Quality 4.0: The model for proactivity

A case study for proactive quality work at Troax

Master's thesis in Quality and Operations Management

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SUMMARY
The manufacturing industry has experienced significant developments in manufacturing, processes, practices, and technologies during the last decade. These developments have led to innovations and a resurgence in manufacturing and engineering activities and are commonly referred to as the Fourth Industrial Revolution or Industry 4.0. Industry 4.0 (I4.0) represents a new paradigm in advanced manufacturing, digitizing, and engineering technologies fueled by data from sensors, Artificial intelligence (AI), the Internet of things (IoT), industrial automation, connectivity, cybersecurity, and big data analysis integrated into daily operations.

Quality 4.0 (Q4.0) is a concept that refers to the future of quality using the new tools and technologies available from I4.0. Q4.0 integrates conventional quality approaches with a new technology that allows for organizational efficiency and business excellence. Organizations that want to remain competitive recognize the need for Q4.0 and a proactive approach to risk and quality management.

This thesis is a case study that evaluates the usage of Q4.0 to increase proactive quality work at Troax, Hillerstorp Sweden. The result of the study is a Quality 4.0 Maturity Model and gap analysis. Based on the gap analysis a priority list was generated to increase proactive quality work at Troax.

Keywords: Industry 4.0, Quality 4.0, Digitalization, Big data, Internet of Things, Change management, Digital transformation.

Abstract

The manufacturing industry has experienced significant developments in manufacturing, processes, practices, and technologies during the last decade. These developments have led to innovations and a resurgence in manufacturing and engineering activities and are commonly referred to as the Fourth Industrial Revolution or Industry 4.0. Industry 4.0 (I4.0) represents a new paradigm in advanced manufacturing, digitizing, and engineering technologies fueled by data from sensors, Artificial intelligence (AI), the Internet of things (IoT), industrial automation, connectivity, cybersecurity, and big data analysis integrated into daily operations.

Several researchers have raised the question about the future of the quality profession and how quality can adopt technologies and tools that constitute I4.0. Digitalization would change the importance of quality as former knowledge of a defect or failure would only spread to a limited number of customers, while today, people from all around the world can obtain knowledge of faulty deliveries from an organization through the internet. Quality 4.0 (Q4.0) is a concept that refers to the future of quality using the new tools and technologies available from I4.0. Q4.0 integrates conventional quality approaches with a new technology that allows for organizational efficiency and business excellence. Organizations that want to remain competitive recognize the need for Q4.0 and a proactive approach to risk and quality management.

This study materializes from a manufacturing company in Sweden, and the purpose is to explore if Q4.0 can promote a proactive approach to working with quality. The case company has recognized that its current state is reactive, where quality deficiencies and internal problems affect the end customer hence the need for an assessment. Through a literature study and interviews with management and officials, the findings suggest a Quality 4.0 Maturity Model, which can be used as an assessment tool for businesses that seek to apply Q4.0 to their current operations. The model support organization in their quality work, notably in becoming progressively proactive, and can be used as a roadmap to initiate the digital transformation toward Q4.0.

In the last part of the thesis, it is concluded that the purpose of increasing proactive quality work was fulfilled. A priority list was generated for the case company where information is presented on how to increase the proactive quality work. In addition, it is presented that future researchers have the possibility to narrow the scope within one of the seven principles in Q4.0 or focus on the future of quality work and Quality 5.0.

Acknowledgment

This report is the final work of our master's thesis conducted via the department of Technology Management and Economics, at Chalmers University of Technology. This thesis is a case study, and it was performed at Troax AB in Hillerstorp Sweden.

First, we would like to thank Troax AB and their department of quality for taking on the project of Q4.0. It has been a fun and engaging project where we have been given large responsibilities and the personnel have welcomed us with open arms. Most of all, we would like to thank Jakob for being our supervisor and throughout the project challenging us and giving us feedback.

Second, we would like to thank our supervisor Mirka Kans. Thank you for helping and guiding us throughout the thesis. Your expertise has guided and contributed to the result of the conducted case study.

Thank you!

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Pierre Karlsson Simon Stockhem

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1 Introduction

This chapter provides the background for the master's thesis, the aim of the study, and delimitations.

1.1 Background

The manufacturing industry has experienced significant developments in manufacturing, processes, practices, and technologies during the last decade. These developments have led to innovations and a resurgence in manufacturing and engineering activities and are commonly referred to as the Fourth Industrial Revolution or Industry 4.0 (Zonnenshain & Kenett, 2020). Industry 4.0 (I4.0) represents a new paradigm in advanced manufacturing, digitizing, and engineering technologies fueled by data from sensors, the use of Artificial intelligence (AI), the Internet of things (IoT), industrial automation, connectivity, cybersecurity, and big data analysis integrated into daily operations (Posada et al., 2015). The extension of IoT and sensors allows devices to interact and communicate with one another through data shared over the internet. As a result, information technology and telecommunications are merging, and organizations face new challenges whilst increasingly becoming more computerized. I4.0 has a significant influence on the production environment and comes with radical changes to operations and execution. Despite the challenges, organizations can expect higher innovation capability, reduced time to market, individualization and customizability, flexibility, resource efficiency, customer focus, and customer satisfaction (Lasi et al., 2014). I4.0 also advocates quality improvements and lean manufacturing, whereas smart and integrated communication systems eliminate the shortcomings of conventional practices, increasing productivity and eliminating waste (Sanders et al., 2016).

Several researchers, e.g., Sörqvist (2014), have raised the question of the future of the quality profession and how quality can adopt technologies and tools that constitute I4.0. Sörqvist (2014) argued that digitalization would change the importance of quality as former knowledge of a defect or failure would only spread to a limited number of customers. Whilst today, people from all around the world can obtain knowledge of faulty deliveries from an organization through the internet. Thus, organizations that remain competitive recognize the need for a proactive approach to risk and quality management (Sörqvist, 2014).

Quality 4.0 (Q4.0) is a concept related to I4.0 that refers to the future of quality through digitalization and the new digital tools that influence people, processes, and technology (ASQ n.d.). Q4.0 focuses on integrating customer-driven business development with technology-driven business development in which digitally enhanced processes and plant structures increase productivity and flexibility in organizations and the supply chain (Sörqvist, 2019). For example, Q4.0 can support organizations with real-time data collecting, process monitoring, and analytics-supported predictive maintenance.

In 2019 Boston Consulting Group (BCG), together with the American Society for Quality (ASQ) and German Association for Quality (DGQ), presented an international study with 221 participating companies that represented industries in major sectors: industrial goods, consumer goods, medical technology, and pharmaceuticals (Küpper et al., 2019). The findings proved that technology is just one piece of the broader quality

transformation in which organizations must also recognize the importance of people and skills. Although most companies realize the benefits of Q4.0 and its potential to create substantial value, few have initiated the preparatory work, defined a detailed strategy, and launched an implementation program. The participating companies identified that a shortage of soft skills such as working in teams, change management, and communication is the main impediment and the most critical skill for success according to Küpper et al. (2019). Simultaneously, they endorse the need to improve their big data skills and analytics. There is a consensus that industries and organizations in different sectors share the same goal to initiate the work towards Q4.0, which supports the ability to create value for customers. However, the BCG study shows that only a few have embarked on the journey of digital transformation.

Recent research on I4.0 has been directed toward manufacturers characterized by the high level of automation and digitalization (Kamble et al., 2018; Alcácer & Cruz-Machado, 2019), but little has been investigated about the transition to Q4.0 and how organizations can adopt the technologies and tools for better decision-making and quality improvements. Additionally, the BCG study presented that only a few businesses have initiated the transformation towards I4.0 and that most face the challenges in the prerequisites of having a strong team, communication, and change management to the disruptive and advanced technologies.

One of the key features of I4.0 and Q4.0 is that they both are data-driven. Quality engineering activities ranging from inspection, maintenance, improving customer satisfaction, and testing could also be data-driven. Zonnenshain and Kenett (2020) argue that today quality engineers generally use intuition and/or qualitative assessments in their decision-making process. The availability of various data types creates the opportunity to develop a data-driven quality system. Kenett and Redman (2019) characterize a data-driven organization as collecting diverse data and viewpoints on any situation possible. The data is then used to develop a deeper understanding of the problem through the business context. The organization can develop an appreciation for variation through the analysis and realize that uncertainty induces room for errors and mistakes. Lastly, the organization should recognize the importance of high-quality data and be ready to invest in trusted sources for further improvements.

1.2 Purpose and research questions

The purpose of this study is to explore how Q4.0 can promote a proactive approach to quality work. The case company represents a manufacturing firm where the quality department aspires to become proactive in daily operations. The company is growing and funds new machinery with smart and innovative functions, which drives the productivity and efficiency in the production. However, the company officials have recognized that current operations are run through conventional practices, being forecast-driven and reactive in quality management and identifying quality deficiencies. Although the company strives to become proactive and transition into Q4.0, it comes with significant challenges. It requires new in-depth theoretical knowledge of what constitutes Q4.0, where the company is today, and how to initiate the work towards implementing Q4.0 into the organization. Therefore, the objective is to develop a priority list that supports the company's transition into Q4.0, the usefulness, and advantages of Q4.0, and its consensus for a proactive approach to quality deficiencies. Thus, the following research questions were established:

> *RQ1: What constitutes Quality 4.0 in the perspective of a manufacturing organization?*
>
> *RQ2: How can the current state of Quality 4.0 in a manufacturing organization be evaluated?*
>
> *RQ3: How can Quality 4.0 support organizations in becoming proactive working with quality?*

1.3 Delimitations

The information gathered in this study was from interviews at the manufacturing plant in Hillerstorp, Sweden. Thus, no further data was collected from other manufacturing plants allocated in other countries. The case company's ambition with the project originated from the department of quality, which led to operational boundaries where the authors chose to target the department of quality, digital business and marketing development, supply chain, and production, delimiting other departments in human resources and finance.

2 Methodology

This chapter explains how the study has been conducted in terms of research strategy, design, and methods.

2.1 Research design

The purpose of the study is to explore Q4.0 and establish a theoretical framework that supports organizations in their digital transformation journey toward Q4.0. Using the knowledge attained through the theoretical framework a case company will be analyzed to identify opportunities to become proactive through Q4.0.

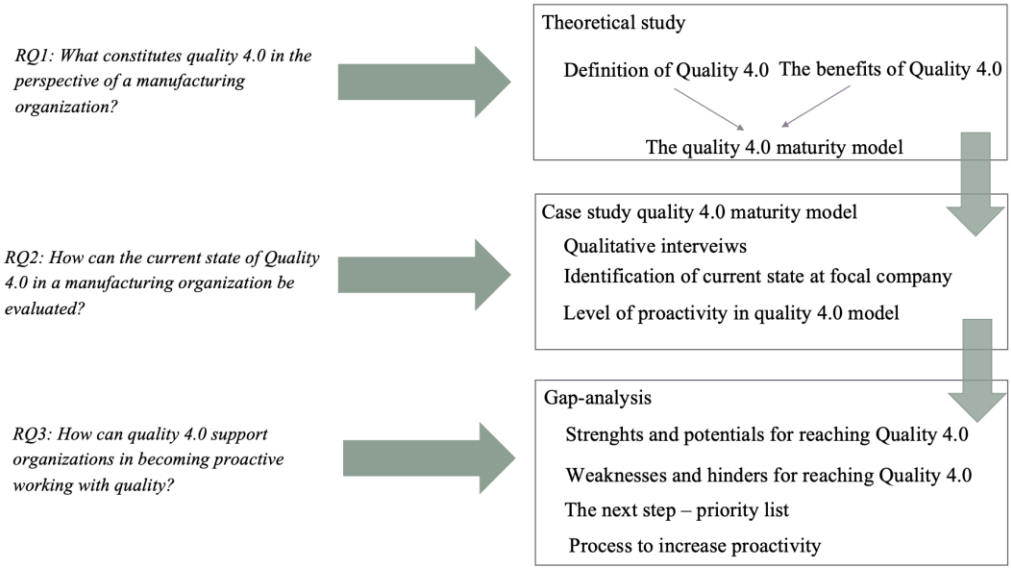

Figure 1. Research design

The study is based on three research questions seen in Figure 1. A literature study and a case study were executed to understand how Q4.0 can support organizations in becoming proactive. RQ1 focuses on the literature study, RQ2 is the case study of an organization, and RQ3 focuses on the analysis of how the Q4.0 can increase proactive quality work within an organization.

To answer the RQ2 and RQ3, a case study was appropriate consisting of qualitative data and an analysis of how the theoretical framework can be used to increase proactive quality work. As the research sought to investigate a single organization, the case study approach was suitable due to the definition of a case study by Bell et al. (2019). According to Bel et al. (2019), a case study is a detailed and intensive analysis of a single case. Yin (2015) elaborates further that a case study approach is chosen if the research question seeks to explain present circumstances that require an in-depth analysis of a phenomenon. Because the research focuses on explaining *what constitutes Quality 4.0 in the perspective of a manufacturing organization, how can the current state of Quality 4.0 in a manufacturing organization be evaluated,* and *how can Quality 4.0 support organizations in becoming proactive working with quality,* it is aligned with the definitions made by Yin (2015) and Bell et al. (2019). Therefore, the case study can provide detailed findings on the current state for the case company, which was used as

the base for gap analysis in RQ3. The qualitative approach was chosen because a qualitative strategy emphasizes words rather than numbers in collecting and analyzing data (Bell et al., 2019). When describing the case company and the current state, the qualitative strategy is an appropriate fit because the research is set out to describe quality work within the organization. In addition, according to Bell et al. (2019), qualitative research can involve testing theories during the research process. The findings from the case study will be compared with the theoretical framework established through a literature review. The advantage of choosing qualitative research is that it will increase the flexibility in collecting data and help include people's own words when analyzing data (Taylor, Bogdan & DeVault, 2016).

The approach for the research is abductive based on qualitative data gathered from interviews at the case company. The abductive approach is defined, by Bell et al. (2019), as the researcher's understanding of the world from the participant's perspective of the study. When applying the Quality 4.0 Maturity Model framework established in RQ1, the abductive method is more suitable than the deductive method because it does not rely on a strict logic of theory-testing (Bell et al., 2019). As Q4.0 can be reached through various integrations of technologies applying the deductive method would be difficult. The purpose of this study is to define the current state at the case company and apply a theoretical framework to enhance the organization's proactive quality work. According to Bell et al. (2019), abductive reasoning will be suitable when selecting the best explanation from competing explanations or interpretations of data. In addition, the abductive method also enables openness and the possibility to be surprised by data rather than confirming preunderstandings.

2.2 Research process

The research followed seven steps illustrated in Figure 2. First step of the project was to identify the problem, which was done through a review of the SWOT analysis performed by the organization. In the SWOT analysis, one of the goals was to become proactive in quality work and reduce external deviations. Proactive quality work was discussed with the supervisor and company representative, and the project of increasing proactive quality work through the usage of Q4.0 was defined. In the second step, a literature review was conducted to understand the topic of Q4.0 and increase knowledge within quality management. The third step was the development of a theoretical framework called Quality 4.0 Maturity Model. During the research process, the framework was redefined to increase its usability. Simultaneously, an interview template was established to gather qualitative data. Step four consisted of conducting and transcribing interviews. After that, interviews were summarized in step five to establish a current state at the case company. Step six analyzes theoretical and empirical findings to identify how the case company can increase proactive quality work by using the Quality 4.0 Maturity Model. In the last step, the method of the research and the findings are discussed. Conclusions and suggestions for future research are discussed in the last step of the research process.

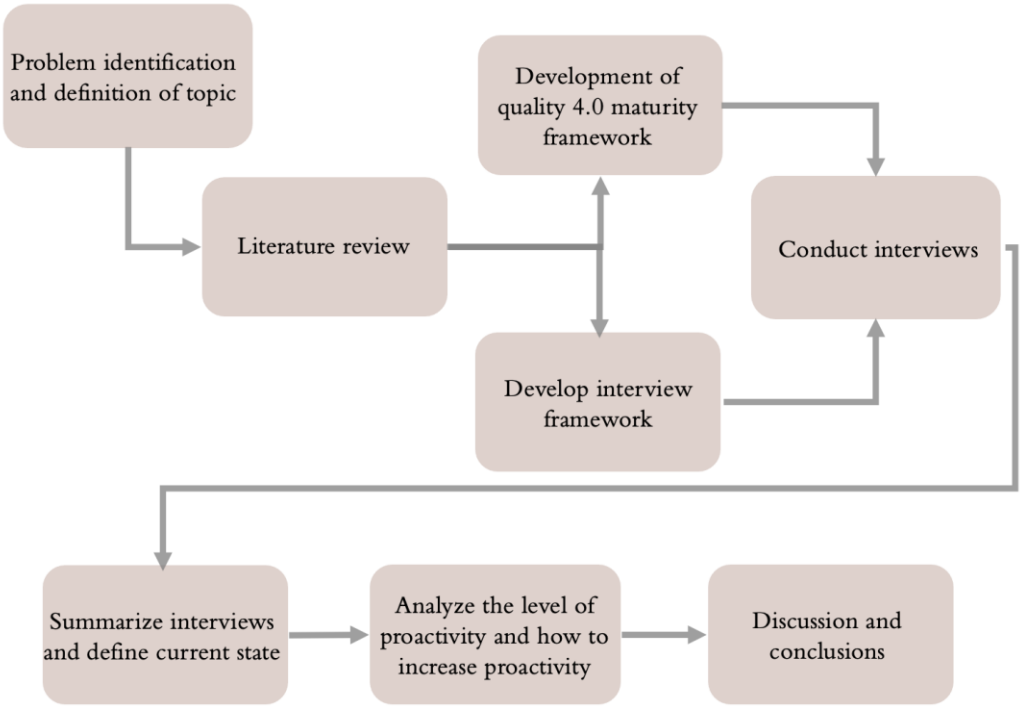

Figure 2. The research process

2.3 Data collection

Data collection was divided into three sources of information; First, literature review and compiling of existing literature to develop a Quality 4.0 Maturity Model. Second, qualitative interviews were held at the case company to identify the current state. Third, observations of the case company and their daily management and Quality Management System (QMS) to increase information on the current state.

2.3.1 Literature review

When developing knowledge in the research scope, a literature review was needed to understand which knowledge already exists (Gustavsson & Säfsten, 2020). Bell et al. (2019) describes this as not reinventing the wheel. It was further explained that the literature review is where you demonstrate that you can engage in scholarly debate. In addition, engaging with existing literature is a means of developing an argument about the importance and significance of the research (Bell et al., 2019). Therefore, it is advisable to conduct a literature review in the early stages of a research project (Gustavsson & Säfsten, 2020). This first review is interested in increasing the knowledge of state-of-the-art research in the field. Later reviews require in-depth review to answer specific questions (Gustavsson & Säfsten, 2020).

Initially, a literature review was conducted concerning different theories connected to Q4.0, quality maturity, I4.0, ISO 9001, TQM, and change management. The starting point of the literature review was to use online libraries and search for related topics to the research questions. The online libraries used to search related topics were Chalmers Library and Google Scholar. Through this review, we generated the keywords mentioned above, searched for relevant titles, and read abstracts to determine the usefulness of the literature. The Boston consulting group was also used in the first

review process. Later in the research process, an in-depth literature review was conducted of the relevant literature for the study. Finally, the reviewed literature was combined to establish the Quality 4.0 Maturity Model.

2.3.2 Interviews

Interviews were conducted with the organization to collect qualitative data. The interviews were semi-structured to allow open discussion between interviewer and interviewee to capture a greater breadth of coverage (Bell et al., 2019). In addition, the follow-up questions outside of the interview template will be asked to understand the underlying reasoning and the organization's current situation. For the selection of interviewees, the purposive sampling strategy was used. Purposive sampling was done to ensure that respondents have information about quality management within the organization and generate relevant answers to the abductive case study. Each interview had the same setup with two interviewers with two different main tasks. The first is responsible for conducting the interview, and the second is responsible for transcribing the interview. Transcribing the interview was useful when analyzing data as it decreases misinterpretations, generating reliable data sets for analysis (Bell et al., 2019). All interviews were recorded, which was used during the transcription of the interviews. This resulted in accurate transcriptions because it allowed for rewinding of the record during transcribing. The material was also viewed during the research process if the interpretation was different between the researchers.

For the study, five structured interviews were performed at the case company. The interviewees from the company were quality manager, production manager, quality engineer, production support, and digital business and marketing developer see Table 1. These interviews were semi-structured, and the interviewees provided information within different areas. All interviewees provided their expert knowledge within their work area, and these interviews were summarized to establish the current state. All interviews held with the organization were conducted in Swedish because it is the native language of the interviewees. As the interviewees were more comfortable speaking the native language, they could speak freely and understand interview questions better. Therefore, transcription of the interviews was done in Swedish. This eliminates translation errors and misinterpretations in the first stage of the qualitative data collection.

Table 1: Interviewees

Interviewee(s)	Area of work	Focus of the interview	Duration
Interviewee 1	Quality manager	How are the operations of quality management structured	41 minutes
Interviewee 2	Production manager	How do the organization work with quality in their production processes	25 minutes
Interviewee 3	Production support	Production monitoring system Axxos	42 minutes
Interviewee 4	Quality engineer	How are the operations of quality management structured	50 minutes
Interviewee 5	Digital business and market developer	What is the strategy for digital transformation	10 minutes

2.3.3 Observations

Qualitative data were additionally collected via the organization's QMS and by observations of the organization. In QMS, the organization has all its control documents, reports of quality deviations, and more. Information from quality inspections was gathered from QMS and used as an addition to the interviews. In addition, observations of its daily management were done. In this observation, the researchers attended the Gemba walk. This is the daily management method used at the case company, and information was gathered on the procedure of its daily management system and sharing of information. Observations in the QMS were also conducted to understand the system compared to Q4.0 and technology usage within the QMS.

2.4 Data analysis

The study's approach was abductive, which led to a different setup when analyzing data. Compared to the inductive approach which is analyzed through the grounded theory where theory is developed simultaneously, the abductive approach relies on a wide array of theorizations (Tavory & Timmermans, 2019). Tavory and Timmermans also explain that the abductive approach sifts to relate existing theories to the observations conducted in the study instead of developing new theories. With the literature study, theories were gathered, and a theoretical framework was generated. A content analysis was done to analyze the scientific articles and with the analysis, it could be concluded if the authors agreed or disagreed with the different theories (Gustavsson & Säfsten, 2020). Theories were then combined to generate a theoretical framework that was used in the gap analysis.

Transcription and coding were used to analyze data from interviews, which allowed for a deep analysis of data and the possibility of making comparisons (Tavory & Timmermans, 2019). Furthermore, when analyzing the data, observations were used to increase knowledge of qualitative data gathered from interviews and the current state of the case company.

2.5 Ethical aspects

When conducting business research, some ethical aspects need to be considered. First, as the organization is traded on the Swedish stock market, information that affects the stock exchange cannot be presented. Confidentiality is therefore important to consider when collecting data so that the company can provide necessary information for the project without exposing it to third parties or affecting their position on the stock market. The company supervisor has therefore viewed the information presented in the report. Second, as the research is partly based on qualitative data collected through interviews, voluntary informed consent is needed (Bell et al., 2019). This is so that interviewees are given as much information about the study to make an informed decision about their participation. The interviewees are also informed of the interview process and how the data will be used in the research. Participants of the interviews will also not be named in the study because revealing information can be harmful when connected to business research (Bell et al., 2019).

2.6 Research quality

Due to the design of the research elements of research quality considered for the work were credibility, transferability, dependability, and confirmability (Bell et al., 2019). For a quantitative study, reliability and validity would be appropriate quality criteria. However, as the purpose of the research is an in-depth analysis of a phenomenon, the four elements would enhance the quality of the research (Bell et al., 2019).

2.6.1 Credibility

Credibility parallels internal validity which, according to Bell et al. (2019), is an evaluation of the fit between researchers' observations and the theoretical ideas that have been developed. The establishment of credibility in findings entails ensuring that research is carried out according to the canons of good practice and submitting research findings to the members of the social world who were studied. According to Bell et al. (2019), this confirms that the investigator has understood the social world correctly.

The usage of triangulation of qualitative data in a case study is beneficial since it avoids weaknesses that can occur from using only one method for data collection. A potential weakness of not using triangulation is that the research can be biased toward one observation theory (Bell et al., 2019). Furthermore, using different qualitative data collection methods could eliminate misinterpretation in a case study and strengthen the results in business research. In addition to triangulation, respondent validation was also used to increase internal validity. Respondent validation, sometimes called member validation, is a process where the researcher provides research material to study participants (Bell et al., 2019). This is frequently used in qualitative studies and is used to ensure a good correspondence between findings and the situation described by the case company. Through this feedback system, misinterpretations and biases can be dealt with at an early stage and eliminate effects in the findings (Bell et al., 2019). To further increase the credibility of the data generated through interviews, a semi-structured template was generated so that interviewees were asked similar questions. This eliminated potential biases as the researcher cannot ask directed or skewed questions that affect the data.

2.6.2 Transferability

Transferability, which is parallel to external validity, is how the researcher can make general claims about the world and evaluate if the research findings are applicable in other contexts (Bell et al., 2019). For research to be transferable, findings must be generalized and applicable to a broader range or specific to a particular study. Generalization is important to consider having external validity in a research project, but it is equally important to consider the context of the research and how changes in time and space affect it (Bell et al., 2019).

The design of the research method is a qualitative case study of an organization. Therefore, findings and analysis are not directly transferable since the findings are connected to the case company. However, the research method and the analysis were explained in detail. Therefore, other researchers can recreate the study and use a similar research approach to understand the usage of Q4.0. In addition, the theoretical framework that was developed for the study is generalized and can be used by other organizations to generate gap analysis and define improvement areas in proactive quality work.

2.6.3 Dependability

Dependability is argued to be parallel with reliability in qualitative research and used to demonstrate that qualitative research is trustworthy (Bell et al., 2019). Bell et al. argue that to create trustworthy research, there is a need to adopt an auditing approach that ensures that complete records are kept throughout the research process. The auditing is done throughout the research and includes assessing the degree to which the theoretical inferences can be justified. According to Bell et al. (2019), the auditing approach can be demanding for peers as qualitative research generates large datasets.

To address dependability in the study, interviews was conducted on the subject of Q4.0 concepts such as digitalization, quality, and maturity for advanced manufacturing. Selecting interviewees is crucial and affects the dependability of the study. All interviewees were approached with questions about their work area which made the information trustworthy. The interviews were also recorded and transcribed so that the research results could be audited and screened. Transcribing the result also provided stored information that could be viewed multiple times, and since the study was over 20-week period findings were revisited while analyzing findings and the theoretical framework.

2.6.4 Confirmability

Confirmability, which parallels objectivity, ensures that the researcher has acted in good faith (Bell et al., 2019), meaning that the researcher does not overtly or manifestly allow personal or theoretical values to sway research findings. Therefore, it is proposed that one of the objectives for the auditors should be to establish confirmability (Bell et al., 2019).

Qualitative research based on interviews is vulnerable to personal interpretation which can decrease the confirmability of the research. To avoid this case study being affected by misinterpretations of qualitative data, findings were confirmed by triangulation of interviewees answering the same questions and observations performed by the researchers. An example used in this study is confirming data from one interview with

other interviews. During the project, a supervisor was used to discuss ideas and interpretations of results and theoretical framework to decrease personal biases in the study. According to Bell et al. (2019), complete objectivity is impossible, but using audits and triangulation biases can be decreased or eliminated.

3 Theoretical framework

This chapter presents the theoretical framework of the study. First, the chapter explores I4.0 and I4.0 maturity models followed by traditional quality research. Secondly, the chapter explores Q4.0 in the digital landscape followed by theory on data-driven organization. Lastly, the chapter presents change management in the dynamic and innovative business environment.

3.1 Presentation of framework

The theoretical framework emerges from the purpose and aim of the study and is outlined in Figure 3. Recognizing the connection between I4.0 and Q4.0 establishes the background for Q4.0, hence the first step in the theoretical framework was to explore I4.0. Following I4.0 was quality, where traditional quality theories are investigated to identify the benefits of quality in current research. Moreover, the framework presents Q4.0 and two important aspects whilst applying Q4.0 in practice: data-driven organization and change management.

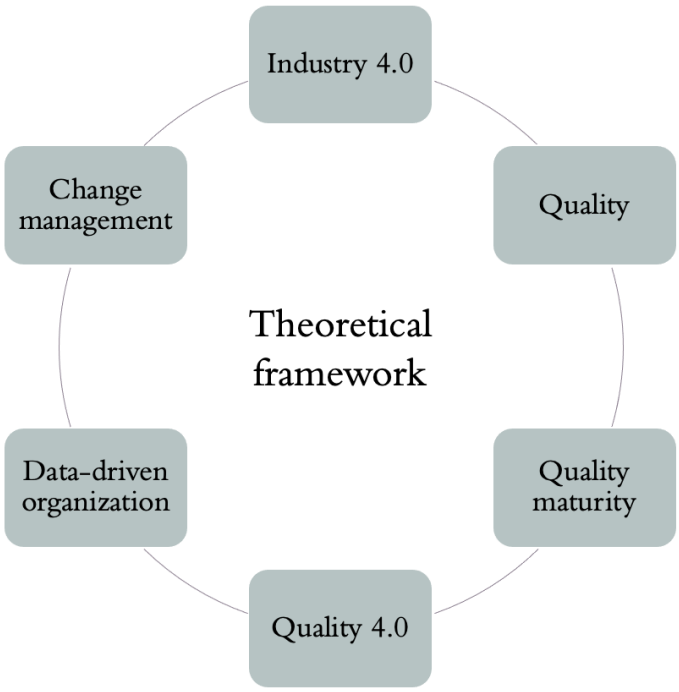

Figure 3. The theoretical framework

3.2 Industry 4.0

In history and the manufacturing industry's development, there have been revolutionary innovations since the industrial revolution (Oluwaseun et al., 2019). The manufacturing industry is currently in the fourth revolution, although the pace of implementation is different (Oluwaseun et al., 2019). These industrial revolutions are represented in Figure 4. The first industrial revolution was centered around increased efficiency through the usage of hydropower, increased usage of steam engines, and the development of machine tools. The second is defined by the usage of electricity and mass production in assembly lines (Oluwaseun et al., 2019). The third revolution is characterized by automation using electronics for mass production. The fourth industrial revolution, I4.0 is led by Cyber-physical systems (CPS) and the integration of the real world with information (Oluwaseun et al., 2019). The development of wireless connectivity was one of the crucial factors allowing for the integration of different devices into a system to gather and analyze data efficiently (Watson, 2019). I4.0 seeks to improve the industry by incorporating new emerging technology advancements (Wang et al., 2016). In addition, I4.0 seeks to improve and advance in global and social sustainability, such as improving people's standard of living and establishing a better work environment for personnel.

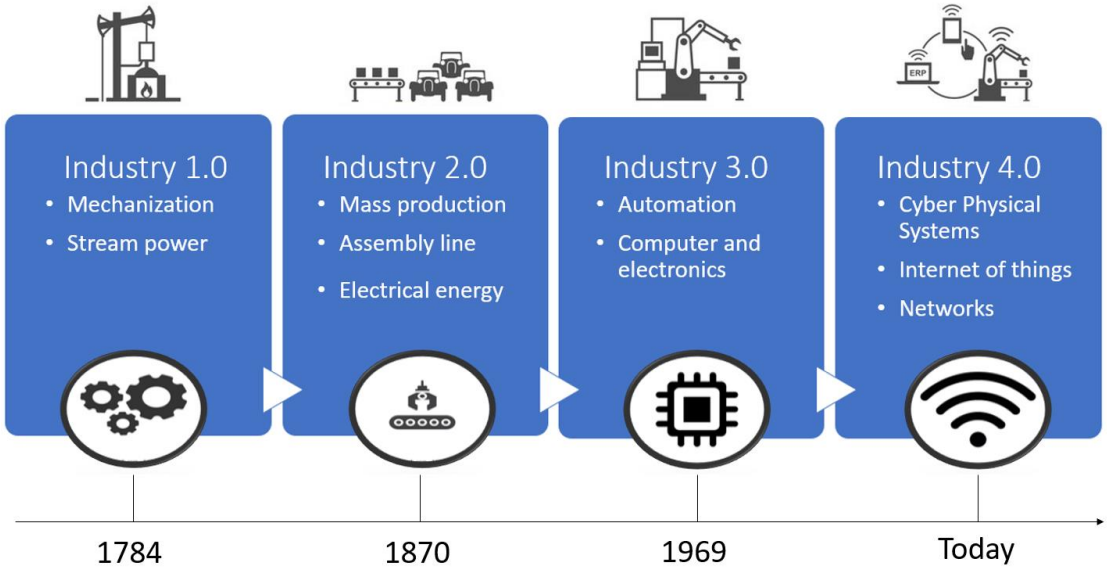

Figure 4. The four industrial revolutions (adapted from LNS Research, 2017)

SAP (System Applications Products Societas Europaea) has listed nine technologies that, according to them, are the nine pillars of I4.0 (SAP, 26 October 2021). In addition, I4.0 has been studied by Meindl and Mendoça (2022) and in the study, the nine pillars were identified as contributors to I4.0. The nine pillars are:

1. **Big data and AI analytics:** Data is collected from various sources, factory equipment and Internet of things (IoT) devices, Enterprise Resource Planning (ERP) and Customer Relationship Management (CRM), and information apps. Artificial intelligence (AI) and machine learning are applied to the data to analyze in real-time, and data insights are leveraged to improve decision-making and automation of areas within the supply chain.

2. **Horizontal and Vertical integration**: Horizontal integration is explained in tightly integrated processes on the production floor, across multiple production facilities, and the entire supply chain. Vertical integration focuses on tying layers of the organization, meaning that data can flow freely through the organization.
3. **Cloud computing:** Data storage provides the foundation for AI, machine learning, and IoT. The storage of data enables the Cloud Platform System (CPS) which is the core of I4.0
4. **Augmented reality (AR):** Overlays digital content in a real environment. For example, with AR systems, smart glasses or mobile devices can visualize real-time IoT data, digitized parts, repair or assembly instructions, etc.
5. **Industrial Internet of Things (IIoT):** Usage of sensors and Radio Frequency Identification (RFID) tags in production to provide real-time data about condition, performance, or location data. This technology lets organizations store data on the performance of the supply chain.
6. **Additive manufacturing/3D printing:** Enable organizations with rapid prototyping tools with a broad range of applications. 3D printing helps store parts and products in computed files in virtual inventories that can be printed on demand.
7. **Autonomous robots:** These robots can perform complex and delicate tasks with minimal human intervention. In addition, they can recognize, analyze, and act on the information they receive from their surroundings.
8. **Simulation/digital twins:** A digital twin is a virtual simulation of the real-world machine, product, or system based on IoT sensor data.
9. **Cybersecurity:** Implementation of Zero Trust architecture like machine learning and blockchain, organizations can automate threat detection.

Among business researchers, the definition of attributes that contribute to I4.0 differs. Kagermann et al. (2013) argue that Horizontal integration through value networks, End-to-end digital integration of engineering across the entire value chain, and Vertical integration and networked manufacturing systems are most important to implement for I4.0. Hermann et al., (2015) discuss and consider three other aspects of I4.0. These aspects are Cyber-physical systems (CPS), Internet of things (IoT), and Smart factory are the key components of I4.0. The authors identify different attributes that contribute to I4.0 both articles do, however, mention integration of systems through the usage of IoT as one of the crucial factors.

3.2.1 Industry 4.0 Maturity Model

Companies looking to improve their current business, using the incentives that embody Industry 4.0, can assess their maturity levels (informal and formal) in different operation areas. The assessment tool can be used for benchmarking and derives from The Industry Competence and Maturity for Advanced Manufacturing (IMAM) framework and is based on the Software Engineering Institute's Capability Maturity Model Integration (CMMI) approach. The IMAM model can also be used to assess companies' strengths and weaknesses and support implementing an improvement plan. Hence, the tool's utility in quality engineering areas supports companies that strive to adopt I4.0 and Q4.0 into the organization. The IMAM model consists of different application areas relevant for engineering and advanced manufacturing including strategy and long-term planning for advanced manufacturing. Within these areas are various activities and actions that companies can exercise to reach an advanced maturity

level. For example, in exploring processes in engineering, the company needs to assess if they have an engineering planning system based on information technologies. Secondly, if the company's tools of engineering design are computerized. In addition, if the company uses simulations for statistical design of experiments (DOE) as part of the design and engineering processes (Zonnenshain & Kenett, 2020).

3.3 Quality

The concepts that constitute the new generation in quality were forecasted by Watson (1998) over twenty years ago. At the time the technological developments and growing availability of the internet, telecommunications, personal computing, and networking could let quality functions become independent and automated. Twenty-four years later, the quality profession has played a significant role, especially in the manufacturing industry. Quality professionals must adapt to the ever-changing business environment of high innovation, radical changes, and technological developments (Zonnenshain & Kenett, 2020). Total quality management was developed by integrating total quality and management theories to take convectional product quality and integrate a broader perspective with customer needs and satisfaction. In the book Quality from Customer Needs to Customer Satisfaction, the authors Bergman & Klefsjö (2010) provide a general description and definition of what constitutes TQM:

> *A constant endeavor to fulfill, and preferably exceed, customer needs and expectations at the lowest cost, by continuous improvement work, to which all involved are committed, focusing on the processes in the organization (s. 37).*

Through active prevention, change, and improvements, quality managers are expected to actively seek continuous improvements and not see quality projects as one-off projects. Rather than a constant activity to evolve as a business and exceed the customers' expectations. If a company chooses to work with TQM, the key to being successful is top management support which establishes a business culture based on the six values seen in Figure 5 the cornerstones of TQM (Bergman & Klefsjö, 2010).

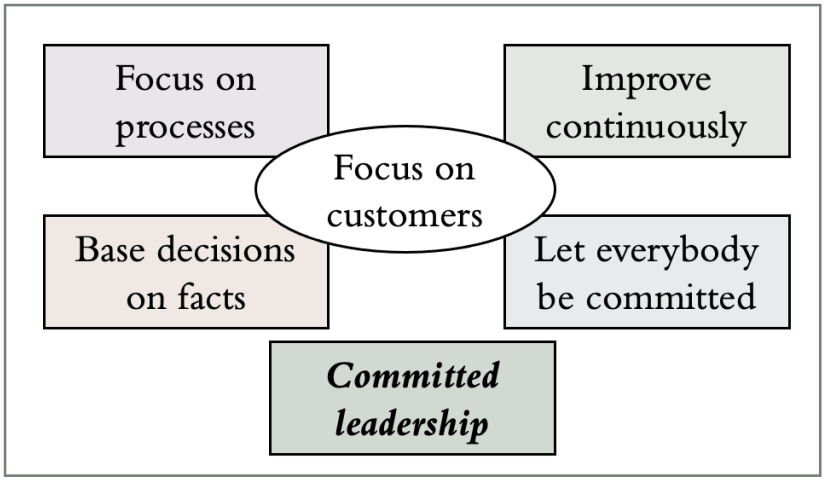

Figure 5. the cornerstones of TQM (adapted from (Bergman & Klefsjö 2010)

While the different values in the cornerstone model are important, committed leadership is acknowledged to be the critical factor for sustainable quality

improvements (Bergman & Klefsjö 2010; Sader et al., 2019). Committed leadership needs to be emphasized on all levels in the organization which engages the commitment of officials and staff to quality work. Combining committed leadership with personal commitment and strong visibility and clarity in the organization establishes a proactive approach to quality (Bergman & Klefsjö, 2010).

Table 2. TQM critical success factors (adapted from Sader et al. 2019)

Leadership and top management commitment	Education and training	Quality culture
Continuous improvement	Strategic management	Benchmarking
Supplier quality management	Statistical process control	Process and product design
Customer focus	Quality information analysis	Process management
Employees involvement	Quality assurance	Product Innovation
Employees empowerment	Quality citizenship	Knowledge management

Today, many industries, notably the manufacturing industry, have adopted the cornerstone values through the ISO 9001:2015 standard for quality management. ISO 9001:2015 forms a management system and can be used to support personnel and officials in daily operations. By strengthening the customer focus, leadership, motivation, productiveness, and efficiency, ISO 9001:2015 standard forms the business working structure with relevant information and documentation of how the business operates. Additionally, ISO 9001:2015 introduces risk-based thinking and evidence-based decision-making for systematic quality work and is applicable in all problem-solving and continuous improvement processes.

3.3.1 Quality maturity

In a business environment where quality is closely associated with the end customer, the people of a business are critical to thriving and delivering customer satisfaction. According to Wilson (2015), the key to modifying behavior is establishing organizational culture and not formal instructions. Hence, the organizational culture excels businesses to deliver a better product or service. To reiterate Bergman & Klefsjö's (2010) definition of TQM: "A constant endeavor to fulfill, and preferably exceed, customer needs and expectations at the lowest cost, by continuous improvement work, to which all involved are committed, focusing on the processes in the organization", which is interlinked with the Quality Maturity Model (QMM) presented by Wilson (2015).

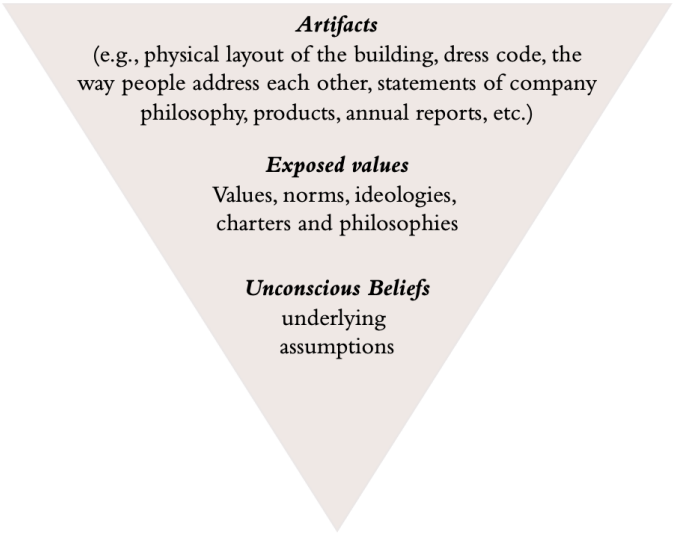

Figure 6. Schein's three levels of organizational culture (adapted from Wilson, (2015)

The purpose of the QMM is first to be a roadmap to enable businesses to determine the current state, what they want to achieve, and how to get there. It establishes a framework for management to prioritize actions. The QMM can also be used as a tool for assessment and allow a common language with a shared vision for different participants across business units or departments.

1. Ad hoc: the quality management is ad hoc or chaotic with few well-defined processes, and success depends on individual efforts.
2. Repeatable: established processes to attain success with more than one customer.
3. Defined: the quality processes have been documented, standardized, and adhere to the organizational strategy.
4. Managed: the quality process is measured in detail through data collection and is understood & controlled.
5. Continuous: the quality function continuously improves through feedback and innovative ideas. There is a strategy and forecast for future requirements to increase the performance.

Wilson (2015) demonstrates and accentuates how to use the QMM shown in Table 3. In summary, the quality maturity of a firm is assessed through the QMM and is a tool for mapping the current state of a company, and how to reach the desired state.

Recognizing that quality improvements should have the customer in mind can be done by developing the organizational culture (Watson, 2015).

Table 3. The quality Maturity Model (adapted from Wilson (2015)

Management of the organization	***Ad Hoc***	***Repeatable***	***Defined***	***Managed***	***Continuous***
Strategic plan generation	There is no strategic or annual operating plan	There is an established, but limited strategic plan	The Strategic plan is defined, and adhere to the business environment	The strategic plan consider the business environment and the top down, bottom-up approach	The strategic plan is continuously improving and used in daily operations
1. Management alignment	Actions are reactive and adjusted to the problem	Strategic plan includes improvement processes, but the actions are unrelated to the strategic plan, hence reactive	Strategic plan includes breakthrough improvement processes. Some actions are still not linked to the strategic plan	Strategic plan includes breakthrough improvement processes. Actions are linked to the strategic plan	The improvement processes incremental and breakthrough are interlinked with the strategic plan and is updated to new developments
…	…	…	…	…	…

3.4 Quality 4.0

Q4.0 arrives from I4.0 and integrates conventional quality approaches with a new technology which allows for organizational efficiency Javaid et al., (2021) and business excellence Martin et al., (2020), which Watson (1998) argued would lead to competitive advantage. Q4.0 builds on these traditional quality values and methods and uses new technologies to reach operational excellence, innovation, and performance (Jacob, 2017). Using the tools and technologies from I4.0, such as machine learning, connected devices, blockchain, and more, these tools contribute to advanced manufacturing and give quality professionals a new role in quality management. Quality management needs to take an active leadership role in these technological initiatives and recognize the need to build a business culture, leadership, and quality processes around digital transformation (Jacob, 2017). The value proposition found in Q4.0 is to improve the performance of people, processes, and products and is presented in Table 4 (Radziwill, 2018).

Table 4. The value proposition for Quality 4.0 (from Radziwill, 2018).

1. Augment (or improve upon) human intelligence.
2. Increase the speed and quality of decision-making.
3. Improve transparency, traceability and auditability.
4. Anticipate changes, reveal biases and adapt to new circumstances and knowledge.
5. Evolve relationships, organizational boundaries and concept of trust to reveal opportunities for continuous improvement and new business models.
6. Learn how to learn by cultivating self-awareness and other-awareness as skills.

Today many quality departments are still working with quality using traditional quality methods by measuring, collecting, comparing, responding, fixing, and repeating (Lyle, 2017). The reactive approach to quality work is nonetheless important for businesses, but it is not enough in a data-driven age with smart manufacturing and I4.0. According to a joint report by ASQ and APQC, “a growing 36% of organizations consider quality a strategic asset and competitive differentiator, " promoting the importance of becoming increasingly digital and using technologies embodied in I4.0 while working with quality. According to Lyle (2017), quality organizations with a high maturity level tend to focus on becoming proactive in working with value creation rather than being relegated to compliance or improvement activities. By doing so, the quality professionals of the company become a strategic partner with the ability to quantify the financial values of its efforts. By reinterpreting the quality professional’s role in a business environment, manufacturers need to realize the power of quality and embrace the technologies available to them, including automated data collection, cloud computing, IoT, etc. However, the steps of digital transformation can seem

overwhelming hence the need for guidelines and a strategy to achieve these goals (Lyle, 2017).

Lyle (2017) argues that manufacturers who seek to implement Q4.0 should start with semi-automating or automating their quality data collection processes. Automatic data collection process grants the business opportunities for improvement, and through centralized data and a reliable cloud environment manufacturer gains a big-picture view across the different units or plants. Once the data is centralized, different stakeholders can visualize, interpret, and understand more than a single aspect of a process or operation. The quality team and executives can now, in real-time, gain visibility over the entire enterprise and supply chain, including suppliers, internal processes, inspections, operations, maintenance, process data, packaging, storage, finished products, and the end-customer feedback. The culminating visibility gives management an operational insight that can be used to identify opportunities to increase output, decrease costs, and overall quality improvement throughout the organization. Recognizing that the unit-specific quality improvements result in incremental cost savings, the larger scope across business units or plants can lead to a game-changing digital transformation (Lyle, 2017). Q4.0, together with I4.0, can also lead to revenue. Boston Consulting Group (BCG) found in their Spiriting to Value in I4.0 report that "The value created by I4.0 vastly exceeds the low-single-digit cost savings that many manufacturers pursue today".

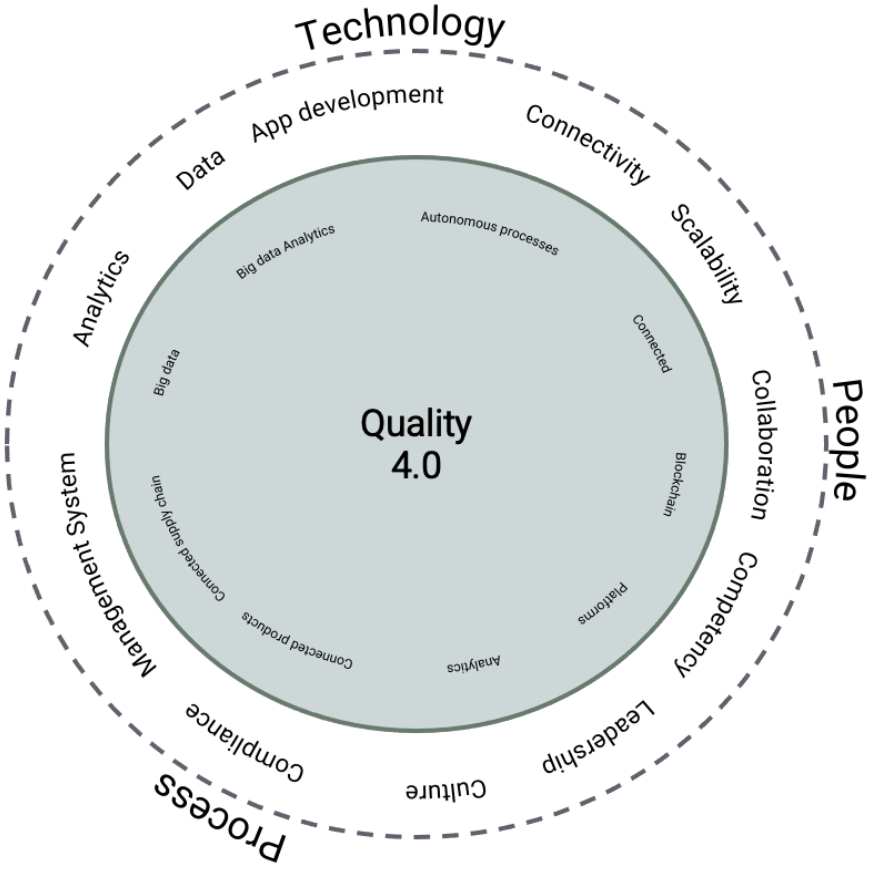

Figure 7. The 11 axes of Quality 4.0 (adapted from LNS Research, 2017)

LNS research (2017) has identified 11 axes or key components of Q4.0. The first key component is data which has always been a vital driver for continuous improvement.

As previously mentioned, many organizations lag in data collection. Organizations should strive to implement the tools and technologies in I4.0 to facilitate a good data collection process that is semi or fully automated, which supports the organization in informed and agile decision-making. Analytics outline that current quality metrics are reactive as they provide information on what happened and why. I4.0 provides tools through machine learning and AI to gain insights into predicting failures and inform the executives what actions are required to change the outcome. Connectivity refers to the link between information technology (IT) and operational technology (OT). For example, the IT tools of an enterprise resource planning system (ERP) and a control system (OT) leverage real-time data collection and can be used for better decision-making and feedback systems. Collaboration supports organizations in streamlining and synthesizing quality practices which can be used to improve compliance and efficiency and gain insights into factors such as customer satisfaction and supplier input. App development represents the digital devices in people's lives, from smartphones, tablets, and other wearable devices where programs and apps can be used from multiple devices and allow brands to connect with customers. Scalability highlights that a centralized data source allows businesses to achieve quality objectives across different plants or units through cloud computing.

The seventh component of management systems accentuates the need for harmonized and automated processes with software to improve business operations and systems autonomy. Compliance adheres to various tools and techniques that enable social collaboration across different divisions and work sites. Through compliance activities, data analytics can alert organizations of potential problems which allow for proactivity in daily work tasks. To adopt Q4.0 and succeed with the integration, the officials and managers need to establish a culture of quality that is accessible to every stakeholder. Through strong leadership, the quality teams should align their objectives with strategy and develop a roadmap or plan to reach the goal. The last component, competency, highlights that using technologies results in new outputs that can improve a variety of fields and areas in new ways.

3.5 Data-driven organization

The advanced and digital transformation technologies and use of data science provide the tools for competitive advantage and valuable insights. Today, the emerging technologies Internet of Things (IoT) smart devices, social media, and more provide a vast amount of complex data sources culminating in big data. Many industries, notably the service industry, have attained a dominating competitive advantage using big data while others (e.g., manufacturers, B2B, healthcare) have dragged behind. Many businesses are aware of the potential of big data but fail to the challenges of employing data-driven approaches to produce business value. To become a data-driven organization, businesses need a comprehensive approach, plan, and strategy for data science and data assets. The plan should align business strategies and objectives with data initiatives and market opportunities (Kayabay et al., 2022).

For businesses that strive to become data-driven, the main driver is strategy, skill, culture, and leadership (Dutta and Bose, 2015; O'Donovan et al., 2016). The literature offers prebuilt roadmaps for other business cases and Kayabay et al. (2022) argue that a business-specific roadmap is essential to succeed in becoming data-driven. The roadmap should include the strategic landscape and link an organization's

technological and commercial functions. Hence the roadmap facilitates communication and a consensus between business units or departments. Kayabay et al. (2022) developed the Data Science Roadmapping (DSR) framework to support data-disadvantaged or archiver organizations, to initiate the works with road mapping. The DSR framework guides businesses and connects organizational resources with business strategies and data. One of the goals of DSR was to generate a consensus among stakeholders, including data experts, the IT department, and top management, and to provide the practitioners with quantitative data which was proven to increase the confidence in decision making.

3.6 Change management

Organizations continuously strive to change and adapt their operations due to an increasingly complex and dynamic business environment (Errida & Lofti, 2021). Therefore, organizations must make investments in their processes and engage in changes to adapt to the complex environment. According to Nasim and Suhil (2011), management literature is replete with thoughts, theories, and models on organizational change and how to manage change. However, despite the literature by change management researchers, organizations fail with change initiatives at a rate of 3:1 (Nasim & Suhil, 2011). The study performed by Errida and Lofti (2021) confirms that 60-70% of organizational changes fail. From an organizational perspective, this is wasteful from both the economic and social point of view, which has been acknowledged by experts (Nasim & Suhil, 2011).

Today's industry has become increasingly digital, and the business environment has become increasingly complex (Errida & Lofti, 2021). Digital transformation has become a fact in the manufacturing industry. Willingly or unwillingly, this has become part of today's society (Sen & Gupta, 2020). The digital transformation has proven to be difficult and the problem, according to Sen and Gupta (2020), is not the technology behind the digital transformation. The struggle is the acceptance of a new system by the masses, and this is because people prefer to continue and remain in the current state without disruption (Sen & Gupta, 2020). To handle the digital transformation, Sen and Gupta (2020) identified three areas that organizations should consider to be successful in change management for digital transformation to handle digital transformation.

- The bottom-up approach works better than a top-down approach while implementing a new digital initiative.
- The objective of a goal should back training initiatives toward successful implementation of digital transformation, both employee and organization agree upon the objective. Change initiative that lacks ownership leads to failure of successful implementation.
- Diverse teams should be in place with different demographics and across different functional areas. Management should be set up to convince those who are resistant to change.

Galli (2018) agrees that change is inevitable, whether change is personal or professional. The author explains that change management consists of three layers: organizations, people, and projects. It is further explained that a proactive organization and project management team has a change plan or strategy for change. The plans

include projects or organization structure, business systems/processes, and employee role change requirements (Galli, 2018). After reviewing the change management models, Galli (2018) identified areas of concern and implications at various levels of the organization. These concerns are meant to aid managers and organizations that a broader picture for applying change management models is needed. The identified areas were:

- Strategic and operational change is essential to remain competitive. Both top-down and bottom-up leadership approaches are needed, and strong leadership could aid change management.
- Training is needed for management and leadership to oversee change initiatives. In addition, training on various aspects and the importance of the overall performance of change initiatives are necessary.
- Resource allocation and financial elements limit organizational change management programs. Focusing on short-term problems may not produce long-term solutions, managers should be aware of this and think systematically and holistically.
- Broadening mentoring by management and increasing leadership skills for every department or team to identify weaknesses. In addition, gap analysis and benchmarking can be used to identify weaknesses against standard industry practices. However, these tools must be handled with awareness and care when integrated with change management models.
- Team thinking, project teams, and organizational leadership need to determine the training content needed for the change initiative.
- Evaluation of team performance is important when managing change. This involves training, measuring, and monitoring various aspects of the team and linking the team performance to business performance.

Researchers within change management agree that the area is a complex and that it impacts the success of change initiatives (Errida & Lofti, 2021; Nasim & Suhil, 2011). Galli (2018) extensively explains the different change management models and concerns regarding change management. Depending on the change, different management is needed, and knowledge within change management and a clear strategy is needed for successful change initiatives. All authors, Errida and Lofti (2021), Nasim and Suhil (2011), Galli (2018), Sen and Gupta (2020), agree that change management is a delicate matter, and to succeed in change initiatives, it must be managed carefully.

4 Findings

The chapter is divided into two sections. The first section presents the theoretical findings used to answer RQ1 and the Quality 4.0 Maturity Model. In the second section, the empirical findings present information gathered through interviews with officials and managers, company visits, and the existing management system.

4.1 Theoretical findings

In this section, the findings from the literature study are presented. First, due to the large scope of Q4.0 and I.40 and the lack of research on the topic of Q4.0, the authors of the thesis had to establish a framework and definition for Q4.0. Secondly, by evaluating existing quality maturity models, a selection of interlinked aspects and areas in Q4.0 and quality maturity models was summarized to conclude the Q4.0 synthesis and present the Quality 4.0 Maturity Model.

> *RQ1: What constitutes Quality 4.0 from the perspective of a manufacturing organization?*

4.1.1 Summary of Quality 4.0 definitions and frameworks

Through research and analysis of existing Q4.0 literature, it was determined that there is no clear definition of Q4.0. Several researchers have tried to define Q4.0 and reach a consensus. Aldag and Eker (2018) defined Q4.0 as a blend of traditional quality management practices and techniques with new technologies presented in I4.0, such as the Internet of Things (IoT), Big Data, and more. Jacob's (2017) definition of Q4.0 aligns with Aldag and Eker (2018) and says it will grant businesses new optimums in business excellence, innovation, and performance. Sader et al. (2021) conclude that Q4.0 is a new generation or evolution of quality management that emerges from traditional quality management and the I4.0 and Information and Communication Technology (ICT) advancements.

Considering that there is no clear definition or framework, the authors of the study present an aggregated definition or interpretation of Q4.0 that contemplate Aldag and Eker, Jacob and Sader et al., view:

> *Quality 4.0 is the next step in quality management that emerges from Industry 4.0, where integration of people ↔ technology ↔ processes is the key to reaching business excellence and performance.*

Acknowledging the link between Q4.0 and I4.0 provides a framework for different tools and technologies supporting manufacturers and organizations working with Q4.0. While embarking on the Q4.0 transformation journey, LNS research has identified 11 aspects of Quality 4.0: data, analytics, connectivity, collaboration, app development, scalability, management systems, compliance, culture, leadership, and competency, which encapsulates the different aspects of Q4.0.

4.1.2 Summary of existing quality maturity models

The section presents a summary of existing quality and Q4.0 maturity models.

4.1.2.1 Quality maturity

The literature review concluded that businesses that seek to assess maturity levels need to consider quality maturity and Q4.0 maturity levels to capture the quality perspective and the readiness for tools and technologies embodied in Q4.0. By reviewing case studies and research, it was also noted that while measuring maturity levels, adaptation and extensions of the models were common to fit the aspects and context of the business. Referring to the views of Jacob (2017) argues that a solid traditional quality foundation is key to success in Q4.0. Wilson (2015) argued that the people of the business or organization need to be the driving force of quality improvements, which management can improve by developing their business culture. As many manufacturing industries have attained the ISO 9001:2015 certification, most have already started their journey in quality management. However, if there is competency bound to personnel or if the organization needs an assessment on how they are currently working with quality, the Quality Maturity Model (QMM) can be used to identify opportunities for improvements. The new Q4.0 approach does not replace traditional quality methods but rather enhances and builds upon them. Hence, the first step in assessing maturity levels is to assess the quality maturity to understand the foundation of quality within the organization.

4.1.2.2 Q4.0 Maturity model

For businesses who pursue the opportunities and tools embodied in Q4.0, the next step is to assess the maturity level toward Q4.0. By reiterating a previous statement, there is a close link between Q4.0 and I4.0, where past research suggests that assessing the maturity level toward I4.0 is an alternative approach. The IMAM model, with its different application areas ranging from strategy and long-term planning for advanced manufacturing, information, and knowledge management to investment in infrastructure and equipment, provides the assessment tool required to evaluate strengths, weaknesses, and the work toward I4.0. However, by recognizing that the topic of Q4.0 is getting increasingly established and acknowledged, the focus must be on quality, increasing the feasibility, and demarcating Q4.0 to its different aspects and contents. While searching for other Q4.0 maturity models, the authors concluded that there is no established Q4.0 maturity model that is easily accessible for companies or researchers. Thus, an interpretation of a Q4.0 maturity model was required.

4.1.3 Synthesis for developing the Quality 4.0 Maturity Model

The basis of the Q4.0 Maturity Model originates from the 11 axes of Quality 4.0 from LNS research (2017), being data, analytics, connectivity, collaboration, app development, scalability, management systems, compliance, culture, leadership, and competency. The 11 axes of Q4.0 were, in turn, analyzed toward existing literature. A recurring element while working with data is the endeavor to become a data-driven organization through the literature findings. The aspect of a data-driven organization is consequently the ambition when working with Q4.0 and supporting the organization in realizing the potential outcome of Q4.0. To reap the benefits of Q4.0, the organization needs to assess its maturity according to Figure 8, which concentrates the vast scope of the 11 axes presented by LNS research and adds two elements: quality maturity and change management. The first element, quality maturity, was added to determine how businesses currently work and encourage quality work within the organization. The second element of change management adheres to the motivation to change in an organization where personnel and managers need to seek disruptive changes and

innovation for new opportunities and improvements. As change initiatives often fail due to poor management, the organization's leaders need to facilitate and support a bottom-up approach to new digital initiatives. To succeed in Q4.0, it is also essential to create a strategy and plan with established roles and responsibilities and allow cross-functional teams for the dynamic and ever-changing digital business environment. The different aspects culminate in readiness for the digital transformation toward Q4.0.

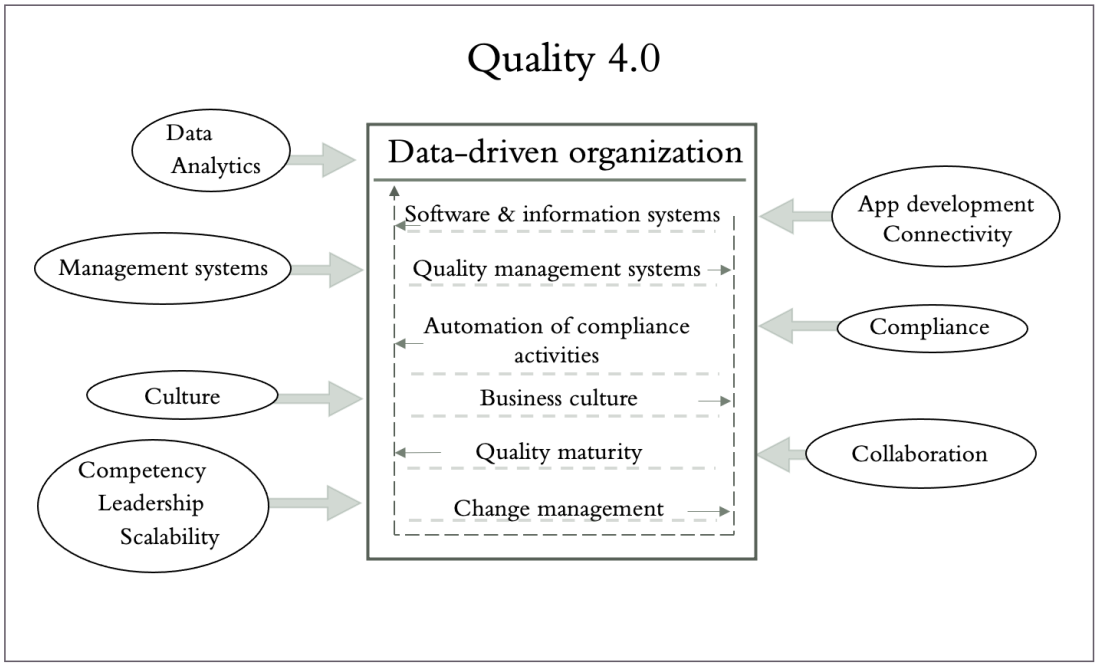

Figure 8. The seven principles of the Quality 4.0 Maturity Model

Data-driven organization

For quality professionals, data is a vital driver for continuous improvements. Using transparency in data ensures that the data is accurate and comes from an official source. However, collecting data from various sources using the I4.0 framework, such as big data analytics and IoT devices, is still a challenge for manufacturing, healthcare, and B2B industries. Therefore, quality professionals must recognize the need for an integrated and automated data collection process that, together with data analysis bridges the gap toward Q4.0. Seizing the technological developments in new platforms and smart systems for data governance shifts the quality professional's analytical role towards an engaging role in new technologies. Thus, the new role supports organizations in understanding these technological developments, their potential outcomes, and determining how and when to use them. Data analytics will nonetheless remain important, and the analytic function improves drastically through digitized systems that allow visualized and descriptive data. To become data-driven, organizations need a comprehensive approach with a plan and strategy for data and data assets that must be aligned with business objectives and different stakeholders' interests. Using machine learning and AI can also support the work in predicting failures, resulting in becoming increasingly proactive within the organization. Additionally, collecting data enables benchmarking, allowing organizations and businesses to compare and evaluate their performance.

Software & information systems
While technologies are continuously improving and new software, ERP, and apps are developed, organizations need to be agile and seek improvement of existing IT/OT. The digital software and apps available on the market enable organizations to build ERP or business systems with features to automatically track quality deviations and utilize tools and technologies embedded in I4.0. In addition, the connectivity and integrated communication channels allow organizations to connect with customers, suppliers, and stakeholders through tablets, smartphones, computers, and other wearable devices. Aligning different platforms is a challenge but the output results in increased productivity and efficiency, in conjunction with flexibility where personnel can access systems remotely or from their home offices. Thus, one tool in I4.0 is cloud computing which increases the flexibility of the organization.

Two fundamental aspects constitute information systems: connectivity and communication. Connectivity in Q4.0 refers to the link between information technology (IT) and operational technology (OT). For example, the IT tool of an enterprise resource planning system (ERP) and a manufacturing control system that connects and leverages the collection of real-time data used in decision-making and automizing feedback systems. The new integrated software also increases the quality by smart and streamlined quality work throughout the organization. In addition to the link between IT and OT, connectivity deems to increase the collaboration within organizations by integrating communication channels with IT systems for faster and more responsive communication over the more traditional use of email. Thus, the new tools and practices of Q4.0 leverage social listening and blockchain to gain insights into quality factors such as customer satisfaction, traceability, and visibility of parts and products through the supply chain.

Quality management systems
Q4.0 management systems refer to the usage or adaptation of quality management systems and modern technology in management systems. Quality management systems can differ between different philosophies, but the system's purpose is to benefit the organization's quality work. Common management philosophies are Lean, Six Sigma, ISO 9001, and CMMI. Through the usage of management systems and social collaboration, organizations can integrate functions and share information to benefit the organization. Q4.0 focuses on integration; compared to Q3.0 and Q2.0, the purpose is to integrate quality management systems and automated processes with software. In addition, it focuses on connecting automated processes with other operations.
An example is the integration of automated production with humans and the integration of business systems, such as customer management systems (CMS). Increasing integration and improving system autonomy will decrease the time spent on execution by high-value staff and management. Therefore, management can focus on strategic improvement and proactive work involving innovation, development, business growth, and quality assurance.

Automation of compliance activities
Q4.0 consists of various tools and technologies that can be implemented to automate compliance activities. Compliance activities are defined as ensuring personnel and activities are in line with laws, regulations, and audits (Jacob, 2017). Implementing social collaboration increases the capability for organizations to share successful compliance approaches across different departments within the company and between

work sites within the organization. Usage of automated compliance activities and data analytics can help alert the organization about compliance breaches and allow organizations to engage in proactive actions. Assessing current compliance strategies and identifying improvement opportunities through automated compliance activities is part of the data-driven and integrated organization in Q4.0.

Business culture

For success in quality work, organizations must adopt a quality culture and have strong leadership. Q4.0 is defined by agile organizations with integrated information systems shared by all company departments. The integration of data, functions, and processes helps organizations improve visibility, connectivity, and collaboration, allowing the company to adopt a quality culture. Q4.0 also emphasizes committed leadership, understanding of quality, and its impact on organizational success. Top management commitment is essential because managers' role in quality is partly to set business objectives, align quality work, and develop strategic aims. Therefore, a culture for quality and leadership plays a vital role in Q4.0 as organizational support is one of the enablers of quality work.

Quality maturity

For businesses that pursue work with Q4.0, the initial step is to assess the organization's quality maturity. Firstly, by assessing the management's understanding and attitude, which measures the leadership's attitude, motivation, understanding of quality management, and the importance of being proactive in working with quality. Secondly, by assessing the position toward quality in the organization establishing quality managers, leaders, and the cooperation with the board and directors. The third assessment area refers to problem-solving and how the company establishes a proactive approach instead of reactive and ineffective problem-solving techniques. The fourth assessment area is the cost of poor quality, where a proactive approach to quality is associated with reduced failure costs. Lastly, the fifth assessment area highlights how the company organizes and maintains improvement processes from sporadic to organized and sustainable processes over time.

Change management

Q4.0 is dependent on integrated systems, for example, IIoT, IoT, and CPS. New technologies are the enabler of Q4.0, and it is reliant on integrated information systems and digital transformation. Managing the digital transformation part of Q4.0 determines the success of change initiatives and proactive quality work. Organizations need to organize, develop a plan, and establish a strategy and ways to control the change process to manage the digital transformation. Controlling a change initiative can be done by measuring the success of implementation according to business objectives and the outcome of a change initiative. Organizations that are proactive in change management have a strategy for change initiatives and work with different approaches, for example, bottom-up or top-down depending on the change initiative. In addition, to manage change initiatives, organizations constantly have to work with resource allocation, training of personnel at all company levels, and mentoring of project work.

4.1.3 The Quality 4.0 Maturity Model

The seven principles of Q4.0 that were established in the synthesis provided a framework for the Quality 4.0 Maturity Model which is presented in figure 9. The model is used to identify a business or organization's current state toward the seven principles of Q4.0 and if there is a reactive or proactive approach within these areas.

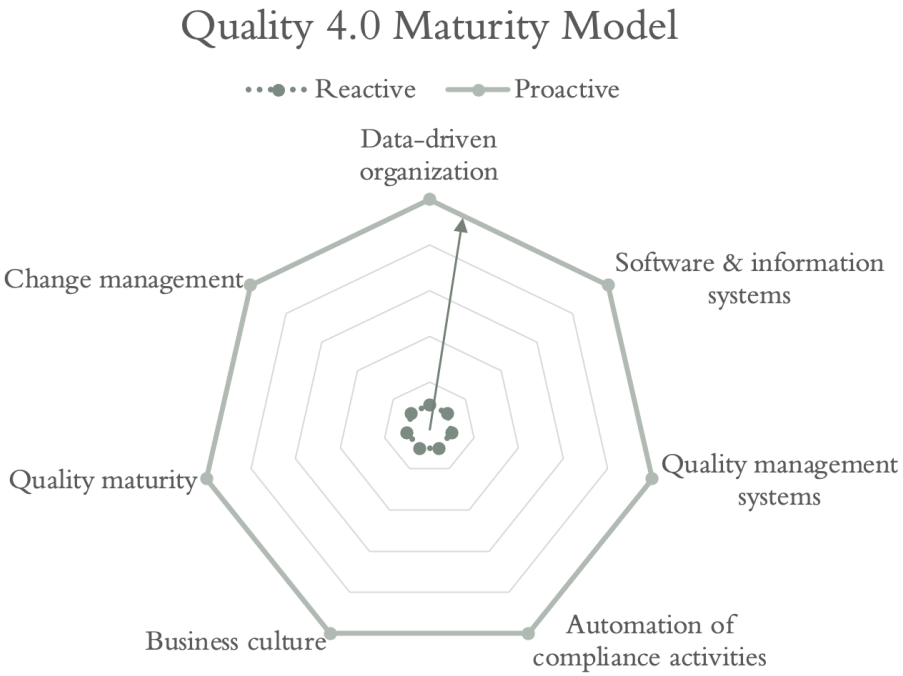

Figure 9. The Quality 4.0 Maturity Model

The scale used in the model presented in table 5 derives from the master's thesis foundation with the ambition to use Q4.0 to become proactive working with quality. Hence, the scale starts from reactive and moves toward proactive. It is worth mentioning that the seven principles are interlinked. If a firm were to develop software & information systems, it would increase the goal of becoming a data-driven organization and the work towards becoming proactive.

Table 5. The scale used to assess a business current state

Reactive ⟶ *Proactive*

Q4.0 factors	***Ad hoc***	***Repeatable***	***Defined***	***Managed***	***Continuous***
Data-driven organization	There is no defined or established data collection process or transformation strategy	There is an established data collection process and transformation strategy	The data collection process and transformation strategy is defined and adheres to the business environment	The data collection process and transformation strategy is managed and support the organization in decision making.	Data is continuously being used and analyzed in decision making. The transformation strategy is reflected and updated to the current operations and changes.
Software & information systems	There is no IT, ERP or communication systems	There is established software's IT/ERP/QMS etc.	There is defined software's IT/ERP/QMS that adheres to the business environment	The software's IT/ERP/QMS is managed and support the organization in decision making	The software's IT/ERP/QMS is continuously improved
Quality management systems	There is no established management system for quality	There is an established management system for quality with limited usage and awareness	There is a defined management system for quality that adheres to business environment	The quality management system is managed and support the organizations quality culture	The quality management system is continuously improved and used in daily work
Automation of compliance activities	There is no established tools or technologies to automate compliance activities	There is established tools or technologies to automate compliance activities, but with limited usage	Automated compliance activities are defined and adheres to business environment	Automated compliance activities are managed and support the business environment	Automated compliance activities are continuously improved and used in daily work
Business culture	There is a business culture that is reactive and lacks leadership and motivation	There is an established business culture Management do not communicate or motivate the importance of proactivity	There is a defined business culture with goals and regulations. Management acknowledge the importance of proactivity	The business culture is managed through policies/QMS etc. Management seek to inspire and motivate personnel and include them in improvements towards becoming proactive	The business culture is continuously improving Management recognize the need for proactivity and use a proactive mindset
Quality maturity	The organization has low level of quality maturity	The organization are aware of quality maturity and asses it with limited usage	The organization asses quality maturity in daily operations	The organizations quality maturity is managed and support organizations culture of quality	The organzations qulaiy maturity is contiously being analyzed and to optimize business operations
Change management	There are no defined or established change management processes	There are defined change management processes with limited usage	Change management processes are defined and, change management model used adhere to business culture	Change management is managed and management models are used to manage change initiatives in the organization	Change management practices are continuously used in change initiatives. Depending on the initiative the organization apply different change strategies, bottom-up and top-down for example

4.1.4 Summary Theoretical Framework

The different principles within the theoretical framework conclude the Quality 4.0 Maturity Model and answer RQ1. The scale used within the seven principles goes from reactive to proactive, which can be used to identify the current situation at a business and how they can work toward becoming increasingly proactive. In summary of the Quality 4.0 Maturity Model, organizations need to assess the quality maturity to identify strengths and weaknesses in the transformation toward Q4.0. Organizations must recognize the need for data collection and how data can support the business in decision making and continuous improvements. Systems can leverage real-time data collection, smarter communication channels, and automated feedback systems through advanced and integrated information and operation technology. The advantage of software & information systems increases the flexibility as personnel can now access business information through their devices, smartphones, from their homes, or while traveling. Integrating management systems with processes leverages customer awareness and satisfaction within the supply chain while becoming increasingly aware of potential problems or defects.

Furthermore, automating compliance activities ensures that personnel and activities are according to laws, regulations, and different requirements, and through collaboration, organizations can share successful compliance approaches across different units/departments. If a business lacks a quality department or knowledge in fundamental quality management, assessing the quality maturity might be necessary to identify how they currently operate in quality. Lastly, recognizing that all these principles and aspects correlate to the organization's leaders and how they choose to manage the digital transformation process. Change management is an enabler for these incentives, which support the organization in developing a digital transformation strategy, structuring, planning, and adopting a business culture that promotes change and disruptive innovations.

4.2 Empirical findings

In this section, the empirical findings are presented from the interviews and data collection from the case company, which answers the second research question of the thesis RQ2:

> *RQ2: How can the current state of Quality 4.0 in a manufacturing organization be evaluated?*

4.2.1 Company presentation

Troax is a manufacturing company established in 1955 and produces refined, innovative steel mesh panel solutions. Troax sells protection for humans, property, and processes. With sales offices in over 42 countries, seven manufacturing units, and approximately 975 employees in eight distribution units, Troax has reached a market-leading position and is the largest producer of mecs panels, with their base in Hillerstorp, Sweden. In addition, Troax produces machine guarding, warehouse partitioning, and property protection. Quality is of importance to the company because as mesh panels are used for protection, they must resist forces that can occur in automated production, storage of products, and protect storage from vandalism and burglary to protect the environment. Therefore, the quality is not only crucial for the

mesh panels. Troax also produces sub-products that have high-quality standards so customers can be assured protection.

4.2.2 Findings from interviews

The study's authors have conducted five interviews with personnel from different departments at Troax. All interviewees were transcribed and are found in the appendix. The interviewees were quality manager (*Appendix 1*), production manager (*Appendix 2*), production support (*Appendix 3*), quality engineer (*Appendix 4*), and digital business and marketing developer (*Appendix 5*). In addition to the interviews were open discussions with the supervisor at Troax and attending the Gemba walk, which mapped out the current state of Troax. From the theoretical framework, the seven principles of the Quality 4.0 Maturity Model differentiate the aspects and establish the structure of the interview findings. The results from the interview are presented in the following section.

Data-driven organization

Troax uses and collects data differently within the production. The organization's various departments collect data on key performance indicators (KPI) to monitor objectives. An example of this presented by the interviewees is that the production manager and production support measure overall equipment efficiency (OEE) for the production operations. The OEE is monitored in real-time in a system called Axxos and shared on screens strategically placed so that machine operators can take part in production efficiency (*Appendix 2*). The shared information is the availability and performance, and machine operators are aware of the goals. For example, if the availability in one shift is low, the machine operators know that they have a backlog, and they can act to increase availability (*Appendix 3*).

The OEE measurement used by Troax does not take quality into account. Their focus is first based on the availability of the machine and second on the performance (*Appendix 3*). The OEE is reported semi-automatically in Axxos. When a stop has occurred, the machine operator will report the cause manually in the system, and the downtime is reported automatically. Stops in machine operations are categorized into extended cycle time, small stops, and more significant stops that must be coded with an explanation by the machine operator (*Appendix 3*). The differentiation is used to identify the type of stop and their losses. Reporting of larger stops has preset headings that explain why the stop occurred. There is also one heading, “other machine error,” that demands a written comment on the reason for the larger stop. The gathered OEE data is analyzed to increase uptime for machines but also analyzed by the maintenance department to decrease maintenance stops. The production department recently installed new vibration indicators to help identify the wear and tear of engines powering a production process (*Appendix 2*). To ensure the quality of products machine operations tests produced products. At the start of producing an article, there is a test on the first piece; after that, they have a sampling of produced products (*Appendix 1*). The sampling is standardized for each production line, and an example of a control interval is the first first piece, 60:th piece, 120:th piece…,. Quality inspection manual consisting of visual inspection and measurements, procedures are standardized and documented in Troax QMS (*Appendix 4*).

The quality department at Troax measures KPIs on quality deviations, both internal and external (*Appendix 1, Appendix 4*). Internal deviations are registered by personnel, and external deviations are registered by sales companies. All deviations are registered manually in their QMS and monitored in the percentage of quality deviation of produced products. QMS and Axxos are not integrated; therefore, quality deviations reported in QMS do not impact the OEE (*Appendix 4*). According to the production support, Axxos does not support quality in the OEE in its current state (*Appendix 3*). The quality deviations are analyzed by the quality department and used for both project work and continuous improvement to decrease the number of external quality deviations (*Appendix 4*).

The department of purchasing gathers data at Troax. It consists of categorizing suppliers and evaluating the suppliers' importance to the organization based on the kraljic-matrix (*Appendix 4*). The purchasers evaluate suppliers, and the matrix is updated manually. Troax has started demanding sharing information from suppliers and the usage of ISO9001 certification (*Appendix 4*).

Software & Information system

Troax has an ERP system, iScala, that is the base of their production facility. iScala monitors the company from stock levels to incoming orders. The ERP system is accessible through company computers and VPN, enabling home offices. In addition to the ERP system, Troax has an OEE monitoring system connected with ERP cycle times and is accessible by personnel on-site and via VPN in home offices (*Appendix 3*). The information on the availability and performance of their production lines is shared through their cloud service. For quality, Troax uses their QMS, an internal communication system for personnel containing management documents, work procedures, internal deviations, and more. Troax's own sales companies also use QMS, and they send information on quality deviations found by the final customer through Troax QMS (*Appendix 4*). The deviation is later processed by quality personnel, and new products are sent as compensation after investigating the issue. Recently Troax department of quality has started to transfer data on quality deviations into power Bi software to help them analyze the deviations (*Appendix 4*). Troax has also evaluated using a vision system in their production lines to find quality deviation without manual inspections (*Appendix 2*).

Order planners at Troax plan production through iScala, use prodstat and excel spreadsheets for the cycle times. The information on cycle times of produced products is transferred into their OEE system to track the availability and performance of production lines (*Appendix 3*). Inventory levels are also monitored, and if it is needed to produce or purchase materials, this is monitored in iScala and imlog. Troax has several production lines where they produce parts and finished products. To monitor the production, job orders are generated and attached to pallets with a barcode (*Appendix 3*). However, in today's manufacturing facility, the traceability of materials and components in production is challenging. This is because when the output of one process is used as input in the following process, the job orders on pallets are deleted (*Appendix 3, Appendix 4*). When products are delivered to customers, Troax can therefore only trace products in its last process, which is painting.

Troax also has a QMS where all the management documents are stored (*Appendix 1, Appendix 4*). The QMS is used for uploading work procedures for the production floor,

assembly, inspection of goods, business SWOT analysis, and more. The purpose of the QMS is to have information accessible by all personnel and that it is a platform for sharing work-related information. When management documents are updated, the departments of interest are informed of the update through email. In addition to QMS, Troax uses a system for OEE. The system connects Troax operations with their ERP system and logs data on availability and performance (*Appendix 3*). Axxos is available for Troax personnel, and the OEE is also shown on monitors placed in connection with production lines (*Appendix 2*). The information from Axxos is also used in daily management, where the OEE is presented on boards. For maintenance, Troax uses a program called IDUS (*Appendix 4*). This program is used to schedule maintenance and follow up on previous maintenance actions. IDUS also stores information on who performed the maintenance and what actions were taken during maintenance.

Quality management systems

Troax adapted ISO-9001 in 1995 and ISO-14001 in 1998, and it has been its management system for quality since. Troax is certified within both standards, and internal and external audits are carried out yearly to maintain certificates and improve processes (*Appendix 1*). The organization is hierarchically structured, and the different departments respond to their nearest manager (*Appendix 4*).

For daily management, Troax has a "Gemba walk," and it contains a walk-through of the production lines at Troax. In the meeting, the departments are represented, production manager, production engineer, maintenance, assembly manager, customer service, and distribution central manager (*Appendix 4*). For all production lines, the OEE is presented, including the number of articles produced, stock levels, and if they are producing products according to the demand. When starting the meeting, they fill two templates: Quality, which refers to if there has been an external deviation that day connected to the process, and Environment, which refers to if there have been any accidents in the production facility. In Gemba Walk meetings, machine operators also report information from production lines.
An example could be that machine sensor signaling often. If actions are needed, they assign staff to take action, and a follow-up plan is discussed (*Appendix 2*). The information about the problem on the board is erased, and the information is not stored (*Appendix 1*).

In addition to daily management, Troax works with continuous improvements part of ISO standards. It was explained that they have a goal of five larger PDCA projects (plan, do, check, and act) every year (*Appendix 4*). For these projects and continuous improvements, Troax has also adopted 5S from Lean. Furthermore, Troax assembles a team yearly consisting of the head of the sales companies to improve product quality. In these called TPT meetings, they discuss customer demands and trends in the market (*Appendix 4*). To further the secure quality of products, Troax works with both incoming quality control and supplier relations that map suppliers according to the Kraljic-matrix (*Appendix 4*). If suppliers are critical for business or have quality issues, Troax audits their process to ensure the quality of supplied material.

Quality Maturity

Troax is continuously improving its quality operations. During the interview with the production manager, he emphasized the need to improve the quality continually. The top management approach to quality management is motivated by allocating resources

to the quality department and setting quarterly KPIs (*Appendix 1*). Thus, as previously mentioned, middle management has gained a central role in managing the quality operations where Troax uses different tools (vibration measurements, Gemba walks, and more.) to manage internal quality deficiencies and reach the targeted KPIs. Additionally, the quality department is responsible for the ISO certificates and the quality management system (*Appendix 1*). While discussing problem-solving at Troax, the interviewees agree that Troax uses a reactive approach and has issues with traceability in the production process (*Appendix 3*). The results are that external deficiencies caused by internal problems are hard to trace and are not registered in a database sufficiently. This causes much extra work if an external deficiency is registered. As a result, the managers must start an unconventional detective work to find the root of the problem, which occupies resources, takes time, and costs money. Moreover, the detective work and the additional resources have not been addressed; hence the money spent is unknown (*Appendix 1*).

Troax works with continuous improvements daily. For example, the Gemba walks where different departments ranging from production managers to technicians, participate and inspect the internal processes in the production (*Appendix 2*). If problems are identified, they are discussed and addressed during these walks, where one or more officials are usually appointed responsible for solving the issue. Troax arguably strives to be organized and sustainable in the improvement process. However, during a Gemba walk, it was noted that when a problem is solved, Troax would remove it from the whiteboards and not register the information in a database (*Appendix 1*).

Business culture

Troax has adopted ISO standards and manages its production to deliver quality products to its customers. Both the quality manager and production manager state that quality is one of the most important goals for Troax (*Appendix 1*, *Appendix 2*). Every employee is responsible for product quality, meaning that employees can stop production if there are quality or safety issues. Middle management visualizes and breakdown performance figures so that employees can understand what is expected of the production lines (*Appendix 2*). In work for quality, Troax wants to reduce external deviation and detect quality deviations internally. Therefore, machine operators can report quality deviation to their nearest manager and share input for future quality projects. Middle management has a strong focus on quality, but top management has not been that involved in goal setting for quality. Top management understands the importance of quality but underestimates the challenge of moving from reactive to proactive work for quality (*Appendix 1*). With the growing market and increased market share, Troax must keep up production to deliver products on demand. Therefore, the focus is currently on keeping production running today rather than focusing on strategic improvements (*Appendix 1*).

Automation of compliance activities

Troax works with ISO standards and has internal and external audits to be a certified organization. The process of audits is not automated and is carried out by the quality team (*Appendix 4*). For supplier audits, the process is the same, and the audits are carried out by either purchase personnel or quality personnel, depending on the type of audit. For processes and workflows, Troax has automated its reorder point system (ROP) so that it alarms when the supply of material is low. This process is automated

and purchasing or production for resupply is handled by the department of customer service & planning (*Appendix 4*).
Troax has automated production lines that produce finished products, but they have to be fed with material, and no product can move through production without human interaction (*Appendix 4)*. However, from feeding the material into production lines of standard products, there is no human interaction until the loading of finished goods before delivery. This results in the implementation of self-driving trucks and automated picking of panels in their coloring process.

Change management
At Troax, they do not work with an established process for change management (*Appendix 1*). Recently the department of quality restructured the packaging process of finished goods after an analysis of the work procedure. After the restructuring, the quality manager felt that they have not come as far as they had hoped in the process of restructuring. According to the quality manager, this was partly because the challenge of change and the consistency needed were underestimated (*Appendix 1*). It was further explained that this was one of the most significant restructurings in years, and the department of quality is learning from the process.

Troax does not have a strategy for incorporating technical tools to increase efficiency or a strategy for digital technologies to decrease quality deviations (*Appendix 4*). Previously this has been the responsibility of the different departments. An example is that the production manager is responsible for the technical tools used in production, and the quality department is responsible for the QMS. The "owner" of incorporating new technologies has been difficult to identify within the organization (*Appendix 1*). However, Troax has assembled an IT counsel, and the purpose is for them to be responsible for incorporating digital tools for production systems, QMS, integration systems, and more. As this team is newly assembled, there have not been any outcomes from the counsel, but the quality manager hopes to see results and a plan for the digital transformation going forward (*Appendix 1)*. Troax does, however, have a strategy and takes steps in their digital transformation in business to the business sales process (*Appendix 5*). This strategy focuses on the possibility of self-service and accessibility, which is a priority of the digital business and marketing department.

4.2.3 Summary of empirical findings

After summarizing the empirical findings, the current state at Torax is defined with the theoretical framework as a background in Figure 10. Troax emphasizes the importance of quality and has regular audits aligned with quality standards. In addition to audits and quality standards, Troax has established a structure for daily management that focuses on quality, internal deviation, and health & safety. For managing quality, Troax has management systems in place, for example, daily management structure and ISO audits which increase proactivity in management systems. However, the organization lacks top management commitment, the focus on quality is high, but the understanding of the width of becoming proactive is low. Therefore, Troax is reactive in its business culture and uses and engages in proactive work such as audits and continuous improvements. Quality maturity within the organization is medium/high because of the above-mentioned factors. Therefore, Troax focuses on quality and quality management systems to increase quality.

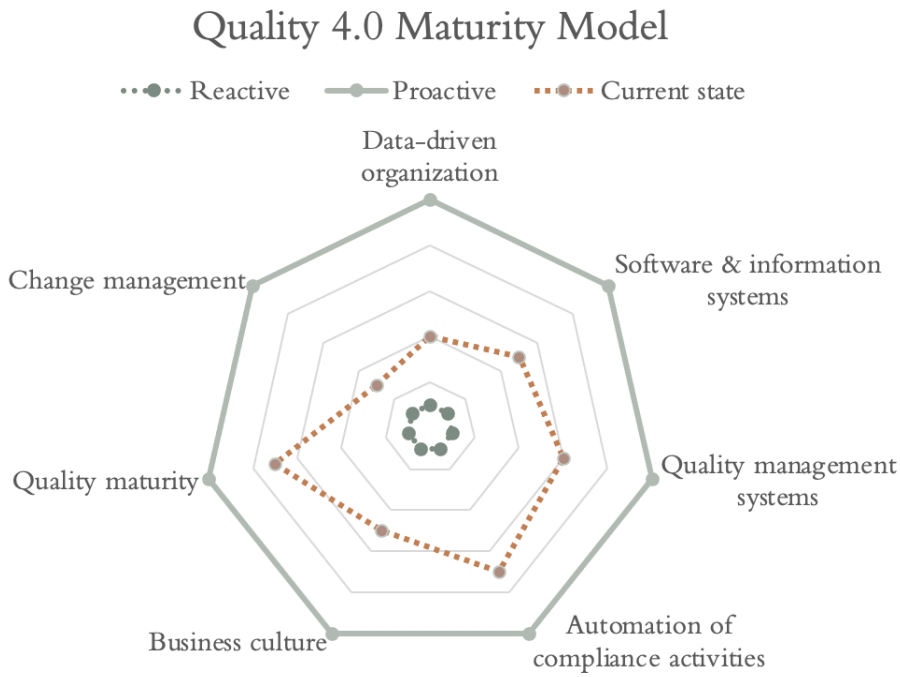

Figure 10. Troax's current state according to the Quality 4.0 Maturity Model

Troax also uses digital tools to monitor and improve quality and production efficiency. The usage of Axxos helps the organization communicate KPIs and performance figures to personnel as it collects data semi-automatically and visualizes collected data. In addition to Axxos, Troax uses a QMS to report internal and external deviations, store management documents, and more. The QMS is built on manual data collection. All Troax systems are accessible by personnel on-site and from home offices. The usage of iScala lets Troax plan production and control stock levels, but it does not support traceability of material and products in production. Troax has digital tools to monitor and improve quality, but they need improvement to support a proactive organization. Therefore, data collection and analysis are reactive due to low traceability, the amount of data collected, and how data is collected. However, the digital tools are accessible, and information is communicated through QMS, Axxos, and iScala. Therefore, communication and connectivity are reactive and proactive on the scale. Troax is aware that updating current systems is needed to support business needs and increase

proactivity. However, there is no strategy for implementing digital tools to increase proactivity in the quality and production departments. In addition, Troax does not have structures for change management and implementation, which results in a reactive organization in change management.

In conclusion to the empirical findings, Table 6 presents improvement areas identified from the interviews and data collection at Troax. According to the Quality 4.0 Maturity Model, these areas affect the proactiveness of the organization and will be further examined in the following analysis chapter.

Table 6: The current state improvement areas

Improvement areas	Identified issues	Factors
Traceability	Lack of traceability in production	Data-driven organization Quality management systems Software & information systems
Digital transformation strategy	No strategy for implementation of digital tools	Change management Business culture Quality maturity
Vision system for quality assurance	Lack of quality assurance/controls in the production process	Quality management systems Data-driven organization Software & information systems
Automation of data collection	Few automated data collection processes	Data-driven organization Software & information systems Automation of compliance activities
Software aligned with business objectives	QMS and Axoss need an update, QMS based on manual data collection Axoss an overhaul on the usefulness and accessibility	Data-driven organization Quality management systems
Establish a business culture for proactivity	The challenge of proactive quality work is underestimated	Business culture Quality management systems Quality maturity
Data collection in daily management	Lack of data collection of internal deviations/problems	Data-driven organization Quality management system

5 Analysis

The following chapter analyzes the theoretical and empirical findings and answers RQ3. The literature findings establish a framework for the case company to be evaluated through a gap analysis. The gap analysis determines which areas need to be prioritized, which is consolidated in the last section's priority list.

5.1 Gap-analysis

This section will answer the third research question through a gap analysis. Through the current state of the case company, seven improvement areas will be analyzed to identify how to become proactive in working with Q4.0.

> *RQ3: How can Quality 4.0 support organizations in becoming proactive working with quality?*

Digital transformation strategy
Q4.0 is built on data-driven organization, software and app development, information systems, and automation of compliance activities. It consists of integrating people ↔ technology ↔ processes to increase quality work with the usage of digital tools. Therefore, the implementation of digital tools is a part of becoming proactive in Q4.0, and according to Errida and Lofti (2021), 60-70% of organizational change initiatives fail. Therefore, establishing a digital transformation strategy and managing change with KPIs is vital to turn the outcome of change initiatives positively. The findings identified that Troax does not have a strategy for implementing digital tools in current production processes. What has been done to assess its digital transformation is the composition of an IT counsel to be responsible for digital tools implemented at Troax. Other than an IT counsel, Troax does not work with change management and does not have a standardized procedure for implementation. Troax should consider establishing a strategy and standardized process for change management to become more proactive according to the Quality 4.0 Maturity Model. As mentioned, 60-70% of change initiatives fail, and becoming proactive demands leadership, resistance management, motivation of employees, and a clear and shared strategy of change (Errida & Lofti, 2021). A strategy for incorporating digital tools in production to gather data, connect functions, and increase communication will increase the success rate of their digital transformation and increase proactive quality work in the Quality 4.0 Maturity Model. In the strategy, it is essential to include KPIs to measure the success and outcome of digital transformation. These KPIs will increase the knowledge of the change initiative and measure how to create a digital transformation strategy aligned with business objectives.

Traceability
Troax production is monitored and planned through iScala, and its current production monitoring does not support traceability in all production processes. Therefore, quality deviations reported by sales companies cannot be traced back to a single process without investigating the quality deviation. In investigating the quality deviation, engineers can identify root causes, but it is difficult because they have little or no data. This has resulted in recurring quality deviations internally and internal deviations that lead to external deviations. Lack of traceability and data collected from production processes have led to a reactive approach from Troax on quality deviations. The

findings show that the current information system does not fully support eliminating root causes. However, Troax does have standardized quality controls in production, which contributes to Q4.0 and proactiveness since it can detect quality deviations before entering new processes or shipment to customers. Traceability can further contribute to a data-driven organization for Troax and help with information to support the process of eliminating the root cause of quality deviations. The elimination of root causes will reduce recurring quality deviations and result in proactive quality work, according to Q4.0. Implementing traceability in its current production will also support information systems at Troax as traceability in production connects IT with OT, which is one of the pillars of the Quality 4.0 Maturity Model. Which also supports the information and data-driven decision making in Q4.0.

Vision system for quality assurance

The current quality inspections happen regularly, and when a problem has been identified. At Troax, the manufacturing process is highly automated, but quality assurance falls short due to these manual inspections. Recognizing the need for an automated quality inspection process can be solved through a vision system that scans and controls the parts and material in the production process. The vision system could be implemented in all internal processes or by selecting critical processes. The information captured from the vision system could then be used and integrated with existing QMS or Axxos for automated quality assurance. In turn, the manual quality inspections would be reduced or removed entirely, and the control over material and parts in the production process would increase drastically.

Automation of data collection

In quality management, decision-making based on facts is discussed and elaborated in Q4.0. Therefore, collecting data on processes, machines, communication, and more is crucial for an organization to deliver quality. Automated data collection can help organizations fill the void of manually collecting data and assist in proactive decision making and increasing the proactiveness of the Quality 4.0 Maturity Model. Currently, at Troax, there are a few automated data collection programs, one for OEE and recently implemented vibration indicators. This data is used to monitor machines and increase the information on wear and tear of production lines. Using vibration indicators is one factor that increases Troax proactivity in the Quality 4.0 Maturity Model since it is a tool that assists machine operators in identifying when maintenance is needed. Automated data collection will also decrease human error, which can affect manually reported data and result in data quality. It was identified that the quality of data collected manually in Troax's OEE system could vary depending on the machine operator. The production manager, see *Appendix 3*, said that it was easy to blame human error in the category "other machine error," and therefore, the root cause remained unknown. Increasing the automation of data collection generates quality data that can be the base of proactive decision-making, eliminating root causes, and increasing the quality of products to customers. Traceability, as discussed previously, will also increase automated data collection and assist in proactive decision-making when eliminating root causes.

Software aligned with business objectives

The study's authors found two software systems, the QMS, and Axxos, that need further assessment. The current QMS function is dependent on manual labor, where elected officials can register quality deviations and administer documentation such as

management documents. Additionally, Troax sales companies use the QMS to register quality deviations from the end customer. The highly manual work required for the QMS to function and be up-to-date is not aligned with Q4.0 since Q4.0 suggests an integrated and automated data collection process. The quality officials managing the QMS need to acknowledge the manual labor and seek automated data registering processes so that the QMS is constantly up-to-date with documentation and its content. There are incentives and tools such as Power BI used within the quality department to track quality deviations and other KPIs. These could be integrated with the QMS to empower its function and usefulness, hence the pursuit to become proactive in working with software & apps.

The use of Axxos within the production to solely measure the availability delimit the software's functionalities where quality and performance are neglected. In turn, not measuring quality and performance affects the overall efficiency and productivity of the manufacturing operation. Hence, the utilization and how well the manufacturing unit operates cannot be evaluated correctly. Therefore, seizing the opportunity to assess the Axxos software and how it is being utilized can support the organization's work toward becoming increasingly proactive in the manner of efficiency and productivity and reaching business objectives and KPI, which enforces the quality management and the progress toward a data-driven organization.

Establish a business culture for proactivity

A central role in the transformation toward Q4.0 is the top management commitment. The management team of Troax has initiated the work with quality management by allocating resources and hiring personnel. The quality department has, in turn, instituted traditional quality operations, which tend to be reactive to signals of deviations after the problems occurred. The findings concluded that a proactive approach to quality management was heavily underestimated, so the incentives to start working with Q4.0. Realizing the usefulness of becoming proactive in the daily operations supports the organization's quality work and needs to be acknowledged and the focus while embarking on the Q4.0 transformation.

Q4.0 and the transformation process rely on a digital transformation strategy recognized as a critical component for Troax. Seeing that the daily operations focus on the current problem-solving, meaning that strategy and long-term thinking can sometimes be rigorous. Hence, developing a step-by-step process or strategy for Q4.0 is essential. Committed leadership also influences the business culture where change management can be applied. At Troax, the organization's hierarchy forces the quality department to become the leaders of the Q4.0 transformation, hence the need for commitment and motivation toward becoming proactive using Q4.0. The strive to use a proactive approach to current operation, is a continuous work endeavor and requires time and dedication.

Data collection in the daily management

The last improvement area addresses the lack of data collection during daily management and Gemba walks. The problems addressed during the daily meetings were written on a whiteboard in each internal process in the manufacturing unit. Once a problem was solved and issued, it was removed from the whiteboard without registering the information in any IT system. Recognizing the need to develop data gathering processes and use data in decision-making facilitates the use of fact-based

decisions, which is a central part of ISO 9001:2015. Additionally, gathering and use of data allow Troax to track internal deviations and identify trends and recurring problems that support the organization's work in continuous improvements.

5.2 Priority list

In conclusion to the analysis, the authors present a priority list that addresses the identified improvement areas at Troax. The improvement areas seen in table 6 affect Troax's current state according to the Quality 4.0 Maturity Model and the incorporated reactive to proactive scale. By working with each improvement area, the proactiveness would increase at Troax; thus, the priority list can be used as a framework and guideline to start the digital transformation toward Q4.0. The first step is to develop a digital transformation strategy that establishes the goal and objectives for the digital transformation process. The strategy should contain KPIs to track the progress, including input from different departments, to be accessible for managers, officials, and personnel. The digital transformation strategy initiates the work toward becoming a data-driven organization and reaching proactivity in current operations. Additionally, the strategy should be continuously updated if the company implements new technologies or innovations.

The second step is traceability increases the awareness and control over parts and products within the production. Working with traceability support Troax to identify root causes of quality deviations that could be implemented in the current QMS or an information system. The third improvement area presented in the priority list is the vision system for quality assurance which is interlinked with the traceability within the production. By implementing a vision system, Troax would drastically increase the traceability and quality assurance in the production, which supports the work of becoming proactive. Problems or quality deviations would be identified before they reach the end customer and would improve the current root cause analysis process for continuous improvements.

The fourth step, automation of data collection, addresses the use of digital tools to collect and manage data. The data collection process is highly manual in current operations and relies on personnel to collect and register data into software and information systems. Shifting from a highly manual to a semi or automated data collection process allows for faster and more responsive decision-making and gives the quality professionals the tool to use real-time data. In the fifth step, software aligned with business objectives is also interlinked with the previous step. This step requires an assessment of the current QMS to align with the business objective of becoming proactive. Q4.0 seeks to mitigate the manual labor that goes into current operations, hence the need for identifying how to improve current QMS with automated data. For example, the software Axxos is used to measure OEE but has solely been used to track availability, neglecting productivity, efficiency, and quality. By assessing Axxos or searching for alternative software, Troax controls and manages the production. New KPIs and business objectives can be identified and used for further improvements.

In the sixth step, data collection in the daily management, addresses the lack of data collection in the internal deviations and problems. Recognizing that minor recurring errors may need to be registered in a database so that it can be analyzed and evaluated

leads to continuous improvement and fact-based decision making, which is a central part of Troax ISO 9001:2015 certification.

Throughout the transformation toward Q4.0, Troax needs to facilitate a business culture of proactivity. The middle management and quality departments have a central role in initiating the work toward proactivity. To gain support from top management and colleagues, a digital transformation strategy toward Q4.0 is required with a roadmap and plan on achieving proactivity at Troax. Additionally, quality professionals must inspire and motivate the need for proactivity, the root-cause problem-solving mindset, and the shared benefits of being proactive.

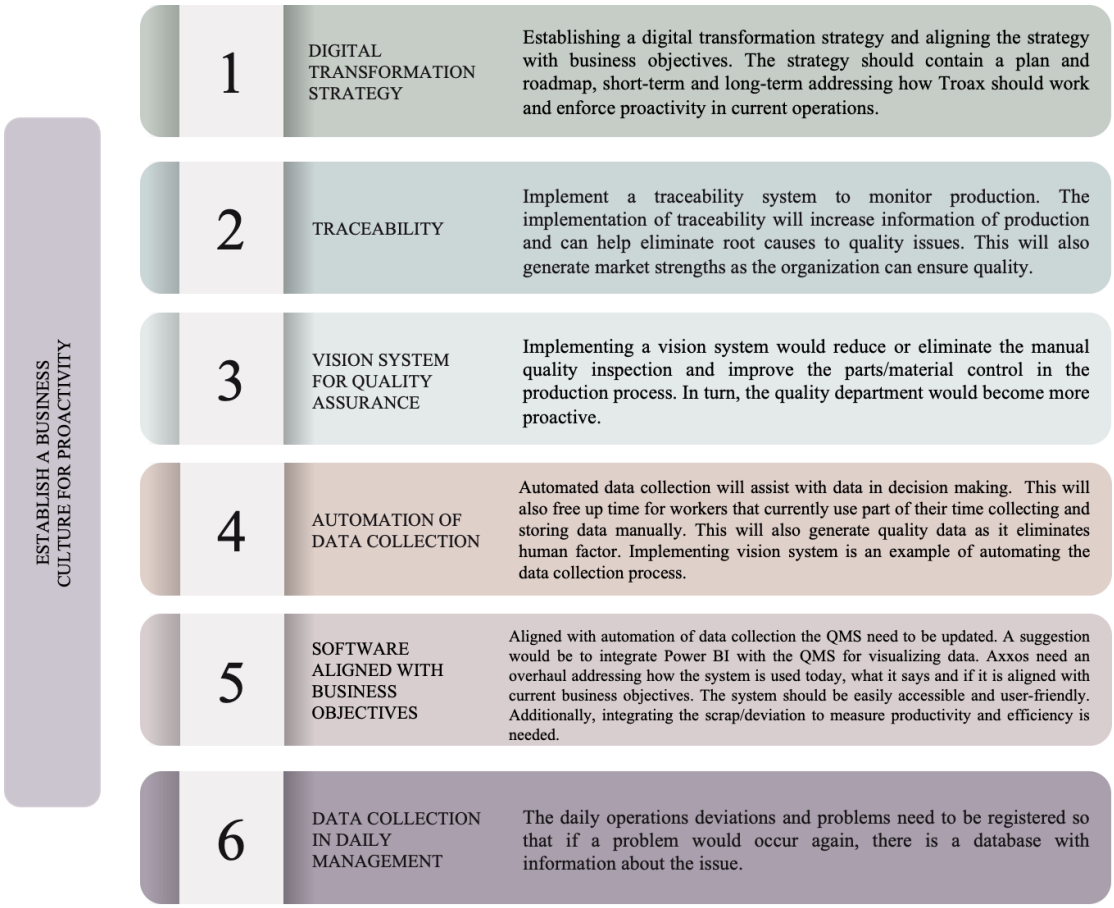

Figure 11. Troax priority list

6 Discussion

In this chapter, the methodology, findings, and conclusions are discussed. First, the methodology for the three research questions is discussed. Second, the findings and conclusions are discussed. Finally, the chapter ends with a discussion for future research.

6.1 Research design

This section will reflect if the chosen research design is suitable for the study and if the method supports the study's research questions. The study is divided into three parts, a literature review for RQ1, a qualitative data collection for RQ2, and analysis and combination of theoretical and qualitative findings in RQ3. The method for answering the research questions is different, and the discussion will connect to each research question.

> *RQ1: What constitutes Quality 4.0 from the perspective of a manufacturing organization?*

Q4.0 is a new management system for increasing proactive quality work which is connected to I4.0. Researchers have not established a theoretical framework. While reviewing literature researchers had definitions and frameworks for Q4.0. However, most literature had common nominators such as digitalization and increasing quality by using digital tools IoT, CPS, and integrated communication systems. To conduct the case study, there was a need to understand what constitutes Q4.0 and the development of a theoretical framework that was used for a gap analysis at Troax.

The method used for establishing a theoretical framework was done through literature review and the framework was inspired by the 11 axes of Q4.0 by LNS research. To develop a Quality 4.0 Maturity Model seven headings was generated to capture the breadth of Q4.0. Change management was included in this framework because it was believed that this plays a vital role in the digital transformation that Q4.0 is. As mentioned previously, change initiatives fail and the addition of change management emphasizes the importance of having a clear implementation strategy and work procedure to implement digital tools to succeed in proactive quality work. In addition to change management, it was important to highlight in the framework that Q4.0 does not only seek to implement digital tools. Part of Q4.0 is an integration of people ↔ technology ↔ processes and increasing quality maturity. To measure the use of Q4.0 in the Quality 4.0 Maturity Model it was decided to have a scale of Reactive-Proactive. The measurement scale was used because the goal is to use the Quality 4.0 Maturity Model to identify gaps and increase proactivity. This was therefore identified as a valid measure for the subjects constituting Q4.0.

> *RQ2: How can the current state of Quality 4.0 in a manufacturing organization be evaluated?*

The theoretical framework was the base for the qualitative research and was used to map the current state of Troax. When gathering data for RQ2 interviews were structured with quality manager, quality engineer, production manager, production support, and digital business and marketing developers. The different interviewees had different

work tasks within Troax and could therefore contribute information in different areas of the company. To capture the expert knowledge semi-structured interviews were conducted and depending on the interviewee, questions were added to elaborate on the current state at Troax. The collected data were summarized, and the current state of the company was established. The results from the interviews may have been affected since the different interviewees were working in different areas. But, as the information of the current state was general information about how work procedures were formed, what systems were used etc. the data gathered was controlled through a discussion with the Troax supervisor. This so that the data was not misinterpreted which would have resulted in an unrealistic interpretation of the current state.

RQ3: How can Quality 4.0 support organizations in becoming proactive working with quality?

For answering RQ3, both findings from RQ1 and RQ2 were used. The theoretical framework and the Quality 4.0 Maturity Model were used to map the company's current state. From the current state, a gap analysis was performed to answer how the framework could support Troax in becoming proactive and reducing quality deviations. The identified gaps were based on the reactive score in the Quality 4.0 Maturity Model. In the analysis, seven improvement areas were identified that will, according to the framework, contribute to a proactive organization. However, in the Quality 4.0 Maturity Model, the different reactive to proactive evaluation levels were identified using qualitative measures. Therefore, the level of proactivity could not be connected to a specific technology or work procedure. But this assumption was done and the levels of practivity were evaluated according to the framework and the researchers' knowledge within the area. The analysis method contributed to seven improvement areas for Troax to work with to increase their proactivity.

6.2 Main findings

The presented study has developed a Quality 4.0 Maturity Model for manufacturers and industries that seek to implement Q4.0 into their operations. Upon examining a Swedish manufacturing company with an established quality department, a priority list was presented with different steps to take while embarking on the digital transformation toward Q4.0. The most critical factor was developing a digital transformation strategy through literature reviews, case studies, interviews, discussions with officials, and company visits. The other improvement areas connect by creating a digital transformation strategy; hence, the strategy’s application initiates the work with, for example, traceability and automation of data collection. Furthermore, the strategy should contain the quality professional’s role in advocating Q4.0 and the advantages of using a proactive approach to quality rather than reactive. Considering that a reactive approach to quality is generally costly, time-consuming, occupies resources, and is ineffective, it promotes the proactive approach, which is sustainable and reduces the defects which affect the end customer. Additionally, the proactive approach supports organizations in identifying internal deviations and using data for both fact-based decision-making and continuous improvements.

During the company visits and interviews, it was noted that the daily operations were focused on problems at hand, which left strategy and long-term planning somewhat overlooked. There was simply a lack of time for the strategy, which left the authors to

the study questioning how to create time for strategy? The conclusion was that the company needed to develop a strategy that focused on a step-by-step process so that long-term goals were broken down into goals and subgoals. With a background in studying mechanical engineering, both authors of the study have participated in and visited different manufacturing companies on a small and large scale, and they all seem to share this experience. Therefore, the planning of the strategy is essential so that it is accessible and can be worked in parallel or in between the daily work tasks.

6.3 Conclusions and future research

The purpose of the study was to explore how Q4.0 can be used to increase proactive quality work within an organization. Therefore, a Quality 4.0 Maturity Model was developed in this study and applied at the case company. Q4.0 is becoming increasingly popularized, as is I4.0 and the adoption of tools and technologies that lie within. After applying the framework at the case company, the findings were that a digital transformation strategy is required to transition into Q4.0, where the quality professionals need to be advocating proactive quality work. In addition, the scale used to identify if a company is reactive or proactive in the principles of the Quality 4.0 Maturity Model could be further investigated so that each level is quantified and defined. For example, this could lead to the use of benchmarking if an organization wants to assess or compare its current quality operations. The established framework was applicable at the case company and after establishing the current state a gap-analysis was performed. This resulted in a priority list for the case company to work with to increase proactive quality work which answered the purpose of the study.

Recognizing that the project's broad scope leaves future research to work with a smaller and narrow scope, focusing on critical elements or selected principles of the Quality 4.0 Maturity Model, which raised questions regarding the principles and use of the Quality 4.0 Maturity Model:

- How does an organization become data-driven?
- What tools and technologies are useful to establish Q4.0 in an organization?
- How do you develop a digital transformation strategy?
- Is the Quality 4.0 Maturity Model applicable in other industries (healthcare, service-based etc.)?
- How do you integrate change management into the existing leadership culture?

It is reasonable to believe that every company or organization is different, and so are the maturity levels and readiness for Q4.0. Some organizations are more likely to be prepared for the Q4.0 undertaking. Hence the need to develop support and enablers for small-scale or less mature practitioners.

- Can ISO 9001:2015 support companies in the digital transformation toward Q4.0?
- What are the prerequisites for working with Q4.0?
- How can small-scale companies integrate Q4.0 into their business?
- How can small-scale companies become proactive using the Quality 4.0 Maturity Model?
- Which are the enablers in the Quality 4.0 Maturity Model and how do you release them?

Lastly, the world is currently in I4.0 but companies and researchers are evaluating Industry 5.0 and therefore future researchers have the possibility to understand Quality 5.0. Taking sustainability into consideration in all aspects of the products and service industries.

References

Alcácer, V., & Cruz-Machado, V. (2019). Scanning the Industry 4.0: A literature review on technologies for manufacturing systems. *Engineering science and technology, an international journal*, *22*(3), 899-919.

Bell, E., Bryman, A., & Harley, B. (2019). *Business research methods* (5th ed.). Oxford University Press.

Bergman, B., & Klefsjö, B. (2010). *Quality from customer needs to customer satisfaction.* Studentlitteratur AB.

Dutta, D., Bose, I., 2015. Managing a big data project: the case of ramco cements *limited. Int. J. Prod. Econ.* 165, 293–306. https://doi.org/10.1016/j.ijpe.2014.12.032.

Errida, A., & Lotfi, B. (2021). The determinants of organizational change management success: Literature review and case study. *International Journal of Engineering Business Management*, 1–15. https://doi.org/10.1177/18479790211016273

Galli, B. (2018). Change Management Models: A Comparative Analysis and Concerns. *IEEE Engineering Management Review, Engineering Management Review, IEEE, IEEE Eng. Manag. Rev*, *46*(3), 124–132. https://doi.org/10.1109/EMR.2018.2866860

Jacob, D. (2017). *Quality 4.0 Impact and strategy handbook.*
LNS research.
https://blog.lnsresearch.com/quality40

Javaid, M., Haleem, A., Singh, R. P., & Suman, R. (2021). Significance of Quality 4.0 towards comprehensive enhancement in manufacturing sector. *Sensors International*, 2, 100109. https://doi.org/10.1016/j.sintl.2021.100109

Kagermann, Wahlster, W and H., Helbig, J. (2013). Recommendations for implementing the strategic initiative INDUSTRIE 4.0. *Berlin: Forschungsunion*, p.77.

Kamble, S. S., Gunasekaran, A., & Gawankar, S. A. (2018). Sustainable Industry 4.0 framework: A systematic literature review identifying the current trends and future perspectives. *Process safety and environmental protection*, *117*, 408-425.

Kayabay, K., Gökalp, M. O., Gökalp, E., Eren, P. E., & Koçyiğit, A. (2022). Data science roadmapping: An architectural framework for facilitating transformation towards a data-driven organization. *Technological Forecasting and Social Change*, *174*, 121264.

Kenett, R. S., & Redman, T. C. (2019). *The Real Work of Data Science: Turning data into information, better decisions, and stronger organizations*. John Wiley & Sons.

Küpper, D., Knizek, C., Ryeson, D., & Noecker, J. (2019). Quality 4.0 takes more than technology. *Boston Consulting Group (BCG)*, 1-14.

Lasi, H., Fettke, P., Kemper, H. G., Feld, T., & Hoffmann, M. (2014). Industry 4.0. *Business & information systems engineering*, *6*(4), 239-242.

Lyle, M. (2017). From Paper and Pencil to Industry 4.0: Revealing the Value of Data through Quality Intelligence. *Quality*, *56*(10), 25-29.

Martin, J., Elg, M., & Gremyr, I. (2020). The many meanings of quality: Towards a definition in support of sustainable operations. *Total Quality Management & Business Excellence*, 1-14.

Nasim, S., & Sushil. (2011). Revisiting Organizational Change: Exploring the Paradox of Managing Continuity and Change. *Journal of Change Management*, 11(2), 185–206. https://doi.org/10.1080/14697017.2010.538854

Meindl, B., & Mendonça, J. (2021). Mapping Industry 4.0 Technologies: From Cyber-Physical Systems to Artificial Intelligence. arXiv preprint arXiv:2111.14168.

Peter O'Donovan, Ken Bruton, & Dominic T.J. O'Sullivan. (2016). Case study: the implementation of a data-driven industrial analytics methodology and platform for smart manufacturing. *International Journal of Prognostics and Health Management*, 7(3). https://doi.org/10.36001/ijphm.2016.v7i3.2414

Adebayo, A. O., Chaubey, M. S., & Numbu, L. P. (2019). Industry 4.0: The fourth industrial revolution and how it relates to the application of internet of things (iot). *Journal of Multidisciplinary Engineering Science Studies* (JMESS), 5(2), 2477-2482.

Posada, J., Toro, C., Barandiaran, I., Oyarzun, D., Stricker, D., De Amicis, R., ... & Vallarino, I. (2015). Visual computing as a key enabling technology for industrie 4.0 and industrial internet. *IEEE computer graphics and applications*, *35*(2), 26-40.

Quality 4.0. ASQ. (n.d.). Retrieved March 3, 2022, from https://asq.org/quality-resources/quality-4-0

Rose, J. Lukic, V. Milon, T. & Cappuzzo, A. Boston Consultancy Group (8 December 2016). *Sprinting to value in Industry 4.0.* https://www.bcg.com/publications/2016/lean-manufacturing-technology-digital-sprinting-to-value-industry-40

Sader, S., Husti, I., & Daróczi, M. (2019). Industry 4.0 as a key enabler toward successful implementation of total quality management practices. *Periodica Polytechnica Social and Management Sciences*, 27(2), 131-140.

Sanders, A., Elangeswaran, C., & Wulfsberg, J. P. (2016). Industry 4.0 implies lean manufacturing: Research activities in Industry 4.0 function as enablers for lean manufacturing. *Journal of Industrial Engineering and Management (JIEM)*, *9*(3), 811-833.

SAP. (n.d.) *What is Industry 4.0?*. Retrieved October 26, 2021 from https://www.sap.com/sweden/insights/what-is-industry-4-0.html

Sen, S., & Gupta, P. (2020). Attitude towards Change Management in Digitization Initiatives in an Organization - A Survey. *Journal of General Management Research*, *7*(2), 27–39.

SS-EN ISO 9001 Ledningssystem för kvalitet - Krav (ISO 9001:2015). *Stockholm: Swedish Standards Institute* (SIS)

Säfsten, K., Gustavsson, M. (2020). *Research Methodology - For Engineers and Other Problem-Solvers.* (First edition). Studentlitteratur AB, Lund.

Sörqvist, L. (2014, October). Future development of the quality profession. Paper presented at the ICQ International Conference on quality 2014, Tokyo

Tavory, I. & Timmermans, S. (2019). Abductive analysis and grounded theory. In *The SAGE handbook of current developments in grounded theory* (pp. 532-546). SAGE Publications Ltd, https://dx.doi.org/10.4135/9781526485656

Taylor, S.J., Bogdan, R. & DeVault M.L. (2016). Introduction to Qualitative Research Methods - A Guidebook and Resource. 4th ed. *Hoboken: Wiley*

Watson, G. H. (1998). Digital hammers and electronic nails--tools of the next generation. Quality progress, 31(7), 21.

Watson, G.H. (2019), "The ascent of Quality 4.0: how the new age of quality might look like in 20 years", Quality Progress, Vol. 52 No 3, pp. 24-30.

Wang, S., Wan, J., Li, D. & Zhang, C. (2016). Implementing Smart Factory of Industrie 4.0: An Outlook. *International Journal of Distributed Sensor Networks*, 12(1), article ID 3159805.

Wilson, F. (2015). The Quality Maturity Model: your roadmap to a culture of quality. *Library Management*.

Yin, R.K. (2015). Case study research. Design and Methods. 5th ed. London: *SAGE Publications.*

Zonnenshain, A., & Kenett, R. S. (2020). Quality 4.0—the challenging future of quality engineering. *Quality Engineering*, 32(4), 614-626

Appendix 1

Interviewee 1 Quality Manager

31-3-2022

Får du stöd från ledningen i ditt arbete med Kvalitet? Vill du ge något exempel?

Nej, det finns ett mål och det är att vi skall minska kund avvikelser och de målen har jag satt själv ända tills i år. Så den påverkan jag fått (inte stöd) är att ledningen har satt ett mål för detta året. Resurs tillsättningen jag har fått det senaste året är det stöd jag fått från ledningen.
Ledningens förståelse finns där men den är inte superstor och då diskuterar jag hur mycket arbete som faktiskt krävs för att vara proaktiv i arbetet istället för att vara reaktiv vid kund avvikelser och kvalitetsbrister.

Jobbar ni nära med produktionstekniker?

Ne inte alls.

Hur engagerar du medarbetare för arbete med kvalitet?

Jag jobbar med återkoppling av det positiva, visar på resultat av gott arbete. kvalitetsarbetet är väldigt variationsrikt och det tar aldrig slut. Mitt engagerade är återkopplande med även diskussion av förbättringspotential.
Vi jobbar med ständiga förbättringar enligt ISO 9001 där vi har interna och externa revisioner. Vi introducerar nu arbetsmetoder som “Five Why” och vi sätter mål på att identifiera interna avvikelser för att minska kund avvikelser.

Vad gör Troax för att skapa en arbetsmiljö tillåter förändring och nyskapande?

Stort ansvarsområde med tillhörande befogenheter gör att arbetsmiljön tillåter förändring och nyskapande. Jag har en chef som är av uppfattningen att jag driver allt och där han inte tycker jag har tänkt till, då säger han ifrån. Annars driver jag förändring och organisationen litar på mitt omdöme.

Finns det någon strategi/struktur för arbetet med digitalisering och nya tekniska verktyg på Troax?

Vi har diskuterat denna fråga men ingen tydlig struktur tidigare. Vi har tillsatt ett IT-råd som skall beröra digitaliseringen. Vi har en del IT-funktioner som inte är integrerade och tanken är att IT-rådet skall arbeta med liknande problem.
(Har ni en strategi för att öka kvaliteten i produktionen med hjälp av tekniska hjälpmedel?)
Det är tänkt att det nya IT-rådet skall arbeta med dessa frågor.

Arbetar ni med integrering av processer samt processer och människor?

Det finns flera system i produktionen som skulle kunna förbättras här idag. T.ex. systemet som mäter “up-time” skulle behöva en förbättring.

Strategin är inte klar men förhoppningen är att IT-rådet skall arbeta med detta och skapa en strategi.

Vad vi har förstått så om ni upptäcker kvalitetsbrister, kan ni inte gå tillbaka i produktionens olika interna processer för att identifiera vart problemet uppstod?

Det beror på karaktären och var den har inträffat, för vi har system som fångar upp kvalitetsavvikelser. Det bygger på att vi kör 1:a bits kontroll 60 bit kontroll och sista bits kontroll. Kör vi 1000 bitar och inser att en kvalitetsbrist har uppstått mellan kontrollerna stannar vi processen, och i det identifierar vi problemet. Vi kan inte göra detta på alla processer. Man får titta på var enskild sak och förstå vad som hänt i produktionen.
Det har hänt att vi skickat fel kulör till kund och där kan vi gå tillbaka och kolla vad som gick fel. Det blev fel av en manuell inskrivning av kulörkoden för systemen pratar inte med varandra. (där har vi haft några avvikelser med problem av manuell inmatning av kulörkod).
Spårbarhet har vi enbart på en produkt idag. Vi har funderat på ett system så vi kan följa men vi har inte kommit till skott. På högvolyms produkter har vi inga sådana system.

Finns det någon plan/strategi för att utveckla detta?

Vi har planer på att införa sådant system för snart tror vi att det kommer komma som ett kundkrav och då måste vi uppfylla det för att sälja produkter.
Tyvärr faller detta projekt för vi är för produktions fokuserade.
Att vara mer proaktiva landar i en resursfråga, vi har mycket på kvalitetsavdelningen som vi vill implementera men har inte tid i nuläget.

Som kvalitetsansvarig, vad mäter du för nyckeltal/KPI'er?

Det är procent ärenden mot antal orders (kund avvikelser). Detta mäts kontinuerligt, statistiken körs varje månad även varje vecka. Så vi ser och identifierar trender omedelbart.

Hur används nyckeltalen i ditt arbete

Jag använder dem kvartalsvis när vi har kvartalsmöten med kvaltie- och miljögruppen. Då kan vi fått in liknande kund avvikelser och då agerar vi för att fixa till orsaken för kund avvikelsen.

Finns det några områden på Troax som du ser det idag, saknar insamling och arbete med data?

Vi har processer och saker vi gör som vi inte mäter i nuläget. T.ex. projektarbeten med införanden av ny maskin med ledtider där vi inte är så effektiva som vi skulle kunna vara om jag jämför med automotive.

Hur ser kvalitetsutvecklingen ut i företaget? Har ni någon strategi för att utvecklas inom kvalitet på sikt?

Resurstillsättning och ta höjd för bättre planering. Jag gick och nötte ett år innan jag fick bifall för att sätta ut en platsannons där vi anställt en till kvalitetsingenjör. Jag vill ha en resurs till så att vi kan börja arbeta med de förbättringspunkter som vi har identifierat men inte haft resurser till att arbeta med. Strategin på utveckling är därav en resursfråga.

Är det nuvarande kvalitetssystem (CMS) i linje med Troax strategiska mål för kvalitet? Stöder nuvarande system kvalitetsutvecklingen?

Var det gäller verktyg ska vi göra ett business case på vad som passar Troax bäst när det kommer till ett Content Management System (CMS). Ett system där vi driver kvalitet, strategi och non conformities (kund avvikelser). Det är läge att uppdatera detta då det ligger lite efter i utvecklingen sett till vad Troax som organisation vill få ut av systemet.

Arbetar ni med benchmarking inom organisationen?

Nej det var en fråga som var uppe för något år sedan där vi egentligen skall ut och göra benchmarking men vi är för fokuserade på dagens händelser och har därför inte tid att genomföra sådana saker. Vi lyfter inte blicken och det är en brist hos mig som chef för det var jag som skulle ta beslut om detta.
Jag ser att detta är något som skulle kunna hjälpa oss att utvecklas.

Troax använder sig av ISO som ledningssystem för kvalitet, använder ni andra management filosofier så som Lean, six sigma etc.?

Till viss del använder vi oss av andra ledningssystem. Vissa punktinsatser, endel PDCA grejer och kaizen så vi gör endel grejer. Men vi jobbar inte övergripande med Lean. Vi har en medarbetare som arbetar med förbättringsprocesser och i det skulle man kunna ta in sådana ledningssystem.

Hur involverar ni slutkunden i era processer för att förbättra produkter? (TPT möte)

Vi säljer i princip allt till våra egna säljbolag och slutkunder intervjuas sällan.
TPT-möten är egentligen våra marknadschefer, alla marknadsbolag faller under olika divisioner/områden och så finns det en VD som ansvarar. Dem är med och styr mot hur produkterna skall utvecklas utifrån vad dom har hört från kunden. Jag vill få med en kvalitetstekniker ut som fånga upp slutanvändaren och montörens synpunkter. Genom det kan vi identifiera förbättringspotential mot dem. Idag ställer vi inte frågan hur vi kan packa produkter bättre för t.ex. montör eller slutkund. Vi diskuterar inte erbjudanden om förmontage etc

Ni har infört nytt arbetssätt på t.ex. DC, hur jobbar du för att få folk att engagera sig i det nya arbetssättet?

Det är en av de större förändringarna vi gjort på flera år. Det har krävt en hel del och vi haltar lite för att det har varit en väldigt stor förändringen i processen. Analysen kanske hade behövt vara aningen mer bottnad. Vi drar lärdom av detta.

Ni har matriser för kunskap, är det något ni jobbar med utbildning för att medarbetare skall kunna medverka i förändringsarbeten?

Vi har matriser för kunskap men jobbar inte så mycket med det. Det med kompetenser kommer lite mellan avdelningarna och det är ibland oklart vem som äger det.

Har ni någon policy för att säkerställa att medarbetare får jobba kvar om t.ex. en automatisering eller ett tekninsk verktyg eliminerar en tjänst?

Vi har ingen policy och det har vi inte behövt då de saker vi implementerat har varit för att öka produktion och det tjänster en automatisering ersätter fortfarande krävs på andra delar. Vissa har börjat jobba med administrativa saker.

Arbetar ni tvärfunktionellt i organisationen?

När det kommer till Tvärfunktionellt finns det förbättringar att göra. Det dagliga arbetet på Troax är väldigt produktions fokuserat.

Appendix 2

Interviewee 2 Production Manager

31-03-2022

Får du stöd från ledningen i ditt arbete med Kvalitet? Vill du ge något exempel?

Ja. I våra övergripande mål är Kvalité en av de viktigare. Vi har uppföljning varje månad med olika krav. Ett exempel på stödet är att ledningen har tillsatt tjänster/resurser som fokuserar på just kvalitet.

Hur engagerar du medarbetare för arbete med kvalitet?

Jag tycker att kvalitet är det viktigaste vi har. Med en bakgrund från Automotive, är kvaliteten det absolut viktigaste. Alla ansvarar för högsta kvaliteten, det vill säga att alla har möjligheten att exempelvis stoppa maskinen om något händer, ur ett säkerhets eller kvalitetssynpunkt.
Mina produktionsledare har uppföljning varje månad, och varje avdelning har brutit ner övergripande mål från högsta ledning.

Hur arbetar ni med daglig styrning, t.ex. morgonmöte. Hur använder ni informationen?

Gemba runda (observations runda), vi startar från en av våra liner. Produktionschef, Produktionsteknisk Chef, produktionstekniker, Underhållschef, produktionsledare är med på denna runda. Alla får se verksamheten under samma tidpunkt. Dyker det upp problem på tavlan som behöver åtgärdas, så tilldelas ansvaret ut med ett slutdatum. → Slipper massa möten därefter. 45min-1h varje dag går genom hela företaget. I slutet går vi igenom totalen, hur det ser ut i maskineriet, lagernivåerna, projekt i pipen, leveranser med mera. Ibland deltar även planeringen och CS-customer.
Produktionsledare får representera utfallet från föregående dag och utgår från säkerhet sedan kvaliteten, effektivitet och utfallen (i tillgänglighet). Vi kollar sedan på om det har varit några störningar, om de är åtgärdade. Vilka punkter ligger för dagen och vem som är ansvarig för dem.

Finns det någon strategi/struktur för arbetet med digitalisering och nya tekniska verktyg på Troax?

Jao? Inte direkt. Vi har en femårsplan på hur vi ska utveckla verksamheten när det gäller maskineriet, exempelvis nya maskiner. Davidsson har ett arbete som ska mäta vibrationsmätare som kan hjälpa oss att upptäcka grejer innan de går sönder. Nytt stadie, installerad i "linefin" som vi lär idag, och vi ska utveckla vidare.

Vad är dina tankar kring Industry 4.0?

Vi har axxos, bland annat som är ett väldigt reaktivt system som säger till efter att något har gått sönder. Vi vill bli mer proaktiva, exempelvis är detta vibrations systemet som säger till att nu är det dags att byta. Exempelvis kan det meddela när det går från grönt till gul. Och inte endast grönt till rött.

Har ni SPC - Statistisk processtyrning? Mäter ni produkter och håller koll på kvalitén på detta sätt?

Nej vi har inget sådant. Vi mäter dock våra produkter och har kontrollinstruktioner.

vad använder ni er av för KPI's?

Hur många tillbud/skador. Kvaliteten hur mycket vi ska sänka i procent mot antal orderrader. Där har vi lite arbeten för att bryta ner exempelvis en procentsats till antal, som hjälper arbetarna förstå siffrorna lite mera.
Övertiden försöker vi också jobba ner. För både personalen och kostnaderna.
Effektiviteten, produktiviteten o skrot använder vi som KPIs

Den senaste produktion delen. Har ni mätning av produkterna under hela flödet?

Line standard. Nej, det gör vi inte. Vi mäter dock rören så att maskinerna inte havererar. Vi har olika diskussioner för vision system som är billiga. Det är dock intressant för framtiden.

Om ni upptäcker kvalitetsbrister, kan ni gå tillbaka i produktion protokollet och identifiera problemen? Kan ni stoppa material effektivt för att undersöka kvalitetsbrister? (Digitala ID) Kan delar, produkter och material identifieras och lokaliseras i produktionsflödet? Hur använder ni denna information?

Spårbarhet. Nej det kan vi inte. Vi har dock projekt som tittar på märkning av artiklar med antingen QR kod, så att man ska kunna se flödet och när den kördes. Idag har vi ordernummer, men efter lacken försvinner detta och då vet vi inte längre vart ursprungsmaterialet kom ifrån. Vi har en viss spårbarhet men långt ifrån vad vi önskar.

Hur sker rapporteringen av kvalitetsbrister, har ni etablerat system för det? Är informationen lättillgänglig?

Alla operatörer ska kunna rapportera kvalitetsbrister. Osäker på om detta är kopplat till axxos, men det går in i vårt affärssystem.

Arbetar ni med benchmarking inom organisationen?
Har använt mig av att jämföra med tidigare arbetsplatser och även nätverk och kontakter som möjliggör benchmarking. När vi gör någonting litet eller stor så tar vi alltid upp punkten med benchmarking så vi inte uppfyller hjulet en gång till. Tycker detta är ett sunt arbetssätt.

Hur arbetar Troax med förebyggande underhåll för att minska exempelvis kvalitets bortfall?

Varje maskin har ett förebyggande underhållsschema → proaktivt. Vi tummar inte på underhållet och det är viktigt för oss. Axxos används för att analysera stopp och sedan ta fram åtgärder.

Använder ni er av simuleringsverktyg? Vad använder ni informationen till?

Nej. Vi ritar i configura och cadd när vi ska nya maskiner.

Mäter ni några KPI's i realtid? hur registreras dessa och hur används dem? Är informationen lättillgänglig för beslutfattare och operatörer?

Tillgängligheten mäts i realtid, hur maskinen går vilket innebär den tekniska tillgängligheten och tillgängligheten dvs hur effektivt jobbar maskinerna, även operatörerna. Varje maskin har skärmar vid sig som jag har satt upp, för att operatörer till chefer ska kunna se i realtid hur vi ligger till i produktionen. Så att operatören exempelvis kan själv se hur de ligger till och håller rätt takt. Skapar på ett sätt en proaktiv miljö då operatören kan se i realtid under sitt arbetspass hur den ligger till, hur många som förväntas tillverkas och kan då ställa sig frågan "vänta nu jag ligger inte i fas" kan det då handla om en inställning eller vad är problemet. I stället för att när skiftet är slut se att jaha, jag låg 200 artiklar minus från förväntat.

Sen jag kom hit hade de Axxos här, med olika typer av stopp. Som ny behövde jag vända mig till Tomas som kunde varenda stopp, men ingen annan visste vad det handlade om. Det gav ingen helhetsbild, vilket vi ändrade genom att köpa och sätta upp skärmarna vid varje process för att tydliggöra effektiviteten och stoppen.

Appendix 3

Interview Production support

04-04-2022

Om ni upptäcker kvalitetsbrister, kan ni gå tillbaka i produktion protokollet och identifiera problemen? Kan ni stoppa material effektivt för att undersöka kvalitetsbrister? (Digitala ID)

Nej. Det beror dels på att vi inte har någon produktmärkning. Vi klipper tråd, vi svetsar nät i nät svetsen. Här har vi ingen möjlighet att för uppföljning överhuvudtaget. Sedan kommer operatör sätter på en pallflagga och sin signatur.
Vidare till line fin. I samband med det så slängs pall kortet. Sålänge vi plockar nät från pallen vet vi vem som gjort nätet. Men när det är fastsvetsat är den kopplingen bruten. Vi kör vidare till höglagret, och sedan lacken. I lacken försvinner spårbarheten helt. Vi kan se vilket rörverk som tillverkat panelen. Saknar en databas som man för in vart materialet kommer ifrån för att få den kopplingen.
För återkommande problem får vi gissa vart problemet uppstod och göra undersökningar eftersom vi inte har spårbarhet. Hittar vi felet när vi kör panelen då kan vi hitta varför felet uppstod.

Ni använder er utav principen bäst från mig, är det därför ni inte sparar data och inte har spårbarhet?

Jag tror inte man har kommit på något sätt att lösa den informationsöverföringen och kopplingen. Det skulle krävas en databas där man hela tiden för in uppgifter, vilket material och varifrån det kommer.

Hur sker rapporteringen av kvalitetsbrister, har ni etablerat system för det? Är informationen lättillgänglig?

Det här är inget som jag jobbar med. Vi har ett avvikelsesystem där kvalitetsbrister rapporteras och genom det systemet håller vi koll på det.

Arbetar ni med benchmarking på Troax?

Inte utifrån en kvalitetssynpunkt. Lite underhållsmässigt men inte lika mycket som jag skulle vilja göra.

Hur arbetar Troax med förebyggande underhåll för att minska exempelvis kvalitets bortfall?

Schemalagt underhåll och schemalagda underhållsfönster. Där vi framförallt fokuserar på tillgänglighets förluster. Vi har större problem med tillgänglighet än kvalitetsbrist, i alla fall så långt jag vet om. Det är lättare och mer handfast för de flesta, syns tydligt när maskinen står still. Konsekvenserna av kvalitetsbrist är inte lika tydliga. inte direkt alltid återkoppling eller att kvalitetsbrister kasseras i maskinen.

Rengöring är en viktig del för det förebyggande underhåll, vilket sköts av Operatörerna. Ingen statistik men känslan är att många akuta underhåll har med rengöring att göra. Det händer att vi får stanna akut för kvalitetsbrister.

Använder ni er av simuleringsverktyg? Vad använder ni informationen till?

Nej.

Vi hörde att ni har vibrations verktyg och mäter vibrationer i produktionslinan?

Angående vibrationsmätare har vi ett handhållet verktyg som kan mäta vibrationer i motorer. Det bidrar med information i tillståndsbaserat underhåll. Vi har även en fast vibrationsmätare på en robot som mäter kulskruvar där vi har kunnat se att slitningen inte sker naturligt utan att de fått stryk.

Hur ser datainsamling-processen ut? (manuell, halv eller hel automatisering). Vem har befogenhet att rapportera

Axxos fungerar genom att vi har en maskin cykel puls den skall komma inom ett visst intervall beroende på cykeltid vilket fås från order planning system. Kommer inte produkten efter en minut blir det för en cykeltidsfölängning upp till 30 sek, då registreras det som förlängd cykeltid. Kommer det efter det och innan nästa nivån registreras det som ett stopp, men kodas automatiskt som kortstopp. Det gör att operatören behöver inte göra någonting det räknas som driftäkethetsförlust. Är stoppet ännu längre än nivå två då kommer stoppet ut och måste kodas av operatör.

Är stoppen kodade eller skriver operatörer egna?

Operatörerna har ett antal stopporsaker att välja på sedan finns det en kategori övrigt maskinfel vilket kräver en förklaring av operatören. Kommentarerna kan variera i användbarhet. Det kan vara ganska mycket fel som hamnar under övrigt maskinfel då operatörer inte själva vill erkänna fel.

Är det tvunget att ge en anledning till stopp i axxos? Maskinen känner till exempel inte av felorsaken själv?

I de nyare system har vi automat koder men vi använder det inte som automat koder utan vi har det som automatisk kommentar. Den kommentaren beskriver då vart störningen uppstår. Problemet med automat koderna är att samma fel kan både vara grundorsak eller följdfel. Skilja på dessa är svårt men jag jobbar med att öka informationen till operatörer.

Om du ser tillbaka, hur har Troax utvecklat sina datainsamling processer?

Lite granna. Hela tiden sedan jag började har det varit andra större projekt i fokus. Det har varit ny lackeringslinje det har varit ny produktionslina så det är svårt att landa och göra såna jobb. Vi har fullt upp med kapacitetsökningar vilket gör att sådant arbete hamnar i skymundan.

Kan data från exempelvis Axxos vara till stöd för olika beslut eller förbättringar?

Det är målet. Att skapa tiden för det arbetet är dock svårare. En del tekniker kollar i Axxos för att förstå vad som är fel i deras maskiner, men tidsbristen och prioritering stör arbetet.
Axxos används för att se resultatet av olika åtgärder.

Hur utvärderar ni den insamlade datan? Reviderar ni exempelvis Axxos/Tak värdet?

Längesedan vi gjorde det sist. Det har inte prioriterats, Axxos kanske inte används i stor utsträckning för faktabaserade beslut. Planeringen jobbar aktivt med T värdet i TAK, hur de lägger batchstorlekar och order ordningen.
Vi jobbar endast med T i TAK värdet (till viss del även A), dåligt stöd för cykeltider. K värdet rapporteras inte in i Axxos. Vi får in de från line fin, men inte från lacken. Vi får inte ut ett trovärdigt K-värde. Ingen koppling mellan de interna processerna i Axxos.

Mäter ni några KPI's i realtid?

Tillgängligheten som visas på skärmen vid varje process. Hur de används och förstås det vet jag inte.
Underhållssystem.
Skulle vara intressant att integrera system som Axxos och UH system.

Appendix 4

Interview Quality engineer

17-03-2022

Hur arbetar ni med kvalitet i det dagliga arbetet på Troax?

I allmänhet jobbar vi utifrån bra från mig principen, vilket innebär att varje intressent eller process skall leverera med så hög kvalite som möjligt till nästa i ledet. DC vår distributionscentral har högsta ansvaret för att se till att rätt kvalite levereras ut.
Vi har ett mål att vi ska arbeta med 5 större PDCA projekt om året, och fokuserar i dagsläget på att utöka arbetet med ständiga förbättringar.
Ett exempel på PDCA projekt, är monteringen som skall montera ihop lås vilket kräver många artiklar där de behöver öppna olika kartonger/förpackningar. Inköp, Operatörer som monterar, Produktionsledning, projekt beredningen var involverade i detta arbete. Resultatet blev att Inköp kontaktade leverantören och frågade om de kunde sluta packa artiklarna i kartonger. Leverantören tyckte det lät som en bra idé, och operatörerna på Troax slapp spendera mycket tid åt att öppna kartonger.
Troax är inte rädd för att involvera operatören till tjänstemän i dessa projekt.
Det är nära till vem som helst i organisationen, vilket gör att operatör såsom tjänsteman kan gå till en beslutfattare med funderingar och förbättringsförslag.

Får du stöd från ledningen i ditt arbete med Kvalitet? Vill du ge något exempel?

Det är ett stort egenansvar, får mycket backup i besluten jag tar. Ledningen han fler saker att fokusera på än kvalitetsarbeten men edningen engagerar sig i högst mån som möjlig.

Finns det någon strategi/struktur för arbetet med digitalisering och nya tekniska verktyg på Troax?

Jag uppfattar att vi inte har en tydlig struktur/strategi kring detta. Vi har en ansvarig för digital utveckling på Troax. Han arbetar mycket med att digitalisera informationen ut mot säljbolagen. Jag jobbar med Power-bi för att förbättra våran kvalitetsuppföljning. Finns många excel-snurror på olika ställen/avdelningar.

I vilken mån samlar Troax in data i sin produktion idag?

Vi har uppföljning av KPI'er, övergripande.

Finns det i varje process ett kvantifiserbart output? Som går att sätta en siffra på?

Det ska det vara.

Är Axxos tillgängligt i alla processer eller är några delar uteslutna?

Vissa maskiner ligger inte inne. Inte heller logistikflödet eller distributionscentralen. Vilket jag ser som en producerande enhet då de packar ihop produkter.

Rapportering kring datan sker automatiskt från varje maskin/process. Programmet kan inte identifiera vad stoppet då får operatörer skriva in vad stoppet beror på. Produktionssupport har bra koll på detta system.

Du har tidigare berättat att Axxos används och att ni mäter TAK värdet i produktionen, men kvalitetsutbyte inte beräknas? Har ni ett fast värde på just kvalitetsutbyte när ni beräknar TAK, eller är det helt försummat?

Kvalitets Utbytet skulle behöva föras in i Axxos. I de olika interna processerna i fabriken, vill man inte lägga dåliga värden på sin egen process/maskin. Upptäcks kvalitetsbrist i närliggande process så skrivs inte dessa kvalitetsbrister in.
Vi mäter kvalitets utbytet till viss del genom att mäta antal KG vi slänger får vi reda på hur mycket råmaterial som slängs. Detta mäts i separat system och används för att analysera hur mycket som slängs kontra inköpt material.

Genom er befintliga mätning på kvalitet utbytet, vet ni exempelvis vilken produkt/artikel, som skapar mer problem. Slänger ni mer nät än stolpar exempelvis?

Inte vad jag vet. Det är möjligt att varje enskild process mäter detta.

Vilka kommunikationskanaler har ni inom företaget? Hur används dessa?

Huvudsakligen används mail och teams. Alla operatörer har inte tillgång till detta, då får de gå till sin närmaste chef.

Kan ni utifrån maskinernas sensorer förutse maskinstopp?

Jag vet att det är en önskan. Har inte stenkoll på om det är implementerat ännu.

Vilka KPI'er mäter du i din yrkesroll?

Jag tar fram KPI'er för kvalitetsavdelningen. Vi mäter interna och externa avvikelser. PDCA projekt samt utfall från förbättringsarbeten.

Vill du beskriva hur ni arbetar kvalitetsledningssystemet? Hur rapporterar ni in data?

Manuellt, skriver in en avvikelse. Definierar antal och i vilken process. Alla har tillgång till att skapa interna avvikelser. Sedan har säljbolagen tillgång till att registrera vilka artiklar/produkter och antal som avvikelsen gäller.
I vårt QMS har vi mätdon kalibrering och dokumenthantering som är lite mer restrikterad, dvs alla har inte tillgång till att ändra i dessa.

Arbetar ni proaktivt i design av produkter för att minska kvalitetsbrister, t.ex. använder ni er av design for manufacturing (DFM)? Design for assembly (DFA)

Vi har det i våran MPI process med visas gater som man skall gå igenom. Vi har även en produktframtagning grupp som innefattar produktionstekniker, konstruktörer etc. Konstruktören är mest aktiv i projekten men om det innefattar t.ex. intern montering är produktionsledaren för monteringen högs delaktig.

Har ni SPC - Statistisk processtyrning? Mäter ni produkter och håller koll på kvaliteten på detta sätt?

Vi mäter och följer upp PPM på produkter och dess kvalitetsavvikelser. Ingen SPC som mäter tillverkade produkter i realtid i de automatiserade produktionslinan.

Om ni upptäcker kvalitetsbrister, kan ni gå tillbaka i produktion protokollet och identifiera problemen? Kan ni stoppa material effektivt för att undersöka kvalitetsbrister? (Digitala ID)

Vi har spårbarhet på våra artiklar fram till lacken, så går produkten ut till kund kan vi spåra och kolla när det är lackerat. Även identifiera produkter lackerade vid samma tidpunkt och närliggande. Sen har vi även tuv certifierade paneler (ett visst produktsegment) som vi kan spåra ända tillbaka till rör leverantören. Om en automatiserad lina skulle producera standardprodukter t.ex. utan tråd och det upptäcks hos kund kan vi inte gå tillbaka för att identifiera brister hos produkter tillverkade i samband med kvalitetsbrister. I vissa fall kan man det men troligen inte. Vad man gör då är att stoppa produkter och kontrollerar dem genom manuellt arbete.

Kan delar, produkter och material identifieras och lokaliseras i produktionsflödet?

Höglagret och bakåt har vi ganska dålig koll på vart produkter befinner sig i tillverkningsprocessen.

Hur sker rapporteringen av kvalitetsbrister, har ni etablerat system för det? Är informationen lättillgänglig?

Alla kvalitetsbrister skall rapporteras i vårt QMS. Det förs statistik på kvalitetsbrister i bland annat Power Bi.

Arbetar ni med benchmarking inom organisationen?

Mot våra andra bolag inom koncernen. Även viss benchmarking mot konkurrenter men inte i samma utsträckning.

Hur arbetar Troax med förebyggande underhåll för att minska exempelvis kvalitets bortfall?

Jobbar systematiskt med vissa underhåll. Underhållsavdelning har löpande veckounderhåll och dom definierar själva vilket/vilka underhåll som behövs.

Har ni något digitalt system för monteringsanvisningar (dörrmontering)?

De monteringsanvisningar som anses vara kritiska finns i ledningssystemet. Finns det mindre anvisningar såsom verktyg t.ex. skruvdragare finns internt på avdelningen. Inga digitala anvisningar vid monteringsstationer det finns en central plats där man finner monteringsanvisningar. Får inte automatisk monteringsanvisning vid ny monteringsorder.

Kan produkterna röra sig genom produktionen utan manuell hjälp?

Från att artiklar matas i våra automatiserade produktionslinor är det sälla materialhantering av personal. Produkter går från produktionslinan till höglager via självkörande truck, sedan till lack linan där det är en robot som plockar av och på. Sedan går färdiglackat material till höglager via självkörande truck.

Ni har automatisk lagerhållning men hur kontrollerar ni systemen?

Löpande inventeringar och kontroller. Samlar data men inget som rapporteras, de följer upp informationen och analyserar stopp relaterat till automatisk lagerhållning t.ex.

Använder ni er av simuleringsverktyg? Vad använder ni informationen till?

Vi har möjlighet att ha simulerade testmiljöer på vår lagerhållning så vi kan simulera flyttningar av material eller liknande. Simulerar inte körning av maskiner enbart i enskilda projekt där man har en CAD-modell av maskinen där man kan simulera rörelser.

Vart sker kvalitetskontrollen?

Vi kör med "bra för mig" så varje process eller varje avdelning skall kontrollera vid leverans till interna kunder. Den mest omfattande inspektion skall ske vid plockning och packning av order (visuell inspektion). Vid producerande maskiner sker stickprov där omfattande tester av nät utförs så det presterar utefter kravspecifikation.

Hur involverar ni leverantörer vid inköp av material/produkter?

Det är en del av vår MPI-process, det beror även på vissa inköpare. Vissa kan vara mer benägna att få ner priset medans andra är mer benägna att strategiskt samarbete med leverantörer.
Kraljic-matrisen där inköparen bestämmer i vilket område leverantören placeras, är du involverad i processen och identifieringen av de olika leverantörerna?
Jag jobbar i dialog med inköparen och så bidrar jag med revisioner på leverantörer som t.ex. är strategiska, har haft flertalet kvalitetsbrister eller vid affärskritiska leverantörer. Efter revisionen diskuterar vi hur leverantörsrelation skall hanteras. Det kan vara att det blir köpstopp om leverantören inte levererar den kvalitet som efterfrågas. Informationen om leverantörer uppdateras manuellt.

Har ni regelbundna revisioner på kritiska leverantörer?

Jag är inte delaktig i alla revisioner men jag är där när inköp efterfrågar det. Inköpsavdelningen skall ha regelbundna revisioner. Informationen som tas vid revision rapporterad i ledningssystemet i form av ett standardiserat excelark

Delar leverantörer med sig av sina kvalitetskontroller, förbättringsprocesser etc.Utvärderar ni leverantörer och deras förmåga att leverera produkter av kvalite?

Ja vi sätter krav på leverantörer att de skall följa vissa standarder, och där ingår bland annat information om antalet avvikelser i procent, vilken leveranskontroll och

ankomstkontroll de har. De delar även med sig av förbättringsprocesser de som leverantör har för att förbättra levererade produkter.

Hur involverar ni slutkunden i era processer för att förbättra produkter?

Representanter från säljbolag, R&D, produktchefer samlar in kunskap/information och identifierar hur produktsortiment kan uppdateras.

Har ni en etablerad feedback loop för kunder så att de kan ge information om upplevelsen av produkten?

Vi ska ha marknadsundersökningar. Den vägen vi har är kontinuerliga marknadsundersökningar mellan slutkund och Troax AB.

Hur arbetar ni med utbildning av medarbetare i system som CMS etc.?

Utbildningarna styrs upp en gång om året i dialog med närmaste chef. Utbilding kan identifieras på två sätt, närmaste chef kan föreslå utbildningar som är relevanta för arbete eller så kommer medarbetar och förfråga utbildning som är relevant för arbetet. För operatörer använder vi oss av kompetensmatriser för olika maskiner, system, utbildningar (truckkort) osv. På tjänstemannasidan är det mer styrt av HR vilka utbildningar som genomförts.

Får medarbetare support i förbättringsarbeten och finns det en standardiserad process för förbättringsarbeten?

Vi uppmuntrar alla komma med förbättringar och de får den support som det finns resurser för.

Appendix 5

Interview Digital business and marketing developer

05-04-2022

Finns det någon strategi/struktur för arbetet med digitalisering och nya tekniska verktyg på Troax?

Jag har när jag klev på min roll tagit fram ett strategi för kommande åren, den innehåller målsättningar för att skapa en god teknisk plattform att möta framtidens säljprocess inom B2B.

Har du högsta ansvar för digitaliseringen och digital utveckling på Troax?

Jag ingår idag i den centrala marknadsavdelningen, jag ansvarar för digitala verktyg för försäljning inom troax bolagen och rapporterar till marknadschef.

Är det något ni specifikt digitalt verktyg/lösning som ni planerar att implementera och varför?

Möjlighet till Self service och tillgänglighet är något som prioriteras högt, göra det enkelt för kunden. Både gällande kommunikation och tillgänglighet.

Vad vi har förstått så arbetar ni med att utveckla ett digitalt integrerat system mot kund. Vill du beskriva detta lite kort? Är tanken att kunden själv ska kunna rita upp maskinskydd och skicka order till Troax?

Vi har utvecklat ett eget webb baserat ritverktyg för kunden att skapa sin egen layout av maskinskydd, detta är väl mottaget och i dagsläget skickar kunden en förfrågan baserat på sitt layoutförslag som vi sedan kan förfina/optimera innan vi skickar tillbaka en skarp offert. Vi planerar att introducera fler produktlinjer via dessa kanaler.

Har ni ett system för information/feedback när det gäller slutkundens upplevelse av produkten?

I Drawit vårt ritverktyg har vi integrerat ett feedbackformulär där kunderna anonymt kan lämna betyg och kommentarer kring ritverktyget. Vi har även en userpoll som inledning för att anonymt fånga användarnas profiler baserat på enkla frågor kring, roll, branch, CAD verktyg de använder etc. detta kan vi sedan använda för att jämföra mot vår målgrupp.

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