re-engineering to be as effective as possible, the process objectives determined during the first step of the process development cycle must align with the company strategy and promote its fulfillment. When determining process objectives, according to Martinsuo and Blomqvist (2010), the following process objectives should be determined:

- discuss with end stakeholders their expectations and requirements for the process
- set performance objectives for the process
- develop sub-processes so that the process performance objectives can be achieved

2.4 Success Factors in Digital Transformation

2.4.1 Change Management

According to Finney and Corbett (2007), change management is one of the most critical success factors when considering ERP-driven BPR projects. It focuses on managing organizational change by building user acceptance and positive employee attitudes in all process improvement activities, especially during the deployment. Similarly, according to American Society for Quality (2024b), implementing a structured change management approach into the BPR project is critical for helping to ensure a beneficial transition while mitigating disruption. Therefore, according to Miller (2020), with change management activities, it can be ensured that the entire organization can navigate the BPR transition smoothly.

Miller (2020) presents five steps for a successful change management process. The steps include:

- prepare the organization for change
- craft a vision and plan for change
- implement the changes
- embed changes within company culture and practices
- review progress and analyze results

Prepare the organization for change. An organization must be logistically and culturally prepared to pursue and implement change successfully. According to Miller (2020), preparing the employees for the change is initially more important than logistically preparing for the BPR. Cultural preparation's most important goal is to help the employees recognize and understand the need for change. This way, everyone involved with the process can act as a force for change and raise awareness of the challenges and problems with the current process. In addition, involving everyone associated with the change management process can help reduce friction and resistance later on.

Craft a vision and plan for change. When the organizational alignment towards the change management activity occurs, and the organization is ready to embrace change, a realistic plan for the change activities is to be developed. The plan determines strategic goals, KPIs, project stakeholders, and scope. The strategic goals are objectives that the company aims to work towards during the change management process, and KPIs are scales for measuring process success. When designing the KPIs, it is important to ensure that they are specific, measurable, and achievable and align with the project's overall strategic goals. Similarly, the scope of the project is to be determined, including defining the project boundaries, such as what steps and actions will be a part of the project and what will remain outside the project scope. Additionally, the project stakeholders who will oversee the change implementation and the team responsible for the implementation are determined. While the plan should be well-structured and thoroughly planned, it is still important to account for possible barriers that require agility to overcome during the implementation timeline.

Implement the changes. After having a clear plan for the implementation, the actual change management implementation can begin by following the steps outlined within the plan for implementing the required change. During the implementation, employees must be empowered to take the necessary steps to achieve the goals. It is important to have open communication and repeatedly recall why change is being pursued and what the organization's vision is to ensure smooth implementation.

Embed changes within company culture and practices. Embedding changes within company culture and practices is critical for preventing the process from reversing to its prior state. Without embedding changes within the company's culture and practices, sliding back to the old habits is easy. Therefore, tools to be considered for embedding change include, for instance, implementing new organizational structures, control, and reward systems.

Review progress and analyze results. After completing the change management implementation, conducting analyses and reviewing the process can help the company leaders better understand whether the change initiatives were successful, failed, or created mixed results. Reviewing the process is crucial, as a completed change initiative does not guarantee that the process was successful. In addition, reviewing the process offers valuable insights and lessons that can be leveraged in future change efforts.

Dimension Label	Description
Leadership Issues	Managerial mission statement and shared values Understanding of why the change is needed Realistic preview of expected outcome
Barriers to Change	Identifying barriers Understanding organizational structure Empowering and supporting employees
Communications	Effective communication channels Communication plan towards employees Single point of contact for ideas and comments
Implementation of Change and Control	Planning implementation carefully Enabling teamwork Collecting employee feedback
People Culture Factor	Establishing new organizational culture
Change Review	Utilize process mapping Set KPIs

Table 1: Challenges in Change Management (Huq et al., 2006)

Similarly, Huq et al. (2006) studied change management challenges in organizations when implementing an ERP-led BPR. They observed six change management dimensions that could be described as pitfalls when implementing change management. These are presented in Table 1.

Leadership issues. According to Zairi and Sinclair (1995), leadership is the most important facilitator of large transformation efforts. The case study of Huq et al. (2006) observed similar results. In change management, leadership is needed to develop a mission statement and shared values and define roles, responsibilities, and expected outcomes. This ensures that the employees and stakeholders understand why change is needed, what the efforts of BPR are, and how management will support the employees during the BPR process. (Huq et al., 2006.) In Huq et al. (2006)'s case study, it was observed that management could not just be part-time leaders and instead for ensuring change management, management should be involved in the project from beginning to end. This helps the management to create a realistic review of the project and its outcome, motivate change, and minimize resistance during the BPR.

Barriers to change. If the organization is composed of loosely structured coalitions of individuals and groups with different preferences and interests, getting employee acceptance for the BPR project can be complicated, even if they understand the need for change. For this reason, management needs to coach the employees to say "goodbye" to how things used to be and involve them in the BPR project to help them grasp new ideas. Moving forward with the BPR should not be an option for the employees but rather a necessity for survival. Therefore, this can cause turnover in some employees. (Huq et al., 2006.)

Communications. Huq et al. (2006)'s case study state that effective communication can dispel communication and employee resistance. In conclusion, Huq et al. (2006) state that the employees must be educated to ensure smooth BPR. Therefore, the plans should be communicated to the employees and stakeholders with an effective communication plan. Also, there should be enough lead time for the employees to get used to the re-engineered process before implementing it. Similarly, a single point of contact should be provided for the employees. This allows them easily to offer their opinions of the BPR and give comments and suggestions. In summary, when involving employees in project planning, design, and development, they will not be indifferent to the project, and resistance during process launch will be minimized. (Huq et al., 2006.)

Implementation of change and control. According to Huq et al. (2006), a carefully planned implementation has to go through preparation, analysis, design, pilot testing, and actual implementation. These steps are further discussed in Section 2.3. Still, it is good to note that collaboration between different teams, top management, and blue-collar workers is needed to understand the business process.

People culture factor. The company culture should support the new work procedure when establishing the BPR project. BPR often requires a cultural transformation for the new working methods to be pervasive. When the employees know what is expected from them and what to expect from the company, cultural transformation can become easier. For that reason, during the BPR, the creation of a new supportive culture is essential. (Huq et al., 2006.)

Change review. Change review of the implementation should encompass comparing project progress to the set timelines, assessing how the new system works across functional boundaries, and continuously reviewing for unforeseen objectives (Huq et al., 2006). Suitable methods for reviewing the change include, for instance, process mapping and the PDCA (Plan, Do, Check, Act) method. Process mapping identifies and describes value-adding activities and associated information and material flows. According to Martinsuo and Blomqvist (2010), methods for mapping the process include, for instance, flowcharts and value chains. Process mapping is also helpful in seeing how the changed process works about other processes Huq et al. (2006). Similarly, the PDCA (Plan, Do, Check, Act) method helps to collect data about the process performance Huq et al. (2006).

Despite change management being one of the most significant challenges when implementing BPR, organizational change management activities are often discontinued after the process improvement pilot test phase. In the third phase of the process improvement, change management activities are either addressed briefly or not covered during the post-implementation phase. (Povey, 1998.) According to Fasna and Gunatilake (2019); Miller (2020), discontinuing the change management activities early during the process implementation phase gives the project a high probability of failing in action. For this reason, the company needs to consider the implications of the project continuously and prepare a change management program for deploying the project.

2.4.2 Critical Success Factors for Digital Transformation

As change management occurs to be the most cited success factor when discussing ERP-driven BPR, other highly important success factors still exists that should also be considered. Finney and Corbett (2007)'s study explored the current literature base of critical success factors. Most of the critical success factors identified in the study were partly already discussed in Section 2.4.1, but in this section, they will be discussed in more detail.

Strategic Factors	Tactical Factors
Top management commitment and support	Balanced team
Visioning and planning	Project team
Managing cultural change	Communication plan
Change management	Empowered decision-makers

Table 2: Strategic and tactical critical success factors in digital transformation (Finney and Corbett, 2007)

Finney and Corbett (2007) state that critical success factors are those factors that the organization must "get right" to enable smooth transformation. The research Finney and Corbett (2007) identified success factors and grouped these into two categories: strategic and tactical. These are presented in Table 2.

Out of the success factors presented in Table 2, top management commitment and support are among the most widely cited. This refers to the need for committed leadership at the top management level, which ensures support when anticipating any glitches that might be encountered in the BPR process. Similarly, according to Finney and Corbett (2007), visioning and planning a strategic success factor as through preparing it, the business vision will be articulated to the organization, clear goals and objectives are identified, and a link between the business goal and the strategy is formed. Also, Al-Mudimigh et al. (2001) state that visioning and planning are important during the process, and best internal and external practices for digital transformation are benchmarked. Finney and Corbett (2007) also observed that managing cultural change should be one of the strategic success factors considered in BPR projects. The need for this was already discussed in Section 2.4.1, similar to change management, as it can be seen as a subcategory.

Finney and Corbett (2007) state that similarly to strategic factors, tactical factors such as balanced team, project team, communication plan, and empowered decision-makers. These as enablers of change management were also discussed in Section 2.4.1. Out of these, the first two relate to the need for an implementation team. From the perspective of a balanced team, the team should span the organization and possess special expertise in IT skills and in different business areas of the company. Similarly, from the project team's perspective, the team should consist of motivated individuals committed to the project and possess the necessary skills to probe for details during the pre-BPR phase. Communication plan refers to the need for open communication within the entire organization, including everyone from shop-floor employees to top management. Lastly, empowered decision-makers refer to the need for the project team to be able to make necessary decisions in due time to enable implementation to be completed on schedule. (Finney and Corbett, 2007.)

2.5 Key Insights of the Literature Review

Firstly, in this literature review, the critical role of the SQM to ensure raw material quality, which directly impacts the quality of the final product, is emphasized. Effective SQM requires organizations to clearly define raw material requirements and foster collaboration with the supplier. Similarly, utilizing structured quality control methods can reduce material defects. Thus, these methods should be integrated into the supplier relationship. However, building a relationship with the supplier requires careful consideration of factors such as the shared level of knowledge and trust. Frameworks such as the supplier-partnering hierarchy and propensity-to-partner matrix provide a structured approach to building the relationship and aligning the desire for partnership.

Secondly, the literature review also discusses the digitalization of quality management and its potential benefits and challenges. Integrating advanced digital technologies with traditional quality methods can enhance operational performance and process visibility. However, for successfully managing such transformations, the strategy has to be clear, and a process development framework must be followed. The literature especially emphasizes the BPR method. BPR recommends systematically analyzing the current state, piloting the process, and continuously improving it based on proposals and comments to ensure successful integration into the organization. Success factors such as change management are key drivers in overcoming resistance and ensuring a smooth transformation.

These findings provide a strong theoretical foundation for the empirical study. The development of the digitalized tool should align with the BPR framework and consider critical success factors such as change management to ensure a smooth process implementation. Also, the appropriate level of collaboration with different case suppliers should be determined using the supplier-partnering hierarchy. When considering suitable methods for incoming raw material quality control, the various strategies presented in Section 2.1.2 should be carefully evaluated.

3 Research Methods

3.1 Research Design

This thesis aims to enhance the case company's current quality control process. To achieve this, the study aims to analyze the current state of the process by collecting qualitative and quantitative data during an intensive period. This cross-sectional data collection includes a variety of methods described in Section 3.2 to gain an empirical understanding of the current state. The gathered data is then analyzed separately in respective formats, and insights are derived from various sources to offer multiple development perspectives. In addition, existing theories and frameworks are analyzed to guide the implementation of improvements identified through empirical research.

The research design follows the research onion model described by Saunders et al. (2019), which provides a structured framework for conducting the methodological choices. Based on the research onion, the chosen methodology is a case study with an inductive approach, employing a mixed-methods research strategy for data collection and analysis. A case study is considered a suitable method because the boundaries between the phenomenon being studied and the context within which it is being studied are not clearly defined, and the research combines both qualitative and quantitative data sources (Eisenhardt, 1989; Saunders et al., 2019). The research follows an inductive approach, as the research objectives are progressively defined during the data collection and analysis. This approach is especially appropriate when the research aims to build understanding through empirical observations (Hamel et al., 1993; Saunders et al., 2019). Furthermore, given that both qualitative and quantitative methods are used in parallel, the study aligns with the principles of mixed-methods research (Saunders et al., 2019).

3.2 Data collection

As described in Section 3.1, the case study research incorporates both empirical data and existing theories. This section describes the data collection methods used in the empirical study. The empirical research setting can be characterized as complex as it includes multiple stakeholders whose objectives do not readily align. Therefore, multiple research methods were employed to incorporate diverse stakeholder perspectives and to comprehensively address the complexity of the problem. The data collection methods and their sources, summarized in Table 3, ensure a comprehensive understanding of the case context. Next, these are discussed in more detail.

Category	Source
Interviews	Internal: Local interviewees Internal: Global interviewees
Secondary data	Global operating procedures Local operating procedures Earlier concepts of the target solution Local supplier quality meeting minutes Data from previous incoming quality inspections
Literature	Articles E-Books
Field observations	Raw material warehouse Quality Control Production
Development workshops	Presenting findings to the steering group Further discussing process requirements Further discussing the proposed tool
Pilot testing	Set up of data and the system Evaluating proposed system in the test system

Table 3: List of data collection methods

3.2.1 Interviews

Interviews with relevant internal stakeholders were held to understand the current state of the process and the operational methods. The interviewees represented multiple departments, roles, and organizational levels within the case company. As they each had different connections to the process and its various stages, the interviews provided a comprehensive overview of the process from multiple perspectives. Table 4 lists all interviewees.

Date	Title / Position of the Interviewee	Duration
21st May 2024	Quality Control Supervisor	37 min
21st May 2024	Quality Manager	43 min
22nd May 2024	Logistics and Warehouse Manager	47 min
23rd May 2024	Material Manager	1 h 23 min
3rd June 2024	Production Manager	52 min
4th June 2024	RM Buyers (2)	1 h 12 min
13th June 2024	Quality System and Supplier Quality Director	43 min

Table 4: List of internal interviews

The interviews were conducted in a semi-structured format and consisted of predefined questions that encouraged open discussion. In a case study type approach, the questions were primarily "how" and "why" types, which guided the discussion toward topics such as the current process, its problem areas, possible root causes, and ideas for improvement. The interviews aimed to gain insight into stakeholders' perspectives on the current process. They were particularly aimed at gathering perspective on the following:

- the current state of the quality control system
- the target state of quality control
- root causes of the current state
- how to develop the target state of quality control
- implementation of the target state process

as well as to understand the undesirable effects of the current system. Furthermore, additional secondary data was obtained during the interview process, as many interviewees shared their documentation on the process and its frameworks.

As is typical in semi-structured interviews, the questions were tailored based on the position of the interviewee (Saunders et al., 2019). For instance, when interviewing quality contacts, the questions focused on existing quality control frameworks, inspection plans for different raw materials, and challenges with controlling incoming quality. Similarly, when interviewing supply chain contacts, the questions focused on themes such as existing ERP system, warehouse management, and supplier management. Specific themes, such as communication and cooperation, were consistently discussed across all interviews.

Local interviews were conducted as face-to-face meetings at the plant site. Due to distance, global interviews were held online. The duration of the interviews ranged from 43 minutes to 83 minutes. The interview data was gathered as written notes, which were expanded after the interviews for further analysis. If any answers required clarification, follow-up questions were sent to interviewees with minimal formality. Furthermore, during the solution proposal phase, the interviewees provided continuous feedback, which helped guide the development project in the right direction.

3.2.2 Secondary Data

The secondary data utilized in the empirical study consisted of the case organization's operating procedures, earlier conceptualized drafts of the target solution, and data from local supplier quality meetings and previous quality inspections of incoming raw materials. The case organization's internal documentation, such as operating procedures for raw material approval, incoming quality inspection, and material traceability at both the global and local levels, provided a valuable and straightforward source for understanding the organization's expected workflows and processes. These documents were compared with practices observed in interviews and field observations to identify bottlenecks and areas for improvement in the system. Additionally, the case organization had conceptualized a draft target solution for the process some years before the thesis work, which was particularly useful for understanding the desired flow in the ERP system.

Furthermore, meeting minutes from local supplier quality review meetings were analyzed to assess previous efforts to enhance supplier quality and the methods to track incoming quality. This data encouraged the empirical study to generate new ideas rather than replicate the past approaches. In addition, gaining access to the previous inspection data helped the researcher understand how the incoming inspection data had been reported in the current state and observe improvement areas.

Data from different secondary sources was recorded in research notes during the review process. Overall, as this thesis aims to enhance the current process, internal secondary data played a crucial role in identifying gaps between expected and actual workflows, and highlighting areas for improvement.

3.2.3 Field Observations

While the interviews provided a high-level organizational perspective on the current process and its undesirable effects, and internal procedures outlined the expected workflows, field observations were conducted to gain a shop-floor-level understanding of the system in practice. The objective of the field observations was to gain a detailed understanding of the current system and its operational practices. The interviews revealed that not all procedures and frameworks were followed as intended. Therefore, the field observations focused on following the operators' ways of working while simultaneously discussing the bottlenecks and undesirable effects of the current system.

Since many operators work in shifts, field observations proved to be a more effective data collection method than interviews. Moreover, field observations allowed the researcher to directly assess the actual state of the process and evaluate the case organization's readiness for the digital tool. The field observations were separately conducted first at the warehouse, where the incoming raw materials arrive, then in the quality control laboratory, where internal tests are completed, and later in production. Field observations at the plant site were conducted during a three-month period. During this time, data was collected by taking notes and pictures, which were later compiled into research notes and analyzed to identify challenges and deviations from expected workflows.

3.2.4 Development Workshops

The development workshops were conducted in two parts. The first workshop was organized after designing the initial draft of the target process. This draft was developed based on findings from interviews, field observations, and secondary data analysis. It aimed to present the identified areas for improvement and gather feedback on the draft version of the target solution and the digital tool. Since this workshop took place during the process development phase, the workshop participants provided valuable improvement ideas and feedback on both the digital tool and the target solution.

The workshop was arranged for several employees from different departments of the organization, which broadened the discussions with multiple perspectives. Since most attendees had already contributed during earlier data collection phases, they were familiar with the project and its objectives. The workshop session consisted of a short introduction to the thesis topic, and the findings of the current state analysis, its bottlenecks, and their root causes were presented. Next, the first proposal for the target solution and the digital tool and its process flows were introduced to the workshop attendees. The session concluded with an open discussion where the attendees provided feedback on the future development of the draft solution and suggestions for its future development.

During the workshop, feedback was collected by taking notes, which were later compiled into research notes. Additionally, follow-up discussions were conducted to clarify specific points. The first workshop was iterative, as following the initial session, the solution proposal was refined multiple times before moving to the pilot testing.

The second workshop took place after pilot testing the proposed solution. It focused on reviewing the pilot testing findings, assessing the case organization's readiness for broader system implementation, and discussing the future development of the system. Additionally, the documentation related to the proposed solution and instructions using the digital tool and other process improvements were introduced. Following the second workshop, the thesis researcher made only minor refinements to the proposed system. The primary goal of this workshop was to conclude the thesis findings and transfer knowledge to the case organization. Additionally, the broader findings that extended beyond the scope of the thesis were discussed.

3.2.5 Pilot Testing

The proposed solution with the digital tool was tested for the case raw materials in the pilot testing. This phase included collecting inspection data from these raw materials, setting it up to the ERP system, and testing its functionality when doing the goods receipt and incoming inspection for arriving raw material deliveries. Pilot testing was crucial to evaluate how well the proposed system and digital tool functioned as an interface during the goods receipt and incoming inspection process. It provided immediate insights into the system's usability, accuracy, and alignment with the case organization's requirements.

The pilot testing process involved several preparatory phases before actual system testing. First, the requirements for the selected case raw material's incoming inspections were gathered from various case organization's databases. Next, the gathered requirements were reviewed in a collaborative meeting with different stakeholders. Then, the data was set up in the system.

Once the data was configured in the ERP test system, the proposed process was tested using different case raw materials with varying inspection requirements. First, the ERP system was tested by the thesis researcher with the support of the case organization's system analyst. This was an iterative process, with multiple rounds of testing focused on refining the system functionality and data accuracy and ensuring system alignment with the requirements of the proposed solution. Next, the system was tested in a demonstration session with multiple case organization employees from different departments. During the demonstration session, employee feedback on the digital system was collected by recording the session, which was later compiled into research notes. Based on these, further refinements were conducted to the proposed solution before the second development workshop.

3.2.6 Summary

Phase of the Research	**Data Collection Method**
Gaining theoretical understanding	Literature review
Gaining practical understanding of the current process	Interviews Field Observations Secondary Data
Developing the solution	Development Workshops Pilot Testing
ERP pilot testing	Pilot Testing Development Workshops
Assessing the final solution	Development Workshops

Table 5: Summary of the Utilized Data Collection Methods

In Table 5, all data collected with different methods introduced above is summarized and linked to the research questions introduced in Section 1.3. The chosen data collection methods presented for each research question were found to be the most appropriate for answering the questions and fulfilling the thesis objectives.

3.3 Data analysis

Data analysis was conducted systematically for each data collection method utilized in the empirical research. Table 3 provides an overview of the data collection methods, and their role in the research process is summarized in Table 5. As is typical for an inductive case study, the empirical research findings emerged through the iterative data analysis (Saunders et al., 2019). Additionally, the empirical study followed the BPR implementation process outlined by Fasna and Gunatilake (2019); Martinsuo and Blomqvist (2010), as introduced in Section 2.3. Therefore, the data analysis was conducted in three phases, aligning with the BPR framework: the pre-implementation, implementation, and post-implementation phase. In the pre-implementation phases, the current process is mapped and analyzed. In the implementation phase, the target process is designed and refined. Lastly, in the post-implementation phase, the system is continuously improved.

In the pre-implementation phase, the main objective was to gain a detailed understanding of the current process, identify deficiencies, and establish requirements for improvement. This was done through interviews, field observations, and secondary data analysis. The data analysis was conducted using thematic coding, where collected data was manually grouped into categories based on emerging themes. Based on the findings, the initial draft of the target process was designed. The analysis began by reviewing internal documentation, such as global and local operating procedures, supplier quality records, and earlier conceptualized target process drafts. Relevant information was recorded in research notes, which were also utilized as the foundation for the empirical research. These also worked as a basis when designing the interviews and field observations, ensuring that the key findings were further explored.

Where the secondary data analysis focused on building a foundation for the empirical research, the interviews focused on understanding the current state, identifying its undesirable effects and challenges, and understanding what is required from the process. The interviews were analyzed one by one using a thematic approach. In the approach, the interview notes were reviewed multiple times, and the responses were categorized into key themes, including, for instance, bottlenecks, deviations from operating procedures, and requirements. If some responses remained unclear, they were clarified through follow-up questions with the interviewees. For a more hands-on understanding, field observations were used to identify more practical challenges in the current process and why specific procedures were not followed in practice. Additionally, field observations assessed the case organization's readiness for the digital. Similarly to the interviews, the field observations were analyzed one by one using a thematic approach. Finally, all findings were triangulated before developing the initial process improvement proposal.

In the implementation phase, the target process was iteratively designed and tested. During this phase, development workshop discussions, iterative feedback rounds, and pilot testing were utilized as data source methods. Similarly to the pre-implementation phase, a thematic approach was applied for data analysis. First, data from the collaborative development workshop, where the initial target process was presented to the key stakeholders, was analyzed by categorizing it. These categories were aligned with the operating procedures, practical challenges in implementing these steps, and the usability of the digital tool. Based on analyzed feedback, the process proposal was iteratively modified and in between the rounds, follow-up discussions with the key stakeholders were conducted to get feedback before the pilot testing. The proposed system was first set up in the ERP test environment for selected case raw materials during pilot testing. Iterative test rounds were then conducted to align the digital system with the developed target process. Similarly to developing the solution proposal, this consisted of multiple iterative rounds to match the functionality of the digital solution with the solution proposal. Data during this phase was mostly collected by identifying gaps between the proposed and actual digital tool and by having discussions with key stakeholders, similar to after the development workshop. A thematic approach was utilized for analyzing the gathered feedback and it was categorized into critical alignment issues, usability improvements, and minor deviations. When the researcher had solved the critical alignment issues and the usability improvements, the digital tool was presented to key stakeholders in a demonstration session. The session was recorded and later compiled into research notes.

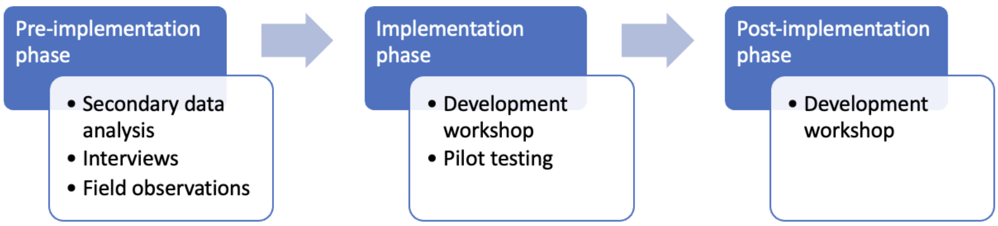

Figure 6: Data analysis process of the empirical research

In the post-implementation phase, data from the demonstration session was analyzed using the thematic approach. In addition, the second development workshop was hosted to discuss the findings of the demonstration session. Similarly than, after the first phase of the pilot testing, the data was categorized into critical alignment issues, usability improvements, and minor deviations. Based on these findings, the principal critical alignment issues and the usability improvements were solved by the researcher, and the minor deviations and improvement ideas beyond the project scope were reported to the case organization as future recommendations. Finally, the data analysis process of the empirical data is presented in Figure 6, summarizing the systematic approach applied in each phase.

4 Case Organization's Incoming Inspection Process Description

This section presents the case organization's operating procedures and documented frameworks that define the ideal quality control process for the incoming raw materials. The findings are based on the secondary data analysis, including local and global operating procedures and relevant local quality frameworks. As the empirical part of this thesis focuses on enhancing topics such as process control and data flow, this section aims to create a baseline for evaluating deviations in the actual process by describing the intended quality process. This section outlines the expected workflow, key responsibilities, and the requirements for different raw materials for the selected case raw materials. However, since this topic is quite broad ans has multiple sub-processes affecting the system, this section aims to provide a high-level overview of the operating procedures.

In the case organization's procedures, the approved raw materials, depending on their supplier, are divided into two categories: free pass and non-free pass. Typically, if the supplier of the raw material and the raw material have been approved, and there have been no non-conformities in the raw material deliveries or their documentation at least within the past four months, the raw material is categorized as a free pass material. Correspondingly, new raw materials, new raw material suppliers, and free pass raw materials where non-conformities either on delivery documentation or on the products have occurred are categorized as non-free pass materials. In order to reclassify a non-free pass material with a free pass categorization, its deliveries shall have no non-confirmities for a certain period. The changes in the raw material and supplier classification are addressed at the purchasing meetings.

Inspection Item	**Free Pass**	**Non-Free Pass**
Labeling of the package	Yes	Yes
Condition of the package	Yes	Yes
Raw material type according to order	Yes	Yes
Quantity according to waybill	Yes	Yes
Checking supplier quality certificate	Yes	Yes
Internal incoming inspection tests	Yes (as sampling inspection)	Yes

Table 6: Scope of the Incoming Inspection Process

In general, the scope of the incoming inspection of the incoming raw material deliveries depends on the classification of the raw material and its supplier. The scope of the inspection can be divided into several categories and is presented in Table 6. As presented in Table 6, the labeling and the condition of the package are to be checked for each raw material delivery. There shall be no damages in the packages, and their labels must be unambiguous and easy to read. The raw material type must be according to the order, and the quantity of the delivery must be according to the waybill. The supplier must present a supplier quality certificate for the incoming goods with each delivery. During the incoming inspection, the test results presented in the certificate are compared to the case organization's requirements.

For non-free pass deliveries, internal incoming inspection tests are carried out for each delivery. Consequently, for free pass deliveries, these receiving inspection tests are carried out as sampling inspections. The incoming inspection test characteristics, requirements, and test frequency (for free pass deliveries) are predetermined by material and quality management.

Finally, approved supplier quality certificates are marked with a green "OK" stamp, the inspector's signature, and the data. Also, approved raw material packages are to be marked with a green sticker presenting their approval or by moving the lot to an area reserved for approved raw materials. Similarly, rejected test reports are to be marked with a red "Rejected" stamp in addition to the inspector's signature and the date. Rejected raw material packages are marked with red non-conformity tape and moved to a quarantine area. These lots are also blocked in the ERP system. If the raw material lot is rejected based on a non-conformity occurring during the incoming inspection or later in production and it is attributable to the supplier, typically incorrect quantity on the delivery, deficiencies in the quality certificate or a non-conformity in the incoming inspection, or in production, a supplier non-conformity notification is to be sent to the supplier. Depending on the nature of the non-conformity, it is completed by the purchasing, material management, or quality department. Typically, purchasing is responsible for notifying the supplier of the actions. In cases where the raw material lot is urgently needed in production before it can be approved by following the presented procedure, the case organization has procedures for such cases. Still, these remain out of the thesis scope and thus are not presented in this section.

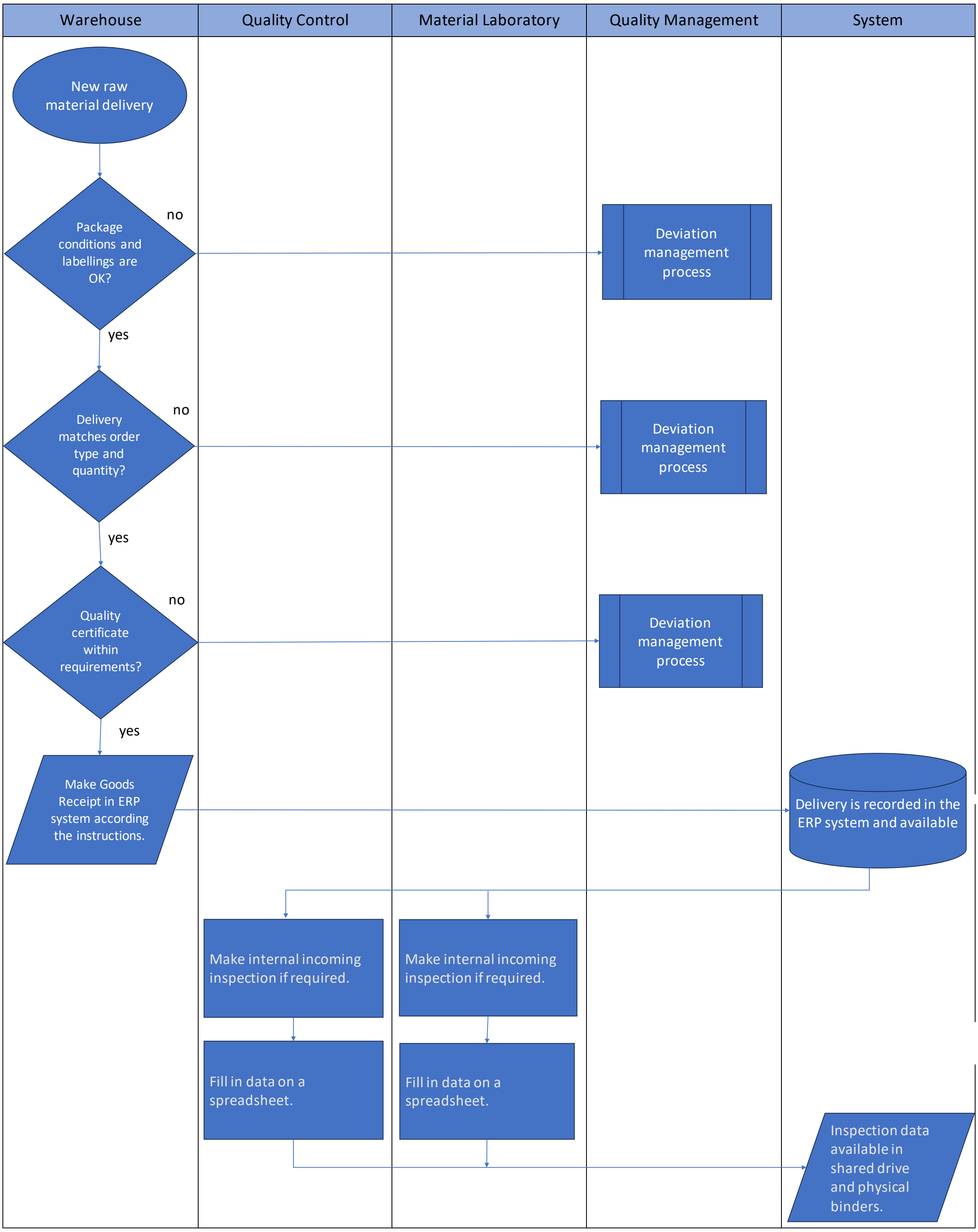

Figure 7: Process of the current incoming quality inspection

Figure 7 presents the flow for the raw material incoming inspection process. In addition to the incoming inspection process described above in this section, it presents the process responsibilities and how the data flows in the case organization's system. The flowchart also shows how some internal incoming inspection tests are completed by the material laboratory and some by quality control. This depends on the characteristics that are tested during the inspection. The flowchart also presents how quality control reports data from the tests to spreadsheets documented in the case organization's shared drive while the material laboratory uses a document software from where the data is as well transferred to the shared drive.

5 Current State Analysis

In this section, the findings of the current state analysis are presented. According to Martinsuo and Blomqvist (2010), a current state analysis provides insights into the efficiency, quality, and performance of the existing process and can be used as a baseline for improvement. The findings discussed in this section were gathered during the first phase of the empirical study through secondary data analysis, interviews, and field observations, as well as in the development workshops. It is important to note that the statements and the comments provided in this section do not offer a complete overview of the situation at the case organization. Additionally, this thesis project focuses only on a few case materials, and the information provided during the empirical study is mainly related to those materials.

In Section 4, the case organization's raw material incoming inspection process is described based on documented procedures analyzed during the secondary data analysis. When reviewing the findings from interviews and field observations, it became apparent that adhering to these procedures has been challenging. Several stakeholders from production, quality, and supply chain mentioned during the interviews that the organization has encountered situations where each step of the incoming inspection could not be thoroughly followed, occasionally leading to production issues. Overall, while the operating procedures were known within the organization, consistent compliance with them was identified as a challenge.

5.1 Challenges in the Current Processes

During interviews and field observations, different stakeholders highlighted challenges within the current process. It was noted early in the empirical study that the current system does not consistently enforce all incoming inspections to be completed according to the characteristics outlined in Section 4 and Figure 7. Many interviewees from departments such as quality, warehouse, and supply chain agreed that following the high-level operating procedures is not always feasible. The findings of field observations also corroborated this finding. During the interviews, it was discussed how this discrepancy contributes to variability in process execution. In addition, an interviewee stated that in some instances, this has resulted in situations where raw material lots have been released to production without completing the entire inspection process.

When exploring the root causes behind this, several interviewees indicated that while the process is clearly defined at a high level, its practical implementation at the shop-floor level is lacking. This gap leads to variability in process execution. When the process tasks are undefined and their responsibilities unclear, skipping process steps to work more straightforwardly by prioritizing other tasks unrelated to the process is made easier.This was also noted during the field observations when discussing the high-level process requirements with the operators. The consequences of these inconsistencies can result in process delays. Respectively, the secondary data analysis indicated that while more detailed shop-floor level process guidelines exist than described in Section

4, accessing them is often challenging for the employees. The following factors were identified as contributing to the gap between the case organization's procedures and actual operations:

- Operating practices are not clearly defined at the operational level
- Roles and responsibilities not well-established
- Delays and miscommunications between departments
- Challenges in accessing and utilizing process data

Next, these characteristics are further analyzed to understand their root causes.

Empirical data analysis revealed that operating practices are not clearly defined at the operational level. Multiple root causes for this phenomenon emerged from discussions with various stakeholders. One interviewee from supply chain highlighted the challenge of lacking detailed, step-by-step instructions:

"There are instructions on the process, but detailed, clearly written step-by-step instructions with pictures that leave no questions after reviewing them, are missing."

During the interview, it was further emphasized that each process step should be clearly defined to enable standardized process execution. Comprehensive instructions should minimize uncertainties for operators. Without detailed procedural frameworks, maintaining standardized practices at the operational level becomes challenging.

This issue was also observed during the field observations, where operators expressed difficulties in keeping up with requirements when handling raw materials. It was highlighted that when there are multiple raw materials from several suppliers with their own and regularly updated requirements, keeping up with all of them is difficult. The case organization uses spreadsheets to document raw material and supplier requirements. However, operators found navigating the spreadsheets inconvenient and time-consuming, especially during busy periods. As a result, they often rely on familiar requirements rather than verifying them against official documentation.

When further discussing the process execution, operators highlighted certain tasks that prolong the process. Overall, the delays were often attributed not to task execution itself but to communication gaps between stakeholders. Ambiguous role descriptions and responsibilities were identified as contributing factors for this. An example mentioned in interviews by production, quality, and supply chain stakeholders was communicating the incoming inspection results. This example was also proven during field observations. Field observations revealed that the internal inspection results for non-free pass raw material were recorded in spreadsheets in the case organization's database. However, raw material packages were not consistently sorted or marked based on these results. Instead, the non-conforming batches were communicated to production informally. Several interviewees also highlighted other communication shortcomings across various process stages, including material arrival, internal testing, and tracking the location of the inspected raw materials. For instance, an interviewee from supply chain noted that the raw material with the non-free pass condition might remain uncategorized for several days due to communication delays. Relating to this, an interviewee from quality stated that communication of an arrived non-free pass material lot might take time, conducting the internal testing might take multiple shifts, and communicating the results and marking the packages accordingly is also challenging as the markings in the raw material packages and the measured samples may have differences. Additionally, the interviewee pointed out that the process communication occurs mainly through phone calls and emails, with no centralized system to monitor the incoming inspection statuses of raw material lots. This sometimes leads to batches being used in production before the inspection completion or even after failing inspection.

During field observations, it was noticed that data from different inspection phases were recorded in various locations. For example, supplier-provided quality certificates were manually organized into binders, while internal inspection results were recorded in spreadsheets stored separately by quality control and material laboratory teams. Several interviewees from quality mentioned that this data fragmentation made it challenging to gain a comprehensive overview of the raw material quality and hindered efficient raw material traceability.

The lack of a system to track batch statutes and requirements was also raised in another interview with an interviewee from the quality department. In the interview, a challenge emerged in conducting the internal incoming inspection tests for the free pass materials. For free materials, internal incoming inspections are conducted on a sampling basis. However, the current system does not provide reminders for test frequencies, leading to potential lapses in conducting necessary tests. The interviewee expressed concerns over the reliance on the current system:

"The current system does not enforce quality, as it does not require any checks or measurements to be carried out when the material is received."

This highlights how challenging it is to ensure the process adheres without systematic control. Relating to this, another interviewee highlighted that currently the received raw material quality heavily depends on the operator handling the goods receipt. The risk of accepting non-conforming materials increases if this operator is unfamiliar with the raw material requirements. Consequently, several team leaders indicated that they and their teams are also responsible for multiple other tasks besides the incoming inspection, with incoming inspection often being among the lower priorities. When stakeholders have competing priorities, they might be unfamiliar with the task ownership, and they limitedly communicate with one another, which results in inefficiencies and delays in the process flow.

Overall, the primary challenge within the current process is the absence of a standardized and harmonized approach to the raw material incoming inspection. The case organization lacks a clearly defined and fully implemented process at the shop-floor level. This leads to variability in process execution, inconsistent resource allocation, and varying stakeholder awareness regarding the expected workflows. To mitigate these issues, a well-defined, clearly communicated, and consistently enforced process is essential to ensure alignment across all levels of the organization and commitment to execute the process according to the procedures.

5.2 Requirements for the Solution Proposal

This section presents the requirements for the solution proposal based on the observed challenges. First, the requirements for the digital tool described in Table 7 are presented. Then, the overall requirements for the solution proposal to enhance the execution of the initial process presented in Section 4 are detailed.

Table 7: Requirements defined for the digital tool

Requirement	Reason for the requirement
Provides an overview of required incoming inspection characteristics for deliveries	Keeps the system responsible for managing incoming inspection characteristics
Allows updating of raw material and supplier requirements	Ensures everyone working with incoming inspections has access to the latest requirements
Prevents defective batches from being moved automatically to production	Ensures the quality of raw material batches is checked before use in production
Clearly displays the status of raw material batches in the warehouse	Provides real-time visibility into the incoming inspection status of a batch
Improves traceability	Enhances efficiency in tracking back to incoming inspection data

The digital tool aims to help the case organization standardize the incoming inspection process and align practices with the operating procedures presented in Section 4. As analyzed in Section 5.1, conducting the different phases of the incoming inspection relies heavily on individual responsibility, as there is no system controlling the process execution. The proposed digital tool offers a structured approach to managing the process and supports individuals in process execution by providing clear process guidance.

As analyzed in Section 5.1, the current system does not require any checks or measurements to be carried out when the material is received. Therefore, a key requirement for the tool is to provide an overview of all incoming inspection characteristics that must be successfully completed before the raw material batch can be moved to unrestricted stock and thus be used in production. When all characteristics are centrally located in one inspection lot instead of the different operating procedures and spreadsheets, getting an overview of the inspection requirements becomes more clearly visible. This also ensures that carrying out the incoming inspection and its steps does not remain the responsibility of an individual. However, there is a system that coordinates the process and supports the individual when carrying out the incoming inspection.

To enable only raw material lots that pass the incoming inspection to be moved to unrestricted stock, the system is required to automatically compare the incoming inspection results to their requirements. This way, it does not remain solely an individual's responsibility to ensure that the inspection characteristics meet their requirements. Also, this requirement for the digital tool was determined by the participants from production in the interviews and the development workshop to ensure that defective batches could automatically be moved to unrestricted stock to ensure that no batches by accident are used in production before conducting each step of the incoming inspection. Also, as the system is required to provide real-time visibility of the status of the raw material batches at the case organization's warehouse, the raw material batches that do not pass the incoming inspection should be blocked in the system for further investigation. Correspondingly, the system should provide an overview of all of the raw material batches that are under the incoming inspection and those that have passed it.

As the requirements and characteristics for raw materials from different suppliers, as well as their categorization in the organization's system, change constantly, it is required that these requirements can be modified in the system. This ensures that everyone working with the process has access to the latest requirements and, therefore, also improves process standardization. This should be a straightforward process to ensure that the system will be kept updated.

Additionally, currently, data gathered during the process is scattered in multiple locations, for instance, the supplier-provided quality certificates are organized in binders at the case organization's warehouse, and the results from the internal tests are in different spreadsheets across its database, the digital tool is required to improve traceability. To improve traceability, the digital tool must combine all relevant inspection lot data in one location. Therefore, in addition to providing an overview of all incoming inspection characteristics, the tool must allow the attachment of relevant documents, such as the supplier-provided quality documents, directly to the inspection lot. Having all of the data in digital format and in one location makes it more accessible and enhances both traceability and efficiency in batch tracking. This way, supplier performance evaluation becomes more straightforward, as presented in Markovitch and Willmott (2014).

In addition to the requirements for the digital tool, requirements for the overall system proposal are formed from the current state analysis. For instance, observed challenges that cannot be solved purely with the digital tool include communication beyond the ERP system level, process roles, and their responsibilities, and clear instructions. When discussing how to improve communication beyond the ERP system level in the first development workshop, warehouse and production participants clearly stated that real-time visibility of the incoming inspection status of a batch should be provided not only on the ERP system level but also at the shop-floor level. This is because, as pointed out by a participant, the raw material packages are moved in the warehouse with a forklift, and it can not be assumed that the operators have constant access to the digital tool in the ERP system. Therefore, it is required that the raw material packages are prominently marked according to their status. Furthermore, to enable efficient communication, workshop participants from quality stated that the proposed system should make reporting on the quality of the raw materials to relevant stakeholders a constant task. This helps the organization efficiently identify issues and promote corrective actions.

A key challenge identified in the current process is that the instructions may leave the reader with unanswered questions. Thus, instructions on how to use the digital tool and other process proposal tasks are required to ensure that it is clear to everyone how to use the proposed system. Similarly, the interviews stated that certain roles and responsibilities for completing process tasks are currently unclear to those working with the process. Therefore, for the proposed solution, the research must clearly determine the different tasks needed to keep the process going.

6 Results

6.1 Description of the Solution Proposal

This section presents the solution proposal, including the digital tool, to enhance the standardization of the incoming inspection process. The preliminary solution proposal was developed based on the findings of the current state analysis in Section 5. Later, the preliminary solution proposal was refined iteratively through development workshops and pilot testing. Feedback from the steering group received during those sessions informed the development of the final solution proposal presented in this section.

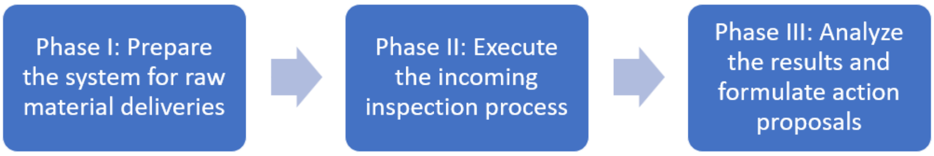

Figure 8: Different phases in the developed system proposal

The solution proposal can be divided into three phases: the prerequisites, incoming inspection, and analysis. The prerequisites and data analysis phases serve as support phases that ensure functionality and flow of the incoming inspection phase. Similarly, during the incoming inspection phase, the actual incoming inspection is executed. Out of the support phases, the prerequisites phase ensures that for each arriving raw material lot, the data is set up and up-to-date in the digital tool to enable process standardization. In the data analysis phase, the data gathered during the incoming inspection is analyzed and reported to relevant stakeholders. If needed, corrective actions are taken based on the findings of the analysis. These phases and the flow between them are presented in Figure 8.

According to Parviainen et al. (2017), digital transformation improves the current process by changing the ways of working at multiple levels. This solution proposal focuses on the first two levels: the process and shop-floor levels. Additionally, Section 7.2 discusses the solution proposal's process development also at the business domain level. Next, the proposed incoming inspection process is introduced. Then, the support phases are introduced in more detail.

Main Phase: Raw Material Incoming Inspection

The initial objective of the process development was to develop a digital tool to enhance process standardization. Based on the challenges of the current system and requirements for the digital tool analyzed in Section 5, the digital tool was developed. Overall, the digital tool aims to coordinate the incoming inspection process so that completing it according to the operating procedures does not remain the responsibility of an individual. This narrows the gap between the case organization's operating procedures and actual workflows and standardizes operations at the shop-floor level.

To meet these requirements, the proposed digital tool gathers all incoming inspection characteristics for raw material delivery into an inspection lot at the case organization's ERP system. Then, during the incoming inspection, data from each characteristic, including the attachment, such as the supplier-provided certificate arriving with the raw material delivery, are entered into the inspection lot instead of different binders and spreadsheets. When all characteristics are filled into the inspection lot, the system automatically compares the entered results to the raw material deliveries' requirements. If the raw material lot passes the inspection, it is moved to unrestricted stock in the ERP system. Similarly, if non-conformities with the delivery are found, it moves into blocked stock in the ERP system for further inspection. Based on the results, the raw material packages are also marked continuously based on their status to enable the process visibility also at the shop-floor level.

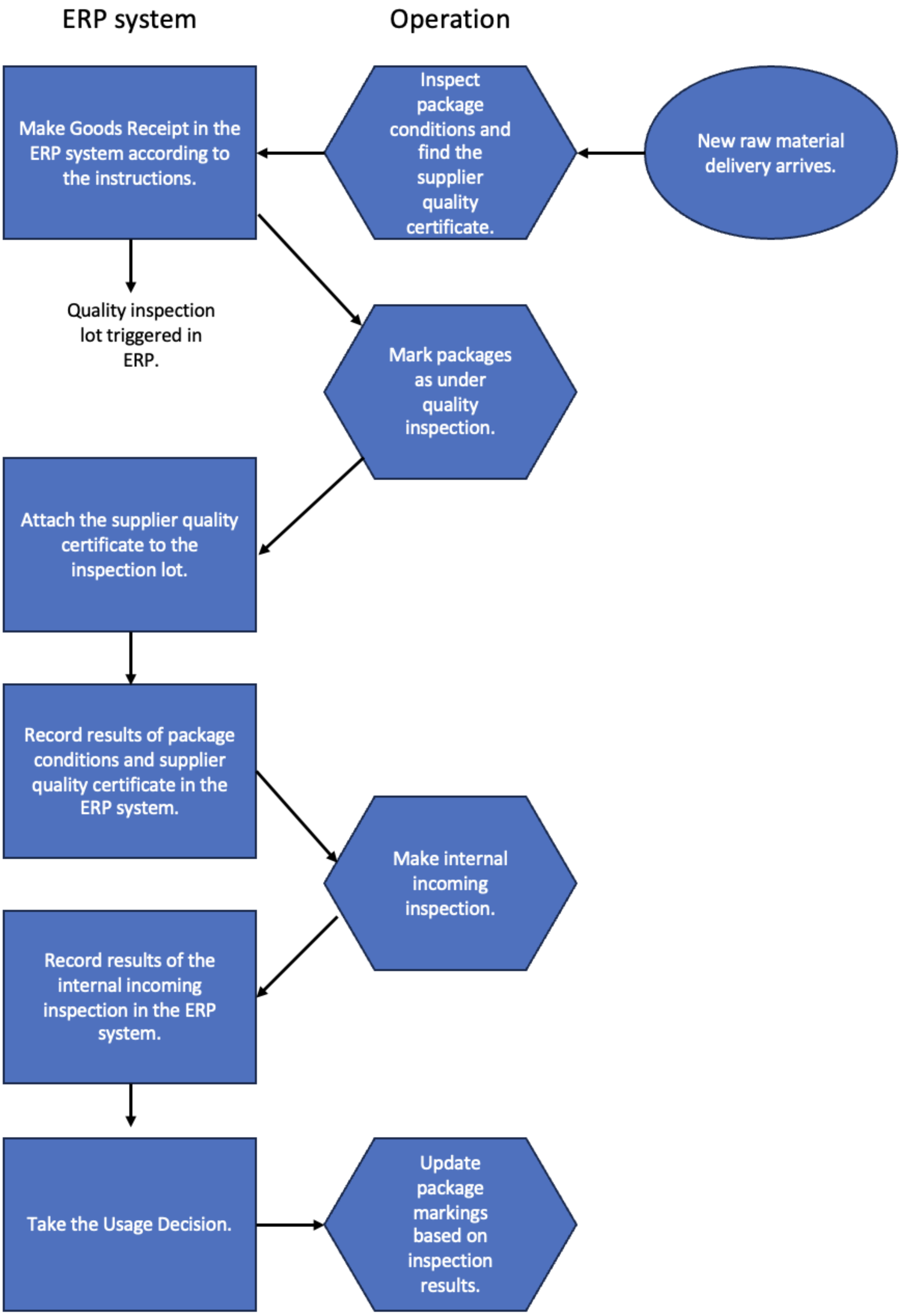

Figure 9: Process tasks and their flow in the incoming inspection phase.

The process flow proposed with the digital tool is presented in Figure 9. The digital tool gets triggered when goods receipt for a new raw material lot is conducted in the

ERP system. After receiving the goods in the ERP system, the system automatically categorized them into the quality inspection stock. Being located in this stock highlights that the batch is undergoing the incoming inspection process. Additionally, batches under the quality inspection stock status cannot be used in production. This status is also presented in the raw material packages as they are marked with white tags with the text "QA hold" to make the process status visible also at the shop-floor level.

The digital inspection lot consists of characteristics that are in the scope of the delivery's incoming inspection as presented in Table 6. Characteristics considering topics such as the labeling and condition of the packages, the delivery type and quantity being according to the order, and the supplier-provided quality certificate arriving with the delivery are presented as qualitative characteristics with "ok" and "not ok" response options. Additionally, relating to these characteristics, the system enables the supplier-provided quality certificate to be attached to the inspection lot. This is also stated in the instructions and is required for the lots to pass the incoming inspection. Consequently, characteristics considering specific values from the supplier quality documents and results of the internal tests are required to be inserted quantitatively. The digital inspection lot allows data from different characteristics to be saved in various parts by different system users. This enables different stakeholders to fill in to the system from different phases of the inspection process.

The digital inspection lot automatically compares the inputted results to the case organization's specification for the raw material. This way, it does not remain any individual's responsibility to ensure that only raw materials within the case organization's specification are used in production. When all characteristics in the inspection lot are filled in and usage decision for the raw material lot is taken, based on the results, the system automatically transfers the lot either into the unrestricted or blocked stock. If the incoming inspection results are within the case organization's requirements, the lot is moved into unrestricted stock and can freely be used in production. Consequently, if the lot does not conform to the requirements, it is moved into blocked stock for further investigation. If a raw material lot is later found to be suitable for use, it can be transferred from blocked stock to unrestricted use by taking usage decision accepted with restrictions. In the system, it is determined that only the system administrator can make this decision. Also, when taking this decision, the user must provide a reason for it. Additionally, after taking the usage decision, the tags in the raw material packages at the shop-floor level are updated to match the status of the package. Lots that passed the inspection are tagged with green "QA approved" markings whereas defective lots are marked with red "QA failed inspection" tags. Simultaneously, based on the results, the packages are transferred from the quality inspection area to their actual storage space or to a non-conformity area.

Support phase I: Prerequisites

The purpose of the prerequisites phase is to ensure that the digital inspection lot in the ERP system remains accurate and up-to-date. During this phase, the item data for the inspection characteristics, on which the digital tool is based, is maintained for existing raw materials and suppliers and developed for new ones. Accurate item data in the ERP system supports having a standardized and efficient inspection process. When the system data aligns with the organization's specifications, it ensures that everyone involved in the process follows the harmonized guidelines and raw material requirements. Given that the raw material requirements constantly evolve based on their performance and new materials and suppliers are introduced regularly, keeping the item data up-to-date is essential for maintaining process efficiency.

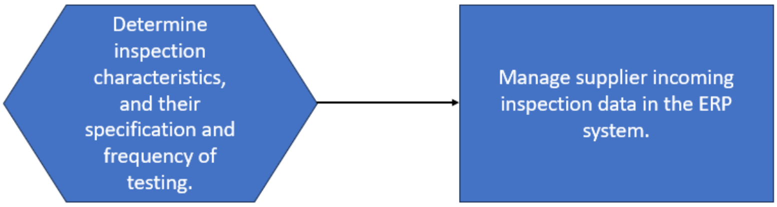

Figure 10: Process tasks and their flow in the prerequisites phase

Figure 10 shows that the prerequisites phase involves key tasks to ensure data accuracy and consistency. This process involves defining inspection characteristics, setting specifications, and establishing appropriate testing frequencies. For each item in the inspection lot, two key factors need to be determined. First, each item must be defined as either a qualitative or quantitative characteristic. This distinction ensures that measurable data, such as numerical test results, and subjective assessments, such as visual inspections, are consistently recorded in the system. Quantitative characteristics allow numerical limits based on the organizational requirements to be set for the item. Then, during the inspection, entered numerical values must fall within these limits for the lot to pass. Similarly, for qualitative characteristics, predefined answer options such as "ok" and "not ok" can be inserted into the system. Consequently, when inserting the results for these items in the inspection lot, a drop-down menu with the defined choices appears to the user. Then, if an item occurs in the inspection lot as a sampling inspection, such as internal testing characteristics for free pass materials, this can be configured with a control indicator. This indicator ensures that the item is only included in the inspection lot according to its specified testing frequency.

Support phase II: Data analysis

Figure 11: Process tasks and their flow in the data analysis phase.

The current state analysis highlighted that when the information relating to the inspection lot is in one location, the process of reporting on the quality of the raw materials should also improve. While the prerequisites phase focuses on setting up a standardized flow for the incoming inspections, this phase ensures that the data collected during the inspections is effectively analyzed and utilized. Analyzing raw material quality helps efficiently identify issues within raw material lots and detect potential changes over time. Similarly, when discussing these findings with the relevant stakeholders, forming and later promoting corrective actions gets easier. Figure 11 shows that this phase involves analyzing and presenting process data. Based on the findings, corrective actions are proposed, and if necessary, non-conformities are raised with the supplier. This phase ensures that supplier evaluation remains a continuous process.

The data analysis process begins by uploading data that the inspection lots in the ERP system have gathered. After uploading, the data is analyzed to gain insights into the product performance, minimize risks, and identify operational inefficiencies. Additionally, continuously analyzing product data helps the organization notice changes in the product earlier by detecting outliers that still meet the requirements and analyzing long-term data trends and patterns. This way, the case organization can prepare in advance for changes in the performance of the raw material. Early detection and analysis of changes in the data ensure that the corrective actions are prepared in time, which prevents the case organization from disruptions in the raw material supply and thus improves material availability.

If needed, the findings from the data analysis are presented to relevant stakeholders during the case organization's weekly quality meetings. This meeting typically includes representatives from the quality, production, process, and purchasing departments, enabling them to form a holistic view of the situation. Similarly, when the data analysis findings are discussed with multiple stakeholders, identifying issues and formulating proposals for corrective actions are made more efficient. Additionally, in the meeting, it is decided whether it is necessary to raise a non-conformity for the supplier.

6.2 Evaluation of the Solution Proposal

The proposed system ensures that the raw material batches undergo a standardized incoming inspection before being moved to unrestricted stock and used in production. This improves the total quality of the case company's products by ensuring that defective raw material lots are blocked from entering production during the inspection. The digital tool, triggering the inspection lots for raw material lots after the goods receipt, ensures that the incoming inspection follows the same guidelines regardless of who is conducting it. Similarly, the digital tool ensures that it does not remain an individual's responsibility that the results align with the raw material requirements. This is achieved by automating the process execution with the digital tool instead of having an individual coordinate the process execution.

Consequently, the digital tool improves communication regarding changes in raw material requirements and process status. First, the tool improves communication of the changes in requirements, as the requirements are inserted into the inspection lot, which automatically provides the operator with the latest update when filling in the inspection lot during goods receipt. Then, the tool improves visibility of the status of the incoming inspection process as all material lots still undergoing incoming inspection are located at the quality inspection block in the ERP system. The solution proposal also enhances the shop-floor visibility by marking the raw material packages with color-coded tags and organizing them in the warehouse according to their process status.

The solution proposal also improves traceability. Instead of being scattershot across physical binders and files at the organization's database, with the solution proposal all data is gathered in one place in digital format. This centralization makes it more efficient to find data related to a specific batch, when all inspection data is stored in the ERP system under the corresponding batch's inspection lot. Having all data gathered in one place and digital format also improves analyzing the data, which enhances the case organization's ability to detect changes in the raw material performance and come up with corrective actions from early on.

Although the solution proposal improves the communication of changes in material requirements and raw material status at the plant site, it does not directly address broader communication issues or clarify unclear processes' roles and responsibilities. This is because the tool displays all characteristics that need to be carried out in the incoming inspection but does not assign these tasks to anyone. This was discussed in the second development workshop. After the workshop, all tasks related to executing the solution proposal were listed and put into a RACI (Responsible, Accountable, Consulted, Informed) matrix. The RACI matrix is a tool for describing various roles in completing a process and, when shared with relevant stakeholders, helpful to ensure that everyone who has a role in the project tasks has properly been accounted for it (Khan and Quraishi, 2014). Therefore, the RACI matrix was found useful for assigning the roles for the system proposal. After filling the matrix with the steering group, it was discussed in an additional meeting with participants from each department working with the process.

The solution proposal performance, and particularly the performance of the digital tool, was evaluated through pilot testing. The results indicated that implementing the solution proposal significantly increased the average process lead time compared to the current system. However, when comparing the average lead times for executing the process, it should be taken into account that in the current process, each process step is not standardized according to the operating procedures. Therefore, the difference in lead time between operating without and with the digital tool may be smaller than the initial comparison suggests.

Despite the increase in process lead time, pilot testing demonstrated several benefits of the solution proposal. Firstly, operating according to the solution proposal reduced overall confusion between different process steps. The digital tool helped users track the progress and status of the incoming inspection more efficiently. In addition, having raw material packages on the floor marked according to their status ensured that the quality of the raw materials was verified before they were used in production. Additionally, pilot testing showed how the solution proposal reduced the time spent on process support tasks. For example, when supplier quality certificates are attached to the inspection lot, less time was required to search the documents from the ERP system compared to searching them from physical binders and copying them to have them in digital format. Furthermore, pilot testing revealed how with the digital tool better insights into raw material performance over time as accessing and analyzing the data was more efficient.

However, pilot testing also revealed areas for improvement. During the pilot testing, it was noted that the digital tool is relatively rigid in its current state. The rigidity became apparent, for instance, when attempting to create different inspection lots for multi-sourced raw material under a single code in the ERP system. This limitation highlights a potential improvement area, as only one inspection lot can currently be assigned to a raw material code.

7 Discussion

7.1 Recommendations for the Case Organization

The thesis presents a solution proposal to standardize the raw material incoming inspection process. This is done with an ERP-based digital tool that combines the different raw material requirements into an inspection lot. During the inspection, data is automatically validated against predefined requirements before the raw material lot is released to the warehouse. Pilot testing demonstrated that the tool positively impacts compliance with operating procedures, supports raw material quality assurance, and improves process traceability. The outcomes illustrate how digitalization can address common challenges in the incoming inspection process, such as inconsistent raw material monitoring, fragmented documentation, and limited visibility into historical data, and thereby improve both process standardization and traceability. This also provides an answer to the first research question, which explores how digitalization can improve the standardization and traceability of the raw material incoming inspection process. However, the testing was limited only to the specific case raw materials. Therefore, before further implementing the tool, some aspects need further reflection to ensure successful implementation and user acceptance. To address these findings and support a smooth transition, several recommendations are proposed to guide the case organization through the transition.

While the digital tool standardizes procedural compliance, enabling its effective implementation and user acceptance requires strategic change management and stakeholder engagement. The second research question investigated how the successful implementation and adoption of the digital quality control process can be supported. To answer the question and achieve effective implementation and user acceptance, the case organization must raise awareness of the importance of ensuring raw material quality. Interviews and field observations revealed that operating according to the operating procedures takes more time than the current, less structured practices. This was also validated during pilot testing when the average lead time for executing the process with the solution proposal compared to the lead time of executing it according to the current practices was significantly higher. It was found that some required process tasks are not embedded into the current practices and, therefore, are seen as extra tasks. Many stakeholders find these tasks time-consuming and non-value-adding, as the current process appears to function adequately without them, and the outputs of these tasks are seldom utilized by management. Shifting this mindset will require demonstrating the value of these tasks to ensure consistent raw material quality.

To overcome these challenges, also considered as the lack of commitment to the process execution, stakeholders should actively acknowledge the importance of compliance with procedures while highlighting the role of standardized inspections in maintaining product quality and operational efficiency. Therefore, the case organization should take into consideration the success factors in digital transformation and ERP-driven BPR projects presented in Section 2.4. For example, the four critical success factors for digital transformation presented by Finney and Corbett (2007) that are the commitment and support of top management, the visioning and planning of success factors, the management of cultural change, and the implementation of change management should be considered. Additionally, to successfully implement change management, particular focus should be given to the phase of embedding changes within the company culture and practices in the successful change management process presented by Miller (2020). Embedding changes is critical to prevent the process from reverting to its prior state. Tools for achieving this include, for example, implementing new organizational structures, instructions, and control systems (Miller, 2020).

Furthermore, to enable the use of the solution proposal, the incoming inspection process should be resourced to meet the needs demonstrated in pilot testing. As discussed in Section 5.1, the current process is prioritized rather low, which means that individuals who work with the process have multiple other tasks that may take precedence. As the pilot testing validated that operating according to the case organization's procedures with the solution proposal significantly increased the process execution lead time, reviewing roles and role responsibilities related to the process is recommended. Therefore, to enhance process efficiency, the case organization could introduce a dedicated raw material quality operator role. Unlike in the current approach, where warehouse, quality control, and material laboratory operators manage inspection tasks alongside their primary duties, this role would centralize the responsibilities for conducting the entire incoming inspection process. In this role, the operator would be responsible for conducting the incoming inspection process in total instead of the current way where operators from different departments conducting small bits of the process, leading to inefficient and non-harmonized process executions.

Additionally, as presented in Section 6.1, setting up and maintaining the system for the digital tool, analyzing and reporting process data, and managing the corrective actions is time-consuming and partly additional to the current process. Therefore, establishing a process owner role could support the case organization in the efficient execution of the incoming inspection process. This role would involve ensuring that the inspection lots are up to date in the ERP system, supporting the raw material quality operator in daily tasks, analyzing incoming inspection data, and managing corrective actions and communication with the suppliers. Integrating these new roles into the RACI matrix, discussed in Section 6.2, will ensure clear role definitions, accountability, and adequate resourcing to align with the requirements of the solution proposal.

Finally, during the further implementation of the solution proposal to support effective implementation, the case organization should further follow the BPR framework outlined in Section 2.3. Additionally, to address challenges during the implementation, critical success factors, such as management commitment and support, open communication, and promoting empowered decision-making, will help facilitate the adoption of new ways of working and managing cultural changes. By adopting these recommendations, the case organization can establish a resilient foundation for the further implementation of the solution proposal.

7.2 Ideas for Future Development

While the solution proposal presented promising results during pilot testing, there are limitations and areas for future development. As discussed in Section 6.2, limitations of the developed tool, such as its rigidity, were discussed. Additionally, it was noted that operating according to the solution proposal increases the average process lead time compared to the current system. While Section 6.2 discusses that the increased lead time may partly result from standardizing the incoming inspection process, pilot testing revealed process steps in the solution proposal that are time-consuming and might not add value to the process. These non-value-adding steps include finding the supplier-provided documents for deliveries and manually entering data from quality certificates into the inspection lot in the ERP system.

First, field observations revealed that finding supplier-provided documents, such as quality certificates, is time-consuming. Some suppliers provide documents to the case organization by email while others include them as physical copies with the delivery. When documents are sent by email at the time of the delivery departed from the supplier, long delivery lead times often result in the email being buried in the inbox by the time the delivery arrives at the plant site. This complicates the process of finding documents and increases the lead time of the incoming inspection process. Implementing a supplier portal could help the case organization by centralizing communication with the supplier and streamlining the document management flow. With the supplier portal, the supplier could submit the delivery documentation to the system under a specific delivery that is visible for the case organization. The system could also be utilized to enhance the overall communication and following the arrival of a delivery.

Furthermore, inserting data from the supplier-provided quality certificate into the inspection lot provided by the digital tool automatically ensures that the data is within its latest requirements. Still, when the data is inserted manually, there is a risk of typing errors. If the process continues to be digitalized, artificial intelligence (AI) could be used to enhance the data entry process. Integrating AI into the process could improve the data entry process, for instance, by automatically extracting relevant information from the quality document to the inspection lot in the ERP system. This flow would reduce manual data entry, minimize typing errors, and increase overall process efficiency. By addressing these limitations in future development, the case organization can enhance the process efficiency and further support the raw material management.

7.3 Applicability to Other Organizations

While the empirical part of this thesis was conducted for a case organization to meet its specific needs, the findings and the proposed solution can also benefit other organizations. This is because the incoming inspection process is not only implemented for the case organization but is also a common practice in the manufacturing industry. Thus, this thesis provides a guideline that other organizations can also apply in similar process standardization projects. Additionally, the proposed ERP-based digital tool can be adapted for incoming inspections beyond raw materials.

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