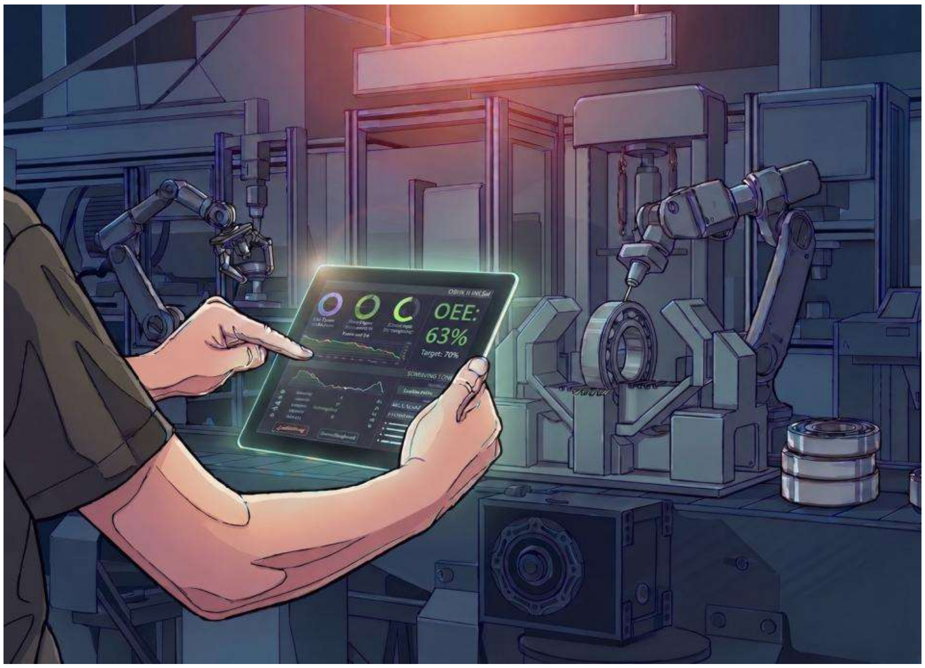
CHALMERS
UNIVERSITY OF TECHNOLOGY



Revising standard operating procedures to improve Time Data Management

A case study at SKF

Master's thesis in Production Engineering

ANTON STEINHAUSEN
DAVID SUNESSON

DEPARTMENT OF TECHNOLOGY MANAGEMENT AND ECONOMICS
DIVISION OF SUPPLY AND OPERATIONS MANAGEMENT

CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2026
www.chalmers.se

Revising standard operating procedures to improve Time Data Management

A case study at a bearing manufacturer

ANTON STEINHAUSEN
DAVID SUNESSON

Department of Technology Management and Economics
Division of Supply and Operations Management
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2026

Revising standard operating procedures to improve Time Data Management
A case study at a bearing manufacturer
ANTON STEINHAUSEN
DAVID SUNESSON

Department of Technology Management and Economics
Chalmers University of Technology
SE-412 96 Gothenburg
Sweden
Telephone + 46 (0)31-772 1000

Cover:
A cartoon-style illustration of a manufacturing intelligence system in bearing production. Generated by Google Gemini's 3.5 Flash model on May 26, 2026.

Use of AI tools: The authors used M365 Copilot, Chat GPT 5 series, and Google Gemini 3.5 Flash to support refinement of written text. All AI generated content was crically reviewed, verified, and edited by the authors.

Gothenburg, Sweden 2026

Revising standard operating procedures to improve Time Data Management
A case study at a bearing manufacturer

ANTON STEINHAUSEN
DAVID SUNESSON

Department of Technology Management and Economics
Chalmers University of Technology

SUMMARY
This thesis investigates how standard operating procedures (SOPs) at SKF can be designed to support reliable Time Data Management (TDM). Reliable time data and efficiency measures are essential for production planning, cost calculation, and strategic decision-making. However, manufacturing companies often experience mismatches between actual shop-floor operation times and the time standards stored in databases and systems. At SKF, the implementation of a new manufacturing intelligence system (MIS) has created new opportunities to improve the quality and traceability of production data. However, reliable TDM depends not only on technological capabilities, but also on clearly defined organizational procedures and responsibilities.

The study was conducted as a mixed-method case study at SKF's roller bearing production facilities in Gothenburg. Empirical data were collected through internal documentation, semi-structured interviews, workplace discussions, observations, and production related data. The collected data was analyzed to identify recurring issues, patterns, and organizational challenges connected to the management of time data and efficiency measures. In addition, several identified issues were further examined through quantitative analysis.

The findings revealed challenges related to both the design of the existing SOPs, and the adherence to them in practice. Weaknesses were identified regarding unclear responsibilities, inconsistent definitions, insufficient alignment between systems, infrequent updates of time data and efficiency measures, and reliance on comparison and estimation-based time determination methods. Together, these challenges contribute to reduced reliability of data used in production planning and standard cost calculations.

Based on the findings, an updated SOP is proposed to support more reliable TDM. The proposed approach establishes clearer ownership of tasks, consistent definitions, improved alignment between systems, and a standardized revision procedure supported by data enabled by the MIS, thereby improving the reliability of data used in production planning and cost calculations.

Keywords: Time Data Management, mismatch, standard operating procedure, manufacturing intelligence system, production planning, cost calculation, time standards, efficiency measures, digital transformation

Acknowledgements

First and foremost, we would like to thank our company supervisor, Richard Hedman, for giving us the opportunity to conduct our master's thesis at SKF and for his patience in answering our many questions along the way. His support and valuable insights throughout the project have been greatly appreciated and have contributed to this work.

We would also like to thank our academic examiner and supervisor, Associate Professor Peter Almström, for his guidance and support throughout the thesis process, as well as for his involvement in initiating and shaping the thesis.

Furthermore, we would like to thank all employees at SKF for their valuable contributions of knowledge and experience, which were essential to this study.

Anton Steinhausen & David Sunesson, June 2026

Contents

List of Acronyms

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

APS	Advanced Planning and Scheduling
BOM	Bill of material
DU	Driftsuppföljning
ERP	Enterprise Resource Planning
KPI	Key Performance Indicator
MIS	Manufacturing Intelligence System
MTM	Methods-Time Measurement
OEE	Overall Equipment Effectiveness
SAM	Sequential Activity- and Method
SC	Standard Cost
SOP	Standard Operating Procedure
TDM	Time Data Management
TVO	Production area
QMPS	Quintiq Master Planning Scheduling

1

Introduction

This chapter introduces the background of the study and presents its purpose, research questions, scope, and limitations.

1.1 Company background

SKF is a multinational company founded in 1907 (SKF, 2026). Today, the company operates in more than 130 countries with a workforce of over 38,000 employees and a distribution network of over 17,000 distributors. SKF develops and manufactures innovative products and solutions to reduce friction, which can be found wherever there is movement. As less friction leads to reduced energy consumption, SKF's products and solutions are enabling society to move toward a future where more can be achieved with fewer resources.

SKF has three production areas (TVOs) in Gothenburg: D, E, and R. TVO D produces medium-sized spherical roller bearings. TVO E produces large-sized spherical roller bearings designed for heavy industrial applications involving heavy-duty machinery. TVO E has an additional remanufacturing department that focuses on the restoration of large industrial bearings received from customers. TVO R produces the spherical rollers used in the bearings. The majority of the total volume is allocated to the bearings manufactured in Gothenburg, while a small share of the produced rollers is supplied to the bearings produced in other countries.

The three TVO units in Gothenburg differ in several aspects of their production environments, particularly with respect to automation level, batch sizes, and cycle times. TVO D is characterized by larger batch sizes, shorter cycle times, and a higher degree of automation, making it well suited for efficient, high-volume production. TVO E, in contrast, operates with longer cycle times and a lower level of automation, reflecting its focus on large, complex bearings and more flexible manufacturing processes. TVO R operates with varying batch sizes, as production is mainly made to order for each batch of bearings. The overall production has a lower level of automation, although certain elements are fully automated.

1.2 Problem background

During the last decades, companies have re-acknowledged the importance of time as a strategic tool and the challenges involved in establishing accurate time standards (Kuhlang et al., 2014). Several companies are experiencing issues related to poor quality time standards, which refer to time data stored in various databases and systems (Almström, 2024). A common problem is a mismatch between operation times on the shop floor and the data stored in databases and systems, negatively affecting production planning accuracy, cost calculation precision, and strategic decisions. According to Almström and Winroth (2010), there are three principal causes for this mismatch: operation times can be defined incorrectly from the beginning, additional allowance time to handle temporary disturbances is prone to becoming permanent and accumulating over time, and the operation times are rarely updated.

SKF is currently implementing a new manufacturing intelligence system (MIS) across its three TVOs in Gothenburg, replacing the existing disturbance reporting and performance evaluation system. The new system, Factbird, provides real-time visibility and data-driven insights into production, enabling faster and more informed decision-making (Factbird, n.d.). By capturing operational data in real time, the system generates more accurate and traceable information, including actual cycle times for different production variants as well as actual setup times. This creates an opportunity to improve the quality of time data and, consequently, operational performance.

SKF is aware of an existing mismatch and aims to evaluate the improvement potential of the new MIS, particularly in terms of its ability to support reliable Time Data Management (TDM). TDM refers to the determination, usage, and administration of time standards. These time standards, such as operating times and setup times, are used to support production planning, cost calculations, and strategic decision-making (Almström, 2024; Kuhlang et al., 2014). However, Hedman and Almström (2017) argues that achieving high quality time data requires more than technological solutions, emphasizing the importance of a well-structured TDM organization. While technological solutions can enable improved data collection, it remains unclear how technological and organizational factors should be aligned to ensure reliable TDM at the company.

1.3 Purpose

The purpose of this thesis is to investigate how standard operating procedures at SKF can be designed to support reliable Time Data Management.

1.4 Research questions

To fulfill the purpose, a set of research questions was formulated to guide the direction and scope of the study. These questions are presented below:

- How are standard operating procedures currently designed and adhered to at SKF?
- What effects do the current standard operating procedures and adherence have on reliable Time Data Management?
- How should standard operating procedures be designed to better support reliable Time Data Management?

1.5 Limitations

The thesis focuses on how reliable TDM can support the supply chain and controlling departments at SKF. Although time standards also influence other departments, these areas are not examined in detail within the scope of this study. The analysis is therefore limited to the perspectives and requirements related to supply chain planning and controlling, and the conclusions should be interpreted primarily within the context of these functions.

The thesis is limited to the TVOs in Gothenburg due to access to relevant interviewees and empirical data. Furthermore, Gothenburg is a site where manufacturing intelligence initiatives related to time standards and performance measurement are being actively developed, making it a suitable context for studying standard operating procedures (SOPs) and TDM.

In line with the purpose of the thesis, the investigation emphasizes how SOPs can be designed to support reliable TDM. While supporting systems and tools are acknowledged as important enablers, the thesis does not describe how such systems should be technically implemented or configured and is therefore discussed only at a conceptual level.

Due to time constraints, this thesis is limited to investigating and, if deemed necessary, proposing an improved SOP. The study does not include the practical implementation of the proposed procedure at SKF, nor an evaluation of its effects after implementation.

2

Frame of reference

This chapter presents the theoretical foundation by introducing relevant concepts and theories that provide the necessary contextual background to support the understanding of the report.

2.1 Measures

Overall Equipment Effectiveness

Overall Equipment Effectiveness (OEE) is a comprehensive key performance indicator (KPI) that reflects the efficiency of a work unit (Almström et al., 2017). It is based on three basic KPIs: availability, effectiveness, and quality. Availability shows the proportion of scheduled operating times that the production unit actually produces. Effectiveness refers to the relationship between the planned cycle time and the actual cycle time. The quality ratio indicates the proportion of the products produced that comply with established quality standards. OEE is calculated by multiplying the three basic KPIs, as shown in equation 2.1.

$$\text{OEE} = \text{Availability} \times \text{Effectiveness} \times \text{Quality} \tag{2.1}$$

Hedman et al. (2016) explains that downtime losses are applied when calculating the availability factor, speed losses are used to determine the equipments effectiveness factor, and quality losses are incorporated into the calculation of the quality factor. Nakajima has defined six big losses which these three factors aim to capture (Nakajima, 1988).

According to Nakajima (1988), downtime losses consist of two main types: equipment failures, and setup and adjustments. Equipment failures losses arise when productivity is reduced or when defective products lead to quantity losses. In contrast, setup and adjustment losses occur when production of one item ends and the equipment must be configured for the next item.

Furthermore, Nakajima (1988) describes that speed losses include idling and minor stops, as well as reduced operating speed. Idling and minor stops losses refers to when the production is briefly interrupted due to small malfunction or when a machine is idling. Reduced speed is the difference between the planned speed and the actual operating speed.

Finally, quality losses, as defined by Nakajima (1988), comprise reduced yield and quality defects and rework. Reduced yield losses occur during the ramp-up phase of production, from the machine startup until stable operation is reached. Quality defect and rework losses arise when malfunctioning equipment causes products to fall short of required quality standards.

Cycle time

Bellgran and Säfsten (2010) defines cycle time as the time required to complete one unit in a process step. This may be delayed by various factors or events such as machine downtime, product quality issues, or operator inefficiency, to name a few examples (Chen, 2026). Chen (2026) also mentions that some authors exclude waiting time from the definition of cycle time, meaning that cycle time is equivalent to the total processing time.

Setup time

Zandin (2001) defines setup time as the time elapsed from the moment when the production of the previous product stops until the production of non-defective units of the next product is confirmed, and therefore includes more than just the time required for changing tooling and parts. Frequent setups, resulting from the production of many different products in small batches, results in lower utilization and reduced production hours. Any line that is not dedicated to a single product will require setup activities. Consequently, setup time becomes unavoidable in many industries.

Quality

Bellgran and Säfsten (2010) defines that quality is achieved when products demonstrate high performance and comply with specified requirements. To assess the quality level of a product, various performance measures can be used, such as scrap percentage, scrap and rework cost, quality of incoming components, and others. The performance measures must be applied in appropriate scenarios and combined in suitable ways to describe quality accurately.

2.2 Bottleneck

Rojas-Cuevas and Caballero-Morales (2025) describes that in manufacturing, a bottleneck is a resource in the production system that restricts the systems total output. It functions as a limiting factor, slowing down operations and reducing overall efficiency. The term bottleneck comes from the analogy of a bottles narrow neck, which restricts how quickly liquid can pass through. Similarly, this constrained resource limits the pace at which products can move through the production system. This analogy is illustrated in figure 2.1. There are different types of manufacturing bottlenecks: static and dynamic (Tang et al., 2024). A static bottleneck arises in production systems with stable operating conditions, where a specific resource consistently constrains throughput over time. In contrast, a dynamic bottleneck is a resource whose constraint on throughput shifts over time as system conditions change due to variability, disturbances, and other operational factors.

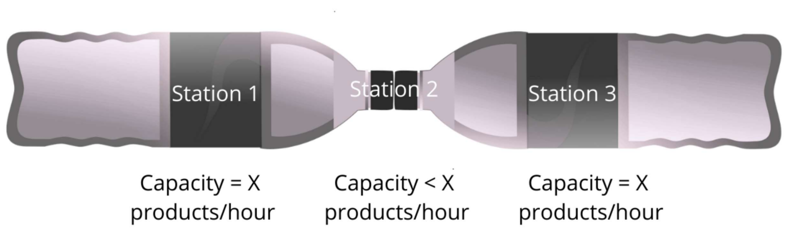


Figure 2.1: Illustration of a manufacturing bottleneck (Rojas-Cuevas & Caballero-Morales, 2025)

2.3 ERP, APS, and MIS

Enterprise Resource planning (ERP) is a system solution that supports organizations by organizing their key operations and information in one platform, making it easier to manage resources and daily operational processes (Soares et al., 2025). This includes areas such as data control, sales areas, sales operations, material requirements planning, and work documentation, supporting efficient task execution as well as effective shop floor control and management. By gathering all this information into one shared platform, ERP provide organizations with a real-time overview of their performance and daily operations, supporting better communication and collaboration across departments. In addition, ERP increases efficiency by automating processes, reducing data redundancy, and lowering the risk of errors.

Advanced Planning and Scheduling (APS) is a system designed to integrate with an ERP system to support the short, mid and long term production planning and scheduling (Kjellsdotter Ivert, 2012). APS systems can function as a standalone system, although ERP system can also have incorporated APS functionalities. The fundamental difference is that APS is designed to support decision making, while ERP systems are mainly oriented toward transactional processing. Kjellsdotter Ivert (2012) argues, based on several sources, that an APS system should include four essential characteristics: it supports planning in the short term, mid term, and long term periods, generates and evaluates different scenarios, considers constraints simultaneously, and uses mathematical algorithms to solve optimization problems. A standalone system operates by extracting master data from the ERP system to support decision making, and once a decision has been made, it sends the resulting decision back to the ERP system for execution.

MIS is a system that plays a crucial role in digital transformation by collecting, integrating, and analyzing data from sensors, machines, and ERP systems (Hastilow & Young, 2012). Its primary purpose is to improve efficiency, product quality, and decision making by providing real-time visibility into manufacturing operations. Operationally, MIS systems should have five essential functions:

- Data collection: Capturing and aggregating real time data from sensors, machines, and ERP systems ensuring no essential data is missed.
- Data integration: Integrating the data into one platform while also ensuring that the data is clean and normalized to ensure consistency and accuracy.
- Data analysis: Transforming raw data into meaningful insights to identify patterns, anomalies, and trends.
- Visualization: Presenting insights through intuitive dashboards and reports.
- Decision support: Enabling informed adjustments to machine settings, maintenance plans, and workflows.

2.4 Time Data Management

As mentioned in the background, Kuhlang et al. (2014) define TDM as the determination, usage, and administration of time standards. A time standard refers to time data, such as lead times, operating times, and setup times, which are stored in databases and systems and used to support planning, cost-calculations, and strategic decision-making (Almström, 2024; Kuhlang et al., 2014). One of the major challenges in TDM is ensuring the quality of time data over time (Almström, 2024).

Companies often experience a substantial difference between real shop-floor operation times and the operations times specified and stored in databases and systems, commonly referred to as a mismatch (Almström, 2024). According to Almström and

Winroth (2010) there are three principal causes for this mismatch: operation times can be defined incorrectly from the beginning, additional allowance time to handle temporary disturbances are prone to become permanent and accumulate over time, and the operation times are rarely updated. Allowance time refers to time spent on necessary but not value-adding activities and undesirable but sometimes necessary activities (Almström, 2024).

The mismatch has a negative impact on areas such as planning, cost calculation, and strategic decision-making. For example, Freivalds and Niebel (2009) mentions that the accuracy of the data used when determining a schedule is directly related to the success of the schedule and that a schedule based on judgment cannot be considered reliable. Additionally, Hedman and Almström (2017) states that earlier research demonstrates that the mismatch contributes to operational inefficiencies, for instance by creating additional workload for production planners. In contrast, the absence of a mismatch, achieved through correct and up-to-date time standards, results in several positive outcomes, as shown in Figure 2.2.

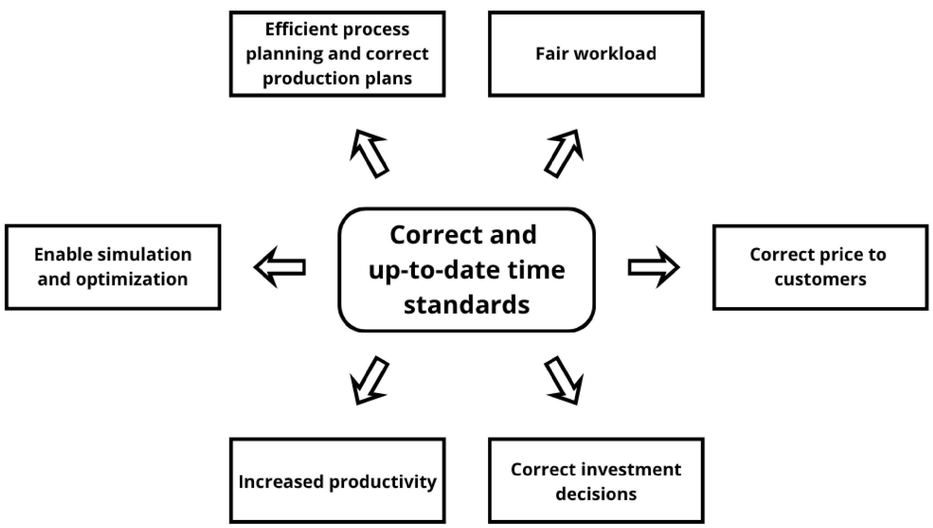


Figure 2.2: The effects accurate and updated time standards (Almström, 2024)

In the context of time data, it is important to distinguish between planned times and actual times. Planned time is the time for each operation step, determined before the work is carried out (Almström, 2024). Planned time is sometimes referred to as ideal time or standard time, but this report uses the term planned time exclusively. Actual times refer to durations of activities that can be measured while they are being performed.

To minimize the mismatch and maintain the quality of the time standards over time, companies can work with constant analyzes and continuous improvements (Almström, 2024). As part of the constant analyzes, actual times are compared to the planned times and any resulting differences are analyzed. If the deviations are due to random variation, no action is required. However, if deviations are caused by process changes, the time standards should be reviewed and updated accordingly in databases and systems. Without these revisions, companies will be unable to realize the benefits associated with accurate time standards. Almström (2024) states that for most value-adding operations, a revision once a year represents a reasonable compromise been precision and cost.

2.5 Time determination methods

To enable this continuous analysis and improvement, appropriate methods for determining planned times are required. Almström (2024) emphasizes that selecting the right method is important, and the choice of method depends on the purpose of the analysis. There is no single method that is optimal for all situations. Zandin (2001) emphasizes the importance of knowing the strengths and limitations of different time determination methods, as it is essential when selecting an appropriate technique, particularly when evaluating the tradeoff between the cost of establishing standards versus the cost of having inaccurate or nonexistent production standards. Figure 2.3 presents a model developed by Almström (2024) that summarizes the most common methods for determining both planned and actual times.

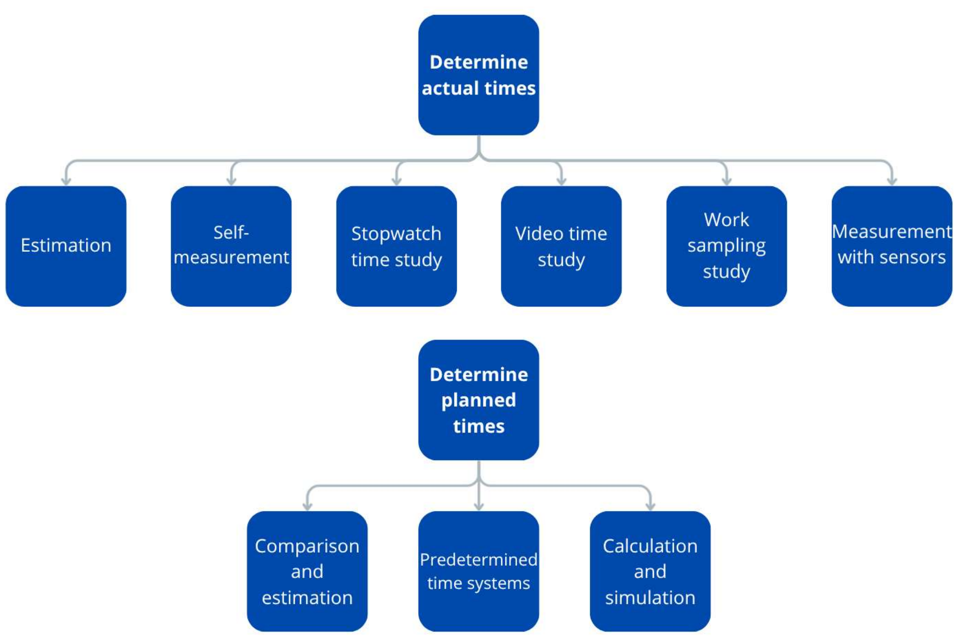


Figure 2.3: Common time determination methods (Almström, 2024)

As the figure shows, the most common methods for determining actual times include estimation, self-measurement, stopwatch time study, video time study, work sampling study, and measurement with sensors. Estimation is a common but unreliable way to determine how long a task takes, as it often relies on guesses or intuition. The estimates are influenced by the operator's attitude and relationship to the manager and company. Self-measurement means that the person performing the task measures their own work, rather than being observed. It can be as unreliable as estimation since the individual is in control of the process and can manipulate the measurement or data that the time determination method results in. Stopwatch time studies are commonly used to measure actual time due to its simplicity and accessibility. In practice, however, time standards based on stopwatch time studies can be challenging to maintain as every product or process change requires the study to be redone. Moreover, the observed actual time is influenced by factors such as performance and utilization which complicates the analysis and comparison to planned time. Stopwatch studies may be used to establish planned time as well as to follow up an existing standard, provided that the performance factor is kept at the right level and that deviations from the standard method can be distinguished from disturbances. The concept of the performance factor is explained in the following section. Performing a video time study is considered a better alternative to using a stopwatch. It involves filming the work being performed and analyzing the video afterwards. A key benefit is that disturbances can be identified and excluded from the analysis. Work sampling study is based on statistical observations distributed over a time period, typically ranging from one day to one week. The method is commonly used to to complement to time studies or to identify losses in the form of disturbances and other unwanted allowance times. The technique is applicable to humans, machines, or any observable operational state or condition (Zandin, 2001). Measurement with sensors is an automatic measurement method that measures the actual time for an activity using technical equipment with sensors and data processing (Almström, 2024). One example of such a system is the use of light sensors. These sensors can detect and register when a products passes a specific point in a process, after which the cycle time can be determined by considering the time interval between the detections.

The most common methods for determining planned times are comparison and estimation, predetermined time systems, and calculation and simulation (Almström, 2024). In the comparison and estimation approach, the planned time for a new activity is assigned the same time as an existing, similar activity that already has a defined time in the systems. As a result, the times are approximate and may lack accuracy. Predetermined time systems, as well as calculation and simulation are better alternatives. A predetermined time system is a motion-based work measurement system in which work times are derived from standard motion elements with known time values (Zandin, 2001). Kuhlang et al. (2014) states that predetermined time systems are primarily intended for manual tasks. On the other hand, Zandin (2001) states that predetermined time systems are one of the most applicable methods for automated processes. Calculation and simulation refer to methods where planned times are derived analytically or through the use of digital models of the production processes. Calculation can involve determining task times based on formulas based on process parameters (Kuhlang et al., 2014). Both simulation and calculation are suitable for automated tasks.

Since the early 1910s, numerous predetermined time systems have been developed, including Methods-Time Measurement (MTM), work factor, motion time study, master standard data, and Maynard Operation Sequence Technique (Almström, 2024; Zandin, 2001). MTM was developed in the 1940s and formed the basis for the predetermined time systems that are dominant today (Almström, 2024). The original system, MTM-1, provides a high level of accuracy due to its level of detail. However, this accuracy comes with the drawbacks of taking a long time to learn and perform analyses with. As a result, its use can be limited in practice, particularly in contexts where resources and expertise are constrained (Benter et al., 2026; Borsdorf et al., 2022). In Sweden, the most commonly used MTM system is Sequential Activity- and Method (SAM) analysis (The Nordic MTM Association, 2024, as cited in Almström, 2024). SAM is designed to be simple to perform, which makes it a balanced trade-off between time efficiency and accuracy.

Several research studies and ongoing projects focus on automating the creation of MTM analyses. These developments aim to address the mentioned limitation that traditional MTM analyses are time consuming and require expert knowledge, which restricts their widespread and frequent application (Benter et al., 2026). One such development was proposed by Borsdorf et al. (2022), who explored the use of artificial intelligence to support the automated generation of MTM analyses. Their approach aims to enable the automatic derivation of MTM analyses by evaluating existing company data, such as routing plans and bills of materials, as well as other text-based information. The approach utilizes artificial intelligence to extract and structure relevant information, from often unstructured company documents. This data is then transferred to a separate software, MTMmotion®, which ensures the final analysis is accurate and compliant with established MTM standards.

Another approach, presented by Benter et al. (2026), utilizes virtual reality and motion capture technologies to generate MTM analyses from recorded motion data. Similar to the previous method, this approach relies on MTMmotion® to transform the captured data into accurate and rule-compliant MTM analyses.

While both approaches have been shown to reduce analysis effort, they also have limitations (Benter et al., 2026; Borsdorf et al., 2022). Artificial intelligence based methods depend on the quality of input data and still require validation, meaning human expertise is needed to ensure that the generated MTM analyses are accurate and reliable. Current virtual reality-based methods, on the other hand, face limitations related to motion accuracy as it can miss certain movements. As a result, it is primarily suitable for preliminary analyses in early design phases, whereas detailed analysis still require expert review or additional data. Future developments are expected to focus on increasing the accuracy and reliability to increase practical applicability.

2.6 Performance rating

In manual work, variations in operator performance can lead to differences in actual times between cycles, even when work conditions remain unchanged. To account for these variations, a performance rating can be made, used to assess the operator's performance relative to a defined standard (Almström, 2024).

To express performance rating quantitatively, a performance factor is used. The performance factor is obtained by dividing the planned time by the actual measured time, as shown in equation 2.2 (Almström, 2024). It requires that there is a determined planned time, for example, from using a predetermined time system. To obtain the actual time, a rule of thumb is to observe and measure ten cycles. The distribution of the observed times can be assessed by plotting them in a histogram, and the actual time may be expressed using either the average or median time.

$$\text{Performance factor} = \frac{\text{Planned time}}{\text{Actual time}} \tag{2.2}$$

2.7 Responsibility and Accountability

To clarify task ownership, this report adopts the concepts of responsibility and accountability originating from the RACI responsibility assignment framework. Responsibility is associated with performing the activities required to complete a task, while accountability is associated with ownership of the task and the authority to approve the completed work (Cadle et al., 2021).

2.8 Visual control

Visual control, originating from lean production, refers to the use of any visual information in the work environment to make it clear how work should be performed and whether deviations from the standard are occurring (Liker, 2003). The purpose of visual control is to support employees in consistent execution by making performance or process status easily interpretable.

2.9 Digital transformation

Digital transformation can be referred to as the organizational transformation enabled by digital technologies (Imran et al., 2021). It has become an important part of industrial development, as the emergence of Industry 4.0 technologies has enabled organizations to develop new ways of operating and improving performance (Imran et al., 2021). However, digital technologies alone are insufficient for successful digital transformation, as fully realizing the benefits requires consideration of additional factors.

Digital transformation can be divided into two main categories: technical systems and social systems, where social systems include people, procedures, and structures (Imran et al., 2021). They stress the importance of a sociotechnical perspective when implementing digital transformation initiatives, referring to how social and technical aspects interact to achieve a common goal. They emphasize that focusing primarily on technological implementation while neglecting social aspects may limit the effectiveness of digital transformation initiatives.

Imran et al. (2021) identify organizational structure, leadership, and culture as the most important social elements for achieving performance outcomes. Organizational structure refers to how responsibilities, communication, and decision-making are organized within the company. Leadership is how the transformation is guided and supported, while culture relates to shared values, behaviors, and openness to change. Imran et al. (2021) further emphasizes the significance of organizational structure in digital transformation, arguing that organizational structures are often insufficiently transformed to support the implementation of digital technologies.

2.10 Focused factory

The focused factory concept was introduced by Skinner (1974), who argued that manufacturing performance can be improved by limiting the scope of a factory's objectives and activities. He stated that factories attempting to produce a wide range of products, operate with different manufacturing processes, and satisfy different market requirements often experience increased complexity, higher overhead costs, and reduced operational performance. Instead, manufacturing should be organized around a clearly defined manufacturing objective and a limited set of products and processes. By concentrating resources, equipment, and supporting systems on a specific manufacturing task, organizations can reduce complexity, improve efficiency, and lower overhead costs.

3

Method

This chapter presents the research strategy, design, and process applied in this study. The research process is described in terms of its overall sequence, followed by a detailed description of each step. Additionally, the chapter addresses relevant methodological considerations, including research quality and ethical considerations.

3.1 Research strategy

Olsson and Sörensen (2021) states that all research begins with one or more questions, problems, or concerns that form the central focus of a research project. These can be approached from either a qualitative or quantitative research perspective, depending on the purpose and intended outcome of the study. According to Creswell (2014), studies typically lean more toward either a qualitative or quantitative approach, although the two perspectives should not be viewed as fixed or opposing categories. The most common distinction is that qualitative research primarily focuses on words and interpretations, while quantitative research emphasizes numerical data and statistical analysis (Creswell, 2014). Furthermore, the approaches differ in terms of data collection methods. Qualitative research commonly relies on interviews, observations, case studies, and documents, whereas quantitative research often uses surveys, experiments, and numerical measurements. Mixed method research combines qualitative and quantitative data collection and analysis, enabling a more comprehensive understanding of the research problem than either approach alone (Creswell, 2014). The thesis uses a mixed methods approach, combining both qualitative and quantitative methods.

The thesis is both descriptive and exploratory in nature. It is descriptive because it aims to map and describe SKF's current SOPs related to TDM. According to Olsson and Sörensen (2021), descriptive research is appropriate when an existing body of knowledge is available and the purpose is to describe or map a current situation, process, or structure. At the same time, the study is primarily exploratory, as it investigates an area with limited prior research. Rather than testing predefined hypotheses, the study seeks to generate understanding and insights into how SKF should design its SOPs in order to realize the benefits of reliable TDM. Creswell (2014) argue that exploratory research is suitable when the objective is to develop a deeper understanding of a phenomenon and generate insights rather than test predefined hypotheses.

The combination of these approaches results in an exploratory sequential mixed methods approach with descriptive elements, which was selected as the research strategy. According to Creswell (2014), this research strategy begins with a qualitative research phase in which data is collected and analyzed. The findings from the qualitative phase are subsequently used to guide the quantitative phase of the study. The qualitative phase can be used to identify relevant variables, develop suitable measurement approaches, and support the design of the subsequent quantitative analyses. This aligns with the thesis, which initially applies a qualitative research approach based on internal documents, interviews, and observations. The findings from the qualitative phase are subsequently analyzed and, where possible, further supported through quantitative data and numerical analyses.

This thesis also adopts a case study approach as its research design, as it aims to provide an in-depth understanding of a specific problem at SKF. According to Woodside (2010) the definition of a case study research is achieving a deep understanding of actors, interactions, sentiments, and behavior occurring for a specific process. Case study research are often associated with using qualitative methods (Woodside, 2010). However, case study research can be further strengthened by combining qualitative and quantitative methods, which is the approach adopted in this study.

3.2 Research process

A methodological approach was developed for this thesis, mainly inspired by a model proposed by Freivalds and Niebel (2009), which explains eight principal steps in a methods engineering program. The approach was also influenced by a methodology described by Banks et al. (2014). Although the model described by Freivalds and Niebel (2009) outlines a procedure to develop a work center, produce a product, or provide a service, the model developed for this thesis uses approximately the same structure as the first four steps in the model. The differences are that the second step is divided into two steps and that the content of each step is adapted to suit the study. The methodology described by Banks et al. (2014) is inherently iterative. In line with this, the model developed for this thesis has an iterative cycle between data collection and mapping the SOPs and current state. As the mapping progresses, additional data gaps can be identified, making it necessary to return to the data collection phase. The model is illustrated in figure 3.1, and the phases are: define the scope, collect data, map SOPs and current state, analyze the collected data, and propose a future state.

Figure 3.1: Developed research method

3.2.1 Scope

The first step of the method focused on establishing the scope of the study. The scope consists of three elements: the purpose, the research questions, and the limitations, which were defined in collaboration with the supervisors and presented in Chapter 1. The purpose was formulated to define what this thesis aims to investigate and achieve. To ensure that the purpose was fulfilled, a set of research questions was developed to guide the work and serve as checkpoints throughout the study. The limitations define what falls outside the scope of the thesis and clarify which aspects are excluded from the purpose and research questions. The limitations also ensure that the thesis is manageable within available resources, time, and expertise. Defining the scope was essential for guiding the subsequent data collection, as it clarifies which information and data was relevant for addressing the research questions and ultimately fulfilling the purpose of the study.

3.2.2 Data collection for mapping standard operating procedures and current state

The second and third steps of the developed model involve the collection of empirical data and the mapping of existing SOPs and the current state of the workflow, including how the operations are actually carried out in practice. These two steps were conducted iteratively, as the mapping process could reveal additional areas of interest that required further data collection. Empirical data were collected from four types of sources: internal documentation, interviews, systems and databases, and observations.

Internal documents were used as a source of empirical data to map and formulate the documented SOPs. Examples of internal documentation included standards, procedures, routines, and company-specific terminology relevant to the study. These documents provided the basis for describing how the work is intended to be carried out, which later enabled a comparison to how the work was actually carried out in practice.

Interviews were conducted with employees from Manufacturing, Manufacturing Reliability, SKF Production System, Supply Chain, Controlling, and Process Development, which are departments connected to the use, management, or support of production data. The purpose of the interviews was to obtain primary data and capture perspectives from different organizational areas. 19 semi-structured interviews were conducted, meaning that they were based on predetermined questions while also allowing additional questions and modifications of the question order (Taherdoost, 2022). The approach is well suited for the study as it ensures consistency across interviews while also facilitating detailed data collection and the discovery of new ideas.

In addition to semi-structured interviews, empirical data were collected through workplace discussions. These discussions were mainly held with members of a team within the Process Development department. Some of these interactions resembled unstructured interviews, as they were not based on a predetermined interview guide but allowed topics to emerge naturally. Written questions sent through digital communication channels were also used when specific information needed to be confirmed or followed up, often after interviews had been conducted.

Interviews were conducted until theoretical saturation was approached. In qualitative research, saturation is commonly used as a criterion for discontinuing data collection (Saunders et al., 2018). This point is reached when additional data no longer contribute to new insights and the researchers begin to recognize patterns and answers.

In addition to internal documentation and interviews, empirical data were collected from systems and databases. The systems and databases provided production-related information, such as cycle times and efficiency measures, which provided quantitative input used to strengthen the analysis of the current state.

Observations were also used as a source of empirical data, although only to a limited extent. According to Olsson and Sörensen (2021), observations can be either qualitative or quantitative depending on the purpose and design of the study. They can be conducted directly, indirectly, or through participation, and can also be structured or unstructured. In this study, the observations were qualitative, direct, non-participant, and unstructured. Direct observation means that the researcher observes what takes place in its natural context, while non-participant observation means the observer stays separate from the activity. Unstructured observation is conducted in an exploratory manner to gather information about a specific area. In this study, observations were conducted in production environments across different factories to gain an understanding of processes such as dressing operations and resetting activities, as well as the overall production setup.

3.2.3 Data analysis

In the fourth step of the developed method, the qualitative data in this thesis were analyzed using the Gioia methodology, which is a structured inductive approach for analyzing qualitative data and developing concepts grounded in empirical observations (Gioia et al., 2012).

The analysis began with a 1st-order analysis, where interview statements, observations, and findings from internal documents were reviewed and coded using terms and expressions closely connected to the participants descriptions and experiences. In this stage, the focus was placed on preserving the original meaning of the collected data while identifying recurring issues, observations, and patterns (Gioia et al., 2012). An example is that an interviewee stated that system and databases has different cycle times, which results in an 1st-order concept of "Time data inconsistency".

The identified 1st-order concepts were subsequently grouped and interpreted into broader 2nd-order themes. In this stage, relationships and similarities between the identified concepts were analyzed to develop broader themes and patterns relevant to the purpose of the study (Gioia et al., 2012). An example of a 2nd-order theme that the 1st-order example "Time data inconsistency" would be grouped into is "lack of system and database integration". Finally, the second-order themes were grouped into broader aggregate dimensions to create a clearer overall structure of the collected data.

This three-step methodology was conducted using digital software, where 1st-order concepts were documented on virtual sticky notes. These notes were then grouped with related concepts into 2nd-order themes, which were subsequently combined into aggregate dimensions.

3.2.4 Propose future state

Milani (2019) argues that once the business requirements have been defined, the current state analyzed, and the company's key challenges identified, the next step is to consider scenarios that address these issues, which is the fifth step of the developed model. This was carried out in this thesis, where the SOPs and current state were mapped and analyzed, enabling the identification of the shortcomings associated with them. Then, with these considerations and relevant theory in mind, a future state was developed to address these shortcomings.

The identified shortcomings determined the scope and level of detail of the proposed future state. According to Milani (2019), a future state may involve minor adjustments to existing processes and system functionalities, or more comprehensive changes such as the addition, removal, or restructuring of significant organizational elements and existing solutions. These minor and extensive adjustments can include, but are not limited to:

- Functional and organizational structures
- Competencies, knowledge, and skills
- Organizational and facilities locations
- Business processes
- Information and data structures and flows
- Information systems, interfaces, and architecture
- Technology infrastructure

The future state can be described with statistics, diagrams, models, figures, or text (Milani, 2019). The future state in this thesis was described using figures, diagrams, and text, consistent with the presentation of the SOPs and current state. According to Milani (2019), using a similar format simplifies the comparison and discussion between the different states.

3.3 Research quality

To ensure the quality of the study, both qualitative and quantitative quality criteria were considered, as the study adopts a mixed method approach. This was particularly relevant since case study research has been criticized for limitations related to research quality, often discussed in terms of validity and reliability (Quintão et al., 2020). For the qualitative parts of the study, trustworthiness was assessed using credibility, transferability, dependability, and confirmability (Lincoln & Guba, 1985, as cited in Korstjens and Moser, 2018). According to Korstjens and Moser (2018), these criteria are widely used to evaluate the quality of qualitative research. For the quantitative parts, validity and reliability was considered as they are quality concept commonly associated with quantitative research (Stenbacka, 2001).

Credibility refers to how well the findings reflect the participants' views and experiences (Korstjens & Moser, 2018). In this study, credibility was strengthened by collecting data from multiple types of sources across different departments and hierarchical levels. This can be referred to as both data triangulation and method triangulation (Korstjens

& Moser, 2018). This made it possible to compare and complement findings from different sources, which helped support a correct interpretation of the participants' views and increased confidence in the results.

During the interviews, emphasis was placed on not imposing the researchers' predefined assumptions or interpretations, for example, from the internal documentation, on the respondents to further support credibility. This was inspired by Gioia et al. (2012), who argue that researchers should avoid imposing prior knowledge and instead allow respondents to describe their work and experiences in their own words during the early stages of data collection and analysis. This allowed the documented SOPs and the current state to be mapped separately, making it possible to identify whether the SOPs were followed in practice. This also supports confirmability, which refers to the extent to which the findings are derived from the empirical data rather than the researchers' own assumptions and interpretations (Korstjens & Moser, 2018). However, qualitative analysis still requires interpretation by the researchers, which may influence how the data is understood and categorized. To reduce this influence, reflexivity was considered throughout the study, which refers to the researchers' awareness of how their own assumptions, prior knowledge, and interpretations may influence the findings (Korstjens & Moser, 2018). This meant that the researchers were aware of how obtained knowledge from internal documentation, previous examples, and observations could influence how questions were asked.

Transferability refers to the extent to which the findings can be applied to other contexts or settings (Korstjens & Moser, 2018). As the study is a case study at a specific company, the transferability is somewhat limited. However, by describing the company context, data sources, and research process, readers are provided with a basis for assessing whether the findings may be relevant in similar contexts.

Dependability concerns whether the research process is clear and traceable, and whether the findings are supported by the collected data (Korstjens & Moser, 2018). In this study, dependability was supported by the documented research process and by the use of a structured inductive approach for analyzing qualitative data and developing concepts grounded in empirical observations.

In this study, reliability and validity were considered in relation to the quantitative data, which was used to further examine pattern and issues identified through the qualitative data. Reliability refers to the ability of method to produce the same research result when repeated, while validity refers to whether the intended object of measurement is actually measured (Stenbacka, 2001). Since the quantitative data were collected from existing systems and databases, the reliability and validity is dependent on the accuracy of these sources and how the data was extracted. Employees at the company supported the extraction process to ensure that the correct data was retrieved.

3.4 Ethical considerations

This study follows established research ethics principles. According to Pruzan (2016), three key areas characterize ethical and unethical behavior in research: potential harm to participants or the environment, the absence of informed consent or invasion of privacy, and the presence of deception or coercion. These principles were considered throughout the entire study.

All interview participants were informed about the purpose of the study, the topics to be discussed, and how the collected data would be used. Informed consent was obtained prior to each interview, and participation was voluntary, ensuring that no coercion was involved. Participants were also informed of their right to withdraw at any time without consequence. To minimize the risk of harm, no sensitive personal information has been disclosed, and care has been taken to ensure that neither participants nor the organization are negatively affected by the publication of the results. Data obtained from interviews, internal documents, observations, and empirical sources has been presented accurately and truthfully, ensuring the absence of deception. Additionally, the company conducted a confidentiality review prior to publication to prevent the release of confidential or sensitive business information. This ensures that the research maintains both ethical integrity and compliance with organizational requirements.

4

SKF's standard operating procedures

This chapter maps SKF's SOPs, which describe how the work is intended to be carried out according to the established standards and guidelines found in their internal documentation. The purpose of this is to provide a benchmark against which the current state, presented later in the report, can be compared. In addition, a brief introduction to company-specific terminology is provided.

4.1 SKF Channel Concept

To understand the subsequent chapters in this report, it is necessary to have a basic understanding of what a channel-based production is. The SKF Channel Concept was introduced in the late 1980's and revolutionized manufacturing by changing the fundamental mindset from "push" to "pull". Although the concept is being further developed to meet the increasing complexity of modern manufacturing, it remains highly relevant and is considered by SKF to be a key concept for ensuring a world-class flow in its factories and across its suppliers.

The SKF Channel Concept is closely related to the focused factory theory proposed by Skinner (1974). According to this theory, manufacturing performance improves when production is organized around a limited and clearly defined set of products and processes, rather than attempting to serve a broad range of objectives. By concentrating resources, equipment, and supporting systems on a specific manufacturing task, organizations can reduce complexity, improve efficiency, and lower overhead costs.

As figure 4.1 illustrates, a channel at SKF is managed as a mini-factory within a factory, with a defined set of operations for the production of a defined group of products. A channel is also planned and controlled by a defined group of people. However, it shares some resources and central factory functions, such as quality and engineering, with other channels.

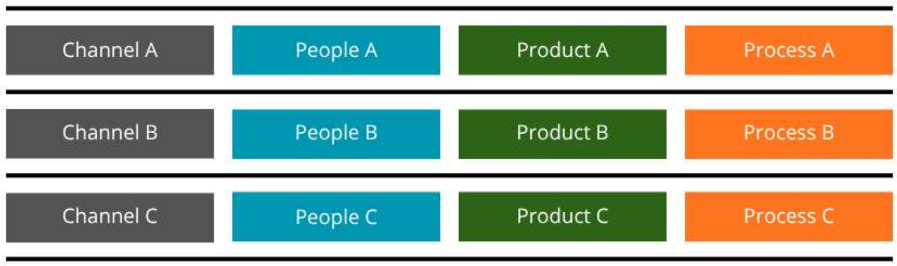


Figure 4.1: Channel concept

A Production Channel consists of a bottleneck machine that defines the maximum output. The bottleneck is the process with the longest cycle time. The bottleneck machine is the planning point of the channel, meaning it defines the cycle time on which production planning is based. While the channel can have a dynamic bottleneck due to special or unpredictable events in the real production environment, planning for all material families is still based on the predefined bottleneck.

Each Production Channel handles specific material families produced within that channel. A material family refers to bearings that share the same raw-material dimensions, use components with lead-times shorter than the raw-material lead-time, and can be produced within a single channel set-up. A material family represents the first level in the product hierarchy, illustrated in figure 4.2. The product hierarchy classifies finished products into hierarchies for planning and material flow purposes. Each material family contains at least one main variant. The main variants are different soft-machining and heat treatment processes, distinguished, for example, by a small machined groove. Each main variant contains at least one final variant, which represents different grinding, assembly, and grease configurations. A final variant is a finished bearing or component before it is packed. Each final variant contains at least one pack variant that is packed according to customer needs. It could, for example, involve individually packed items in cardboard boxes or multiple items packed together on an EUR pallet.

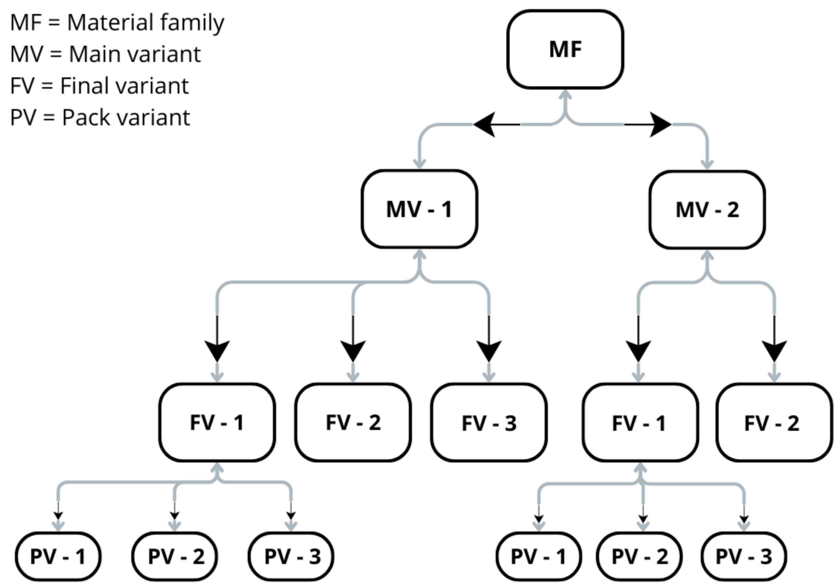


Figure 4.2: Product hierarchy at SKF

4.2 Organization

To provide a clear understanding of the responsibilities defined in the SOP, the roles and functions of these departments are briefly described. Although this section does not constitute part of the SOP itself, it serves as an important foundation for interpreting how responsibilities are assigned and managed in practice. This section presents an overview of the departments relevant to this study.

Manufacturing

The three TVOs in Gothenburg are organized into two manufacturing areas: one consisting of TVO D and TVO R, and the other comprising TVO E and the remanufacturing operation. Both manufacturing areas have largely the same organizational structure. Each is led by a Manufacturing Manager, followed by a Channel Group Manager who oversees the Production Managers. Each channel is managed by one Production Manager, with operators reporting below this level. In the manufacturing area that includes the remanufacturing operation, dedicated roles are responsible for the remanufacturing service center and customer service, while the Manufacturing Manager retains overall responsibility. Both manufacturing areas also have maintenance personnel responsible for centralized and corrective maintenance, as well as maintenance activities requiring specialist support.

The manufacturing areas also have dedicated support functions, including Manufacturing Reliability (MR), the SKF Production System (SPS), Supply Chain, Controlling, and Process development. These support functions and their organizational structures are described in the following sections.

Manufacturing Reliability

MR is a support function for manufacturing that includes production engineers and maintenance technicians. Production engineers may either be assigned to a specific channel or specialize in areas such as assembly, machining, or heat treatment. Their primary responsibility is to drive manufacturing improvement initiatives, and they are generally not involved in daily operational activities. The maintenance technicians are responsible for addressing planned maintenance tasks.

Supply Chain

The Supply Chain department can be divided into sub-departments that are responsible for purchasing, investment and asset management, and logistics and demand chain. The sub-department most affected by time data and efficency measures is the Logistics and Demand Chain Department and will therefore be the focus of this master's thesis. Henceforth, references to the Supply Chain department refer specifically to this sub-department.

Logistic and demand chain department is responsible for sales and operations planning (S&OP). S&OP is a global monthly process to balance supply and demand, bringing all business operational plans into one integrated plan. It consists of three processes: sales forecasting, manufacturing supply planning, and supply planning. The monthly S&OP process starts with a Sales Forecasting process and the aim of the process is to create the best forecast possible of the future demand. Manufacturing supply chain process is to decide production volumes to fulfill future demand, stock and service targets. The aim is to proactively identify needs for adjusting the production capacity to balance the supply with the demand and to make sure that the production plan is updated accordingly. Supply planning process is to secure material and component supply by sharing demand information with suppliers. The Logistics and Demand Chain departments include a manager and several supply chain planners, with each of the three Gothenburg TVOs having its own.

Controlling

The controlling department in Gothenburg consists of a factory business controller, a business controller for TVO D and R, a business controller for TVO E and remanufacturing, a business controller and support role, and a manufacturing finance developer. The department is responsible for supporting factory management through economic control and by translating operational activities into monetary terms. For this thesis, particular attention is given to the Manufacturing Finance Developer, who is responsible for the annual standard cost (SC) calculation.

Process development

The Process Development department serves as a support function within manufacturing, with the responsibility of developing and implementing solutions, as well as supporting the skills and knowledge required to achieve efficient and competitive manufacturing operations.

4.3 SKF's IT systems

To provide a clear understanding of the systems referenced in the SOP, this section provides brief descriptions of the relevant systems. Although it does not constitute part of the SOP itself, it serves as an important foundation for understanding their functionality and context. Accordingly, this section presents an overview of the systems relevant to the study.

SAP ERP

SAP ERP is an ERP system that integrates various departments and functions across a company onto a single system that can serve all departmental needs. Hereafter, SAP ERP will be referred to simply as SAP. At SKF, SAP is used by manufacturing, quality, MR, purchasing, Supply Chain, logistics, and more. A single system makes it possible to achieve both a more detailed view and a better overall overview of the processes in the company. SAP is also used to coordinate all the resources, information and activities needed to complete business processes, while also allowing each department to store and retrieve information in real time. SAP has a wide range of information for example production related information such as bill of materials (BOMs), cycle times, resetting times, efficiency rates, scrap rates, and cost information.

QMPS

Quintiq Master Planning Scheduling (QMPS) is an APS system used for production planning in TVO D and TVO E at SKF. While production planning is technically possible directly in SAP, as is done in TVO R, QMPS provides more advanced planning and scheduling functionality required for the higher level of complexity in these production environments. An example is that QMPS is updated in real time, whereas SAP can have delays of up to 24 hours. The time data and efficiency data should be consistent between SAP and QMPS to ensure accurate production planning as well as correct product cost allocation.

DU

Driftsuppföljning (DU) is a disturbance handling system currently used at SKF and is being replaced by the new MIS, Factbird. The purpose of the system is to identify and quantify losses to enable effective continuous improvement and improved factory control. In this system, operators manually report disturbances by entering both the type of stop and the duration of the stop. The duration is estimated by the operator. Disturbance reporting should be based on hourly loss monitoring, meaning that data is intended to be recorded on an hourly basis. These reported values are used to calculate several KPIs in the Key Data Report (KDR), including OEE, which is reported to higher management. The KDR is a structured document that summarizes operational data and KPIs.

4.4 Time data and efficiency measures

This section outlines the definitions, determination methods, and assigned responsibilities for time data and efficiency measures as described in SKF's SOP.

Cycle time

SKF defines planned cycle time, or Pure Cycle Time, as the total time required to produce one part on a machine, including loading, unloading, and dressing time, if applicable. Dressing time refers to the time required to resharpen the grinding wheel. The parameter is the theoretical optimal time required to produce a part and plays a key role in calculating different efficiency measures, as any cycle time longer than the planned cycle time results in a speed loss.

The Pure Cycle Time is calculated according to equation 4.1. The total operating time is measured in seconds on the machine using a stopwatch, and the output during the operating time is counted. Because SKF incorporates dressing time in their planned cycle time for the grinding machines, it needs to be measured over time to capture the dressing operations and account for it in a reasonable way.

$$Pure\,Cycle\,Time = \frac{Total\,operating\,time}{Number\,of\,pieces\,made\,during\,total\,operating\,time} \tag{4.1}$$

SKF's factories are expected to update their planned cycle times at least once every year, and preferably even more often, such as every three months or in line with improvements of the machines. The annual update should preferably be done in line with the business planning cycle so that the SC is based on the correct planned cycle time. SC is explained in detail in chapter 4.7.

Process Development or Manufacturing Reliability is responsible for defining and maintaining the cycle times on all machines for all products.

Efficiency

SKF is mainly working with two efficiency measures: OEE and running efficiency. OEE is the central performance indicator used within the production department. It gives them, and SKF as a whole, an indication of how well the equipment is performing in relation to its theoretical maximum output. Similarly to the six big losses presented in chapter 2.3, SKF has defined their own structure, '7 Big Losses', connected to the three basic KPIs to which all the more detailed loss types must be grouped. The '7 Big Losses' are:

- Down-time
- Resetting Loss
- Tooling Loss
- Missing Resources
- Process Adjustment
- Speed loss and Minor Stops
- Scrap and Rework

These seven categories form the basis for determining the OEE measure and identifying what reduces the efficiency in the production process. In addition to the OEE formula presented in chapter 2.1, the measure can be calculated by dividing effective hours with scheduled hours, both of which are illustrated in figure 4.3. Effective hours can be obtained by multiplying the cycle time by the number of produced pieces.

Running efficiency is the defined efficiency measure in SAP and QMPS and is determined by dividing effective hours by production hours. As shown in figure 4.3, the key difference compared to OEE is that running efficiency does not include resetting hours. Legal and union hours refer to hours during which production cannot be manned due to legal requirements or union regulations, for example public holidays such as Christmas Day. Free hours refer to periods when production is neither manned nor planned to be in operation. Resetting hours refer to the time spent on changeovers between material families. Waste refers to time lost due to stoppages at the channel bottleneck, whether planned or unplanned. Both running efficiency and OEE are defined at the channel level, meaning that all material families produced within the same channel share the same efficiency value. There are, however, some exceptions, such as when a specific material family is significantly harder to produce. These exceptions were not considered in this study. The different time categories used in the calculations are defined as follows:

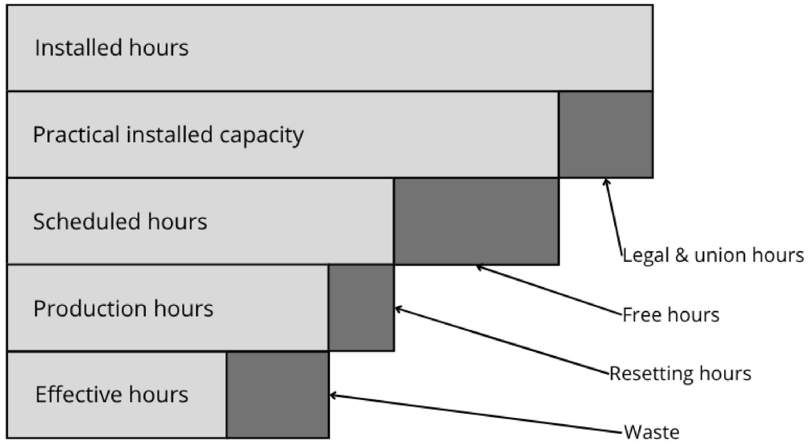


Figure 4.3: Capacity concept

The Production Manager is ultimately responsible for approving OEE results before reporting them.

Resetting time

SKF defines resetting time as the loss of production output due to resetting between different material families plus the time required to change from one final variant to another. However, only the resetting time for the material family is used in the SC and planning process at SKF. The Resetting time for the final variants is included in the running efficiency of the channel. In the SC and planning process, it is assumed that resetting is done in a defined time, independent of both the number of available personnel and their competence, and shift changes are assumed to have no impact.

"TR" calculation is the standard method to capture the resetting time for a material family. As figure 4.4 shows, the TR period is from that output is lost to the point when the new material family reaches its planned production output. This means it includes both the downramping and upramping phases, since these periods represent a loss of output in pieces per hour compared to the planned production. The figure shown represents a specific situation, but the TR calculation can be applied universally, regardless of the material family or the production channel considered.

The TR calculation requires several terms in its equations. $T_{ø}$ which is the monitoring period should be long enough to capture the moment that output is lost to the point when the new product reaches its planned production output, the rest of the terms and their definitions are presented in the list below. The first step in the TR calculation is calculating the equations 4.2 and 4.3 which are the running-out (T_1) and running-in time (T_2). Then using the monitoring period $T_{ø}$ and the calculated T_1 and T_2 values, the Channel resetting time (T_r) can be calculated according to equation 4.4.

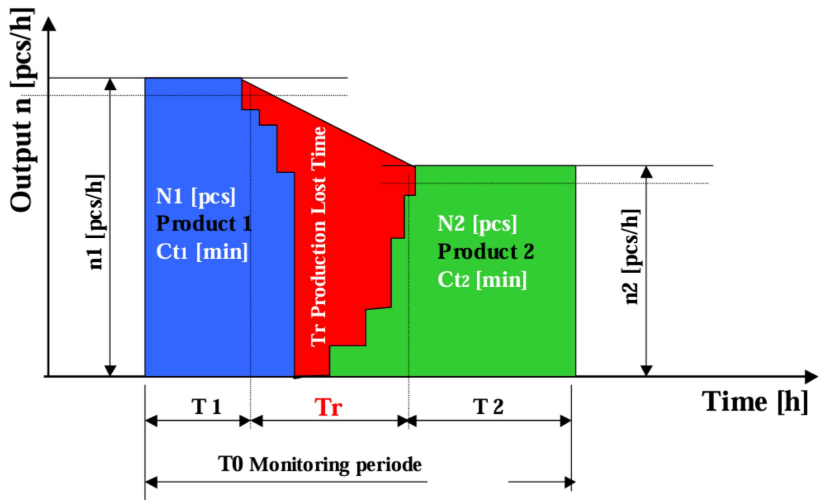


Figure 4.4: TR calculation

- $T_{ø}$: Monitoring period.
- T_r: Channel resetting time [hours].
- N_1: Quantity produced from Tø start to zero output of Product 1.
- N_2: Quantity produced from output start to Tø stop of Product 2.
- 0.9: Reducing distorting influence of low channel OEE or Availability-rate.
- n_1: Theoretical production rate of Product 1 [pieces/hour].
- n_2: Theoretical production rate of Product 2 [pieces/hour].
- T_1: Running-out time of Product 1.
- T_2: Running-in time of Product 2.

$$T1 = \frac{N_1}{0.9 \cdot n_1} \tag{4.2}$$

$$T2 = \frac{N_2}{0.9 \cdot n_2} \tag{4.3}$$

$$T_r = T_{ø} - (T_1 + T_2) \tag{4.4}$$

SKF's factories are expected to review their resetting times once a year, and any identified changes should be updated accordingly. Production manager and the operators are responsible for defining and maintaining the resetting times on all machines for all products.

4.5 Production planning procedure

The Supply Chain department is affected by time data and efficiency measures, and this chapter describes how the daily production planning process should be performed as well as how the planning system is aligned with the time data and efficiency measures in SAP.

In the bearing factories, TVO D and TVO E, the Supply Chain department's daily production planning processes are carried out in QMPS. This system generates a tentative production schedule with corresponding quantities which is based on customer orders, forecasts, current inventory levels, cycle times, resetting times, and running efficiency. QMPS allows a specific resetting time to be defined for each material family transition within a production channel. These resetting times are defined in a matrix, where each entry represents the time required to change from one material family to another. QMPS determines the required material family by analyzing customer orders, forecasts, and inventory levels, whereas time data and efficiency data form the foundation of the resulting production schedule. To support a clearer understanding of the production planning process, the procedure is illustrated in figure 4.5. As shown in the figure, the first required action is an M-decision which gives the planner a set amount of days to decide whether the material family will be produced and in what quantity. The set number of days is based on the longest lead time of the externally sourced products listed in the BOM. The planner must then make a D-decision which determines how the total quantity of the material family is distributed across the main variants to be produced. Once the D-decision has been made, the subsequent E-decision follows, in which the main variants are divided into final variants. The final decision the planner must make is the P-decision, which determines the choice of pack variants.

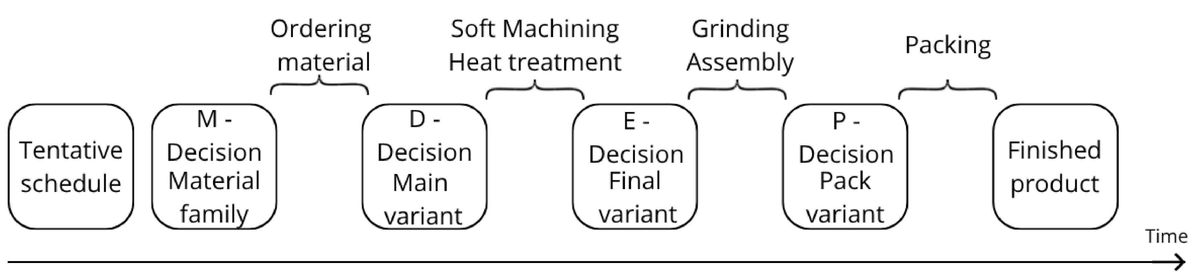


Figure 4.5: Illustration of the planning process in TVO D and TVO E

The Supply Chain department in TVO D and TVO E should deliberately postpone the M-, D-, E-, and P-decision until as late in the planning process as possible. This approach ensures that the most critical products can be prioritized while also preserving the flexibility to allow changes to occur shortly before production begins. However, to ensure that manufacturing receives the necessary information sufficiently in advance, the Supply Chain department should generally follow the rule of releasing orders five days ahead. In addition, the Supply Chain department in TVO D and TVO E is in charge of priority control, meaning that they have the responsibility for determining the sequence in which orders should be manufactured . The manufacturing department can adjust the order sequence in certain situations, such as when there is a material shortage or adjusting which order the main variants and final variants are produced.

In contrast to the daily operational planning process in TVO D and TVO E, the planning in TVO R is carried out directly in SAP rather than QMPS. For the most part, their work follows the plan defined by the planners in the D and E factory, given that rollers are a critical component in the roller bearings.

The supply chain planner in TVO R manages all incoming orders from TVO D and TVO E through a digital planning board in SAP, which displays everything from tentative orders to those already in production. The planning board uses a set of color combinations to indicate the current phase of each order, similar to figure 4.6. The first phase of an order is marked in blue, representing tentative orders that the supply chain planner in TVO D and TVO E has not made an M-decision on. At this stage, both the planned production date and the quantity can still be adjusted. The next phase is shown in blue with a black line through it, indicating that an M-decision has been made and that the tasked TVO R planner has to order material for the order. The third phase is marked in brown, indicating that the order is now visible to the production but has not yet been released. In order for production to start working on an order, such as performing set-up or preparing material, the order must first be released. Once released, the order changes to a pink color. When the pink color has a triangle in front of it, it indicates that the production on the order has started. When the order is finished, it disappears from the digital planning board. In some cases, the order may still remain visible which indicates that it is not fully complete yet. This can occur due to additional quality checks being required, material shortages, or other follow-up actions. The planning board shows detailed information on when an order should start and when it should be completed. It also displays the planned start times and planned finish times for both setup and manufacturing. These displayed times are calculated based on time data and efficiency measure in SAP.

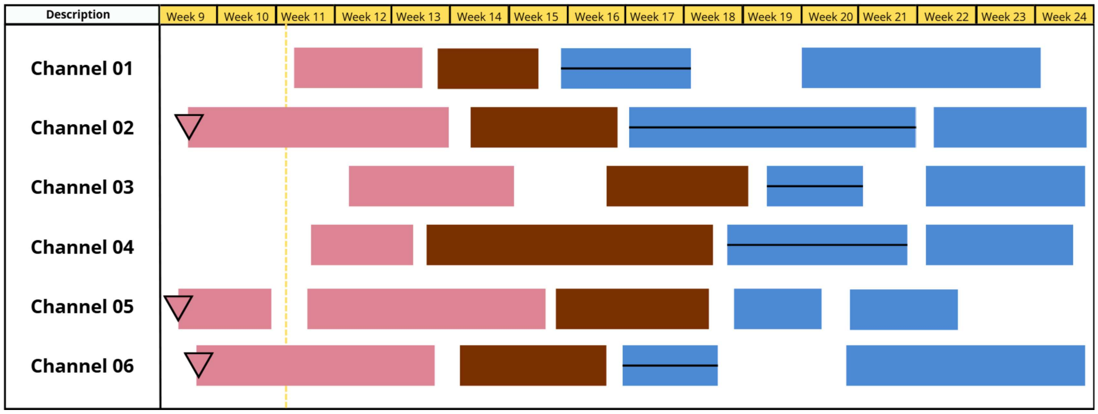


Figure 4.6: Illustration of the digital planning board

As mentioned, the Supply Chain department does not work directly with time data and running efficiency. Instead, these parameters are embedded within their systems, operating in the background and impacting plans and recommendations. However, Supply Chain is the owner of the time data and running efficiency in QMPS, which should be aligned with the data in SAP. The responsible departments for defining and sustaining the data in SAP were presented in chapter 4.3.

The process for updating the time data and running efficiency is that the Supply Chain department at TVO D and E should be notified whenever changes have been made in SAP. Following such updates, Supply Chain is responsible for ensuring that the corresponding data in QMPS is updated accordingly.

4.6 Standard Cost procedure

Within SKF, there are several cost concepts used for products, each serving a different purpose. One of those concepts is SC, which is a technique for allocating production costs fairly among products. SC is used to measure the year-over-year performance of a manufacturing unit, but it also serves as the foundation for calculating several other cost concepts used for profitability analysis and calculating the cost of goods sold, to name a few examples. SC is calculated once a year and remains unchanged throughout the year. The process of calculating the new SC typically takes place from mid-August until mid-November and takes effect from 1 January of the following year.

The SC process allocates the total historical production cost for the SC period, which is the previous 12 months, by considering the quantities during that period. Every activity in manufacturing has a financial consequence that is fairly distributed to each product. The SC has four elements: direct material/external subcontracting, variable value-added cost, fixed value-added cost, and resetting value-added cost. The latter three, which represent the different types of value-added costs, are combined to calculate the total value-added cost. Examples of fixed value added cost are wages for employees and planned maintenance while variable value added cost are utilities, product packaging, shop supplies, and repair costs. The value-added cost can then be used to calculate a value-added (VA) rate per hour which is calculated by dividing the value-added cost with the scheduled hours for the SC period as shown in equation 4.5. The VA rate is in turn used to calculate two cost per piece measures: VA cost per piece and resetting cost per piece. As equation 4.6 and equation 4.7 shows, the former is obtained by multiplying the VA rate by the cycle time of the bottleneck and dividing by the running efficiency, while the latter is calculated by multiplying the VA rate by resetting hours and dividing by the lot size which is an average batch size. Both VA-cost per piece and resetting cost per piece are calculated at the final variant level. This means that any cost differences arising from packing operations in pack variants are evenly distributed across a single final variant.

$$\text{VA Rate} = \frac{\text{Value added cost}}{\text{Scheduled hours}} \tag{4.5}$$

$$\text{VA cost per piece} = \frac{\text{VA Rate} \cdot \text{Bottleneck cycle time}}{\text{Running efficiency}} \tag{4.6}$$

$$\text{Resetting cost per piece} = \frac{\text{VA Rate} \cdot \text{resetting hours}}{\text{Lot size}} \tag{4.7}$$

As the formulas reveal, the costs per piece measures are dependent on bottleneck cycle time, running efficiency, and resetting time. This data is found in SAP, which, as previously mentioned in chapter 4.3, is updated by different departments.

5

Current state

This chapter presents how the operating procedures are actually carried out in practice, in contrast to the intended way of working that was defined in the previous chapter. It also identifies weaknesses in both the SOPs and the current state. These findings are then used to quantitatively evaluate the impact on the affected departments.

5.1 Analysis of time data and efficiency measures

This section presents how time data and efficiency measures are determined, who is responsible, and outlines the different definitions used at SKF. It also compares the differences between the current state and the SOPs, while identifying the weaknesses in both.

Cycle time

The previous chapter described the process for determining cycle times according to SKF's SOP. It states that planned times should be determined by measuring the total operating time. However, to obtain an accurate planned cycle time, the total operating time must be measured under disturbance free conditions. The SOP does not specify how such disturbance free measurements should be conducted, and without this guidance or knowledge, there is a risk of including disturbances in measurements, resulting in inaccurate planned cycle times.

In practice, a less time consuming process for determining cycle times is frequently applied. It is to use comparison and estimation which is often based on similar material families within the channel or the responsible departments' knowledge of cycle times. The outcome of this process is that the determined planned cycle time is closely aligned with those of similar material families, or well informed approximations. This process can produce cycle times that are acceptable, however if the similar material families are incorrectly defined the newly determined cycle time will be significantly inaccurate.

According to SKF's SOP, Manufacturing Reliability is formally responsible for defining and maintaining cycle times. In practice, this function retains responsibility, but often relies on collaboration with production managers in the Manufacturing department when support is required. At the same time, internal documentation from Supply Chain training states that the production manager is the owner of cycle times, which contradicts the responsibility described in the SOP. In addition, the Process Development department, which is also stated as responsible for cycle times in the SOP, was not observed to be involved in any activities related to the cycle times in practice. The involvement of two departments, both described as responsible in different sources, combined with the lack of observed involvement from a third department identified as responsible, creates uncertainty regarding responsibility.

SKF's SOPs further state that planned cycle times should be reviewed at least annually and preferably more frequently. In contrast, cycle times are, in practice, reviewed only sporadically. This was emphasized during an interview with a production planner, who stated that some cycle times had not been reviewed for several years. According to Manufacturing Reliability, planned cycle times are only reviewed when mismatches are detected. However, as planned times are rarely compared to actual times, mismatches are unlikely to be detected, resulting in limited updates to the cycle times. Instead, updates are mainly triggered by obvious discrepancies.

According to SKF's SOP, cycle time should be defined as the time elapsed from one unit exiting the machine until the next unit exits the machine, plus any additional dressing time needed. However, sometimes only the machining time and not loading-, unloading-, and dressing time is considered, which results in a cycle time that is too short. It was mentioned during an interview that such an example occurred at TVO E, where the cycle times for a channel were updated by an individual who only considered the machining time. As a result, incorrect planned cycle times were entered into SAP, and the entire cycle time determination process had to be repeated. The definition includes dressing time, which is an additional component that can easily be overlooked.

During visits to the TVOs, it was observed that dressing occurs frequently and has a short duration. For an observed medium-sized bearing, dressing took place every other cycle and lasted only a few seconds, whereas it was mentioned that it may occur even more frequently for larger bearings. Dressing operations therefore represent a recurring part of the production cycle and have been defined by SKF as part of the cycle time. Excluding it would result in an underestimated planned cycle time.

Efficiency

As mentioned in the previous chapter, OEE gives SKF an indication of how well the equipment is performing in relation to its theoretical maximum output. In a similar manner, running efficiency provides an indication of equipment performance during production, excluding resetting activities. Both measures necessitate that the planned cycle times are correctly defined, which, as described in the previous section, is not always the case. Incorrect planned times result in an inaccurate speed loss calculation and efficiency measures that fail to reflect reality. Furthermore, as explained in chapter 1, DU poses a risk of coding incorrect losses, since the durations and types of disturbances during the shift are reported at the end of the shift and therefore rely on memory. This deviates from the SOP, which states that reporting should follow hourly loss monitoring, and may result in inaccurate and misleading efficiency values.

While running efficiency is the defined efficiency measure in SAP and QMPS, it is not automatically measured or calculated at SKF currently. The only way to obtain running efficiency is through manual calculation based on data from the KDR. However, this is not performed consistently. In some channels, running efficiency is determined based on qualitative judgment through collaboration between the supply chain planner and the production manager rather than being derived from production data. If production data consistently fails to meet the production plan, the running efficiency value is adjusted accordingly. While this approach could support accurate production planning, it lacks a data-driven foundation and is dependent on work experience. It also fails to accurately reflect true running efficiency and may hinder improvement efforts, as inefficiencies are not systematically identified or quantified, thereby limiting the effectiveness of continuous improvement.

The running efficiency for many channels has not been updated in several years in planning systems. For example, four production channels (D01, D02, E02, and E04) were last updated on 1 January 2024, 1 February 2024, 1 October 2024, and 1 August 2025 in QMPS. This indicates that updates are performed infrequently and at irregular intervals. Possible reasons for this include the absence of a responsible person for reviewing running efficiency and a defined interval for how often running efficiency should be updated in SKF's SOP.

Running efficiency is not an established KPI within the production department and is not used in their daily operational work. Despite this, a running efficiency value is still expected to be reported to SAP and QMPS for production planning and SC purposes. In these two systems, the measure is referred to as "efficiency" which can create uncertainty regarding which type of efficiency is intended. Given that OEE is the primary and most familiar efficiency measure for Manufacturing Reliability and the production managers who usually update this data, there is a risk that OEE is confused with running efficiency. This may lead to OEE being entered into SAP and subsequently QMPS, instead of running efficiency. A quantitative analysis of OEE and running efficiency for channels at SKF reveals instances where this appears to be the case. One such example is the channel E06.

Table 5.1 presents a comparison of the different efficiency measures associated with channel E06, where incorrect efficiency measures are marked in red. Here, it can be observed that the running efficiency in SAP and QMPS is probably based on OEE instead of running efficiency. Running efficiency in QMPS and SAP should be 51.3% instead.

Table 5.1: Efficiency comparison

2025	E06
Running efficiency calculated based on data in KDR	51,3 %
Running efficiency in QMPS	42,7 %
Running efficiency in SAP	42,7 %
OEE from KDR	42,8 %

Resetting

SKF's SOP chapter presented that only the resetting time for a material family is used in the SC and planning process at SKF, and that TR calculation is the standard method to capture the resetting time for a material family. However, TR does not represent the resetting time that Supply Chain and Controlling requires in their planning and SC process. They are interested in the resetting time, corresponding to what Zandin (2001) defines as setup time, which is the time elapsed from that the previous batch produced its last bearing until the next batch has produced its first bearing meeting the quality requirements. While TR is a good method for mapping the full resetting process, which is valuable when analyzing and improving resetting performance, it is not suitable to be put in the ERP system as a planning parameter. This implies that, depending on the context, resetting may be defined in different ways. The SOP describes two definitions, while a third definition emerged during the mapping of the current state. The three different definitions are:

- Loss of production output between material family resetting plus the time between FV resetting
- Loss of production between material family resetting (TR)
- Time elapsed from that the previous batch produced its last bearing until the next batch has produced its first bearing meeting the quality requirements.

In contrast to TR, which is calculated, the resetting time of interest to the production planners and manufacturing finance developer is determined differently. Similarly to cycle times, resetting times are estimated by employees with extensive experience in the resetting process, resulting in approximate values.

According to SKF's SOP, the production manager and operators are formally responsible for defining and maintaining resetting times. In practice, they retain this responsibility but often collaborate with Manufacturing Reliability when support is required.

SKF's SOP states that the resetting times are expected to be reviewed once a year, and if any changes are identified they should be updated accordingly. However, in practice, these reviews are conducted sporadically and primarily triggered by obvious discrepancies rather than continuous analysis. This was highlighted during an interview, where it was reported that operators were reluctant to performing a reset for a particular material family as it was not feasible to complete within the required time and would negatively impact the OEE.

5.2 Alignment between SAP and QMPS

As described in section 4.5, updates to time data and efficiency measures in SAP and QMPS are carried out by separate departments. This means that there are two departments that need to be synchronized whenever the time data and efficiency measures needs to be updated to ensure that the data remains aligned between the two systems. According to SKF's SOPs, the responsible department for time data and efficiency measures are expected to inform Supply Chain immediately when changes are made in SAP, who then update the data accordingly in QMPS. This way of working relies heavily on manual follow-up and frequent reminders to ensure that updates are completed. In practice, this communication flow is not functioning seamlessly, as it in interviews was reported that Supply Chain is not always informed when a change is made. Given this way of working, one could suspect that there are misalignment between the time data in the two systems. Therefore, this section analyzes the extent to which misalignment exist in the time data and efficiency measures between the two systems, evaluates the magnitude of the differences, and assesses the implications of these differences.

The following quantitative analyses performed in this chapter are limited to cycle time and running efficiency and does not include resetting times. Restricting the analyses to cycle time and running efficiency was considered sufficient for examining the alignment between the systems. The analyses are also only performed for four channels:

D01, D02, E02, and E04. It can be assumed that a similar pattern can be seen for the other channels within TVO D and E, as the same workflow of updating data in the systems applies on to all channels. The channels had 113, 140, 77, and 32 cycle time observations in SAP and QMPS, corresponding to different variants produced within each channel, where the cycle time is defined at material family level. However, each channel has only one running efficiency value that applies for all material families.

To analyze and evaluate the extent to which cycle times are synchronized between the two systems, the misalignment rate was calculated. It quantifies how often the values differ. As shown in equation 5.1, the metric represents the percentage of material family observations for which the value in SAP, *x*, does not match the value in QMPS, *y*. If the misalignment rate is greater than 0%, there is at least one inconsistency. Table 5.2 shows the calculated misalignment rates for the different channels, which demonstrates that inconsistencies between the systems are present in all the observed channels. However, the extent of variation differs significantly.

$$\text{Misalignment Rate} = \frac{M}{N}, \tag{5.1}$$

$$\begin{aligned} x_i &= \text{value in SAP for observation } i, \\ y_i &= \text{value in QMPS for observation } i. \\ M &= \text{number of observations where } x_i \neq y_i, \\ N &= \text{total number of observations,} \end{aligned}$$

Table 5.2: Misalignment rates for cycle times between QMPS and SAP

	N	**Misalignment rate**
D01	113	22.12%
D02	140	7.14%
E02	77	77.92%
E04	32	12.5%

While the misalignment rates indicate the frequency of misalignment, they do not capture the magnitude of the difference between the systems. The size of these deviations is critical, as minor differences might be harmless, whereas larger deviations may have a significant impact on the company. To analyze the magnitudes of these differences, bar charts comparing cycle times in QMPS and SAP were created, where QMPS is shown in blue and SAP in orange. These charts are presented in figures 5.1, 5.2, 5.3, and 5.4, and illustrate the observations for the four channels where the systems are not aligned.

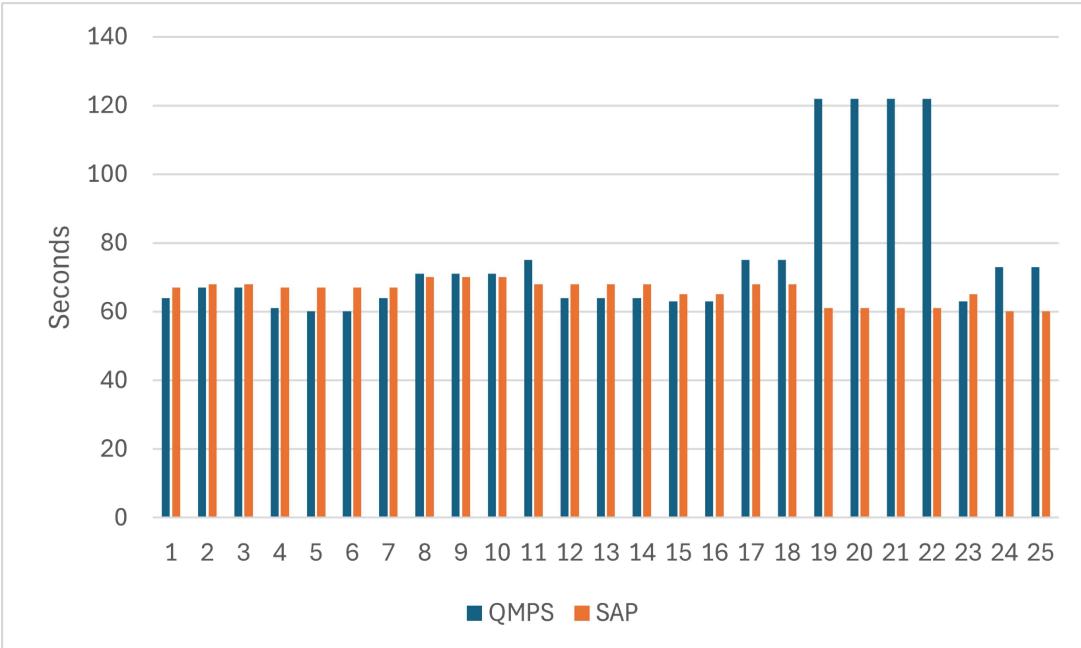


Figure 5.1: Cycle times for material families in D01

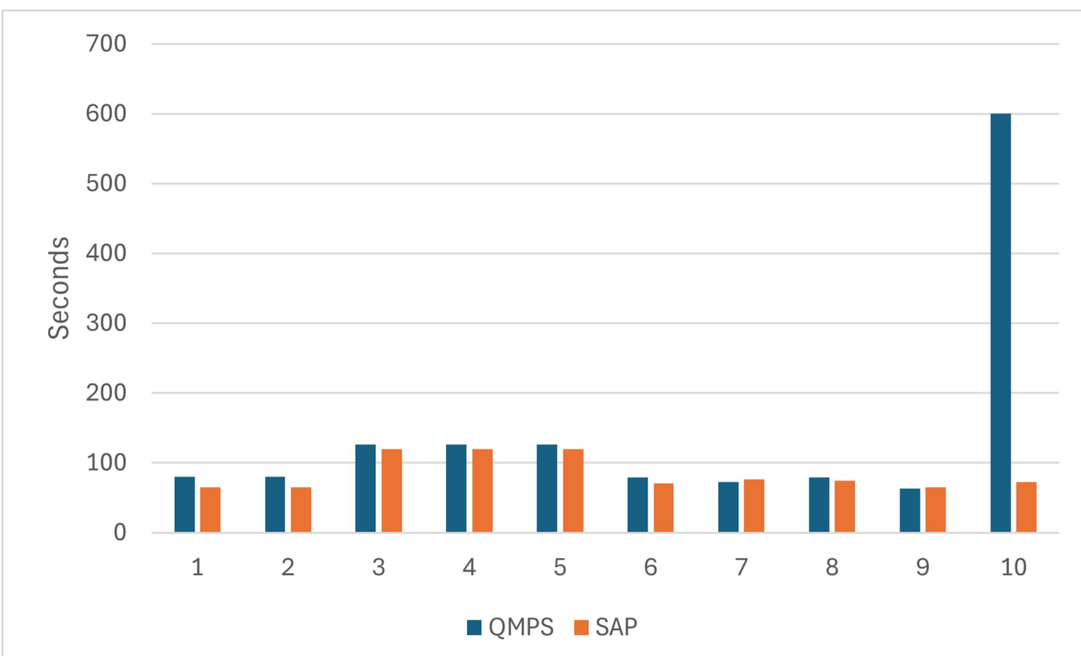


Figure 5.2: Cycle times for material families in D02

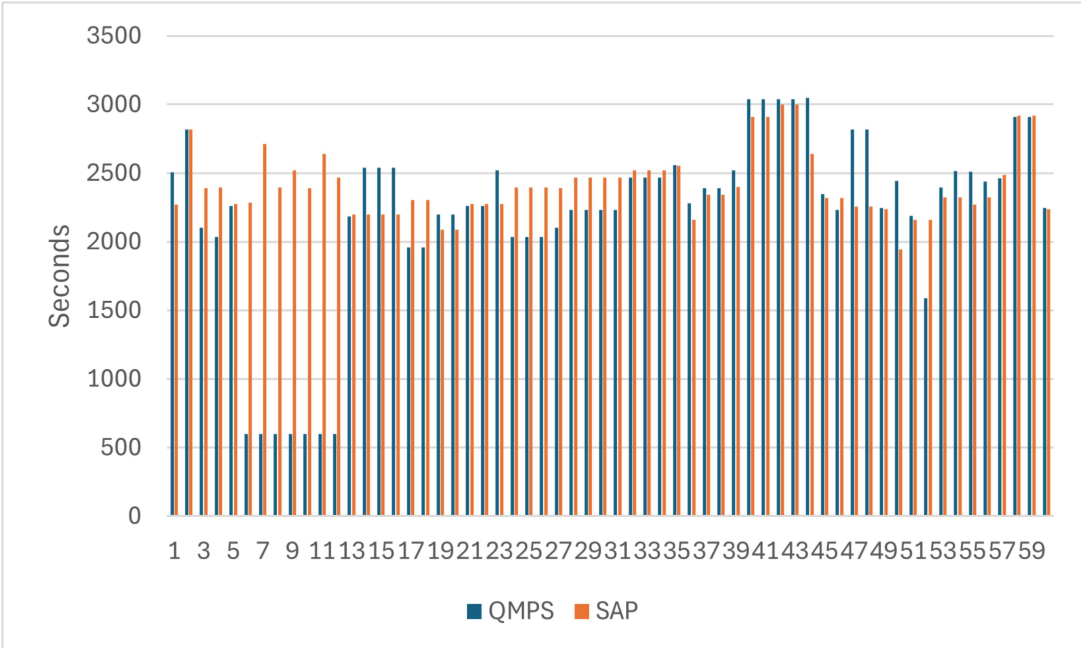


Figure 5.3: Cycle times for material families in E02

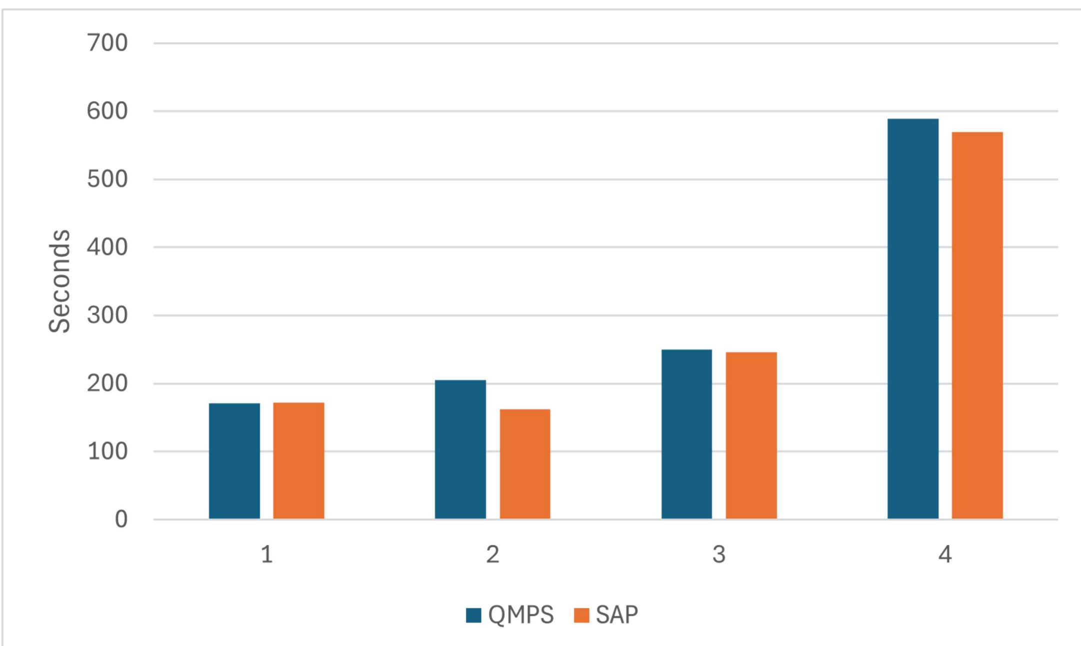


Figure 5.4: Cycle times for material families in E04

To support analysis of the results, the magnitude of the differences can be classified into three categories: minimal, noticeable, and large differences between the systems. These categories are defined using a ratio-based measure calculated by dividing the longer cycle time by the shorter cycle time and expressing it in percentage terms. Differences of less or equal than 5% are classified as minimal, differences between 5% and 20% as noticeable, and differences of 20% or more as large. These threshold values are not theoretically established but are introduced by the authors to facilitate interpretation and reasoning regarding the severity of the misalignment. The minimal category was the largest, accounting for 44% of the differences, followed by the noticeable and large categories at 35% and 21% respectively. Figure 5.1 illustrates that four material families within channel D01 have a cycle times in QMPS that are twice as long as those in SAP. Figure 5.2 shows that a material family within channel D02 has a cycle time that is 8.22 times longer in QMPS than in SAP. Figure 5.3 contains many examples from all categories, where the differences range from only one second to 2112 seconds. No consistent pattern indicating that cycle times in SAP were systematically higher or lower than those in QMPS could be identified. However, it could be observed that in all cases where the differences were extreme, it was the QMPS values that seemed unreasonable when compared with the other cycle times within the same channel. Since each channel produces roller bearings of similar size, relatively similar cycle times can be expected.

As each channel only has one running efficiency value, the misalignment rate is either 0% or 100%. Therefore, only the differences in percentage points were evaluated. These are presented in table 5.3. The result show that three out of four channels exhibit misalignment between QMPS and SAP in regard to their running efficiency. However, the magnitude is relatively small.

Table 5.3: Running efficiency difference between QMPS and SAP

	QMPS	**SAP**	**Difference (in percentage points)**
D01	66%	60%	6
D02	60%	58%	2
E02	64.5%	63%	1.5
E04	67%	67%	0

The identified inconsistencies in both cycle times and running efficiency indicate that the current way of working does not ensure synchronization between the two systems. It shows that the manual and communication-driven process between the responsible departments and Supply Chain not only increases the workload but also fails to ensure updated time data and efficiency measures in the systems.

The four running efficiency rates in QMPS were last updated on 1 January 2024, 1 February 2024, 1 October 2024, and 1 August 2025, which indicates that updates are performed infrequently and at irregular intervals. Based on interviews, a similar pattern can be expected for cycle times, with several cycle times appearing to be reviewed updated even less frequently. Despite being reviewed and updated infrequently, differences are still present. If updates were performed more frequently in line with SKF's SOPs, which recommends updates for cycle times at least once per year and preferably once every three months, it is reasonable to expect that differences would become even more common given the insufficient coordination. On the other hand, more frequent updates could allow noticeable and large differences to be detected sooner.

5.2.1 Effects of outdated data in QMPS

The lack of synchronization between SAP and QMPS indicates that SKF's SOPs are not being adhered to. If a change of time data and efficiency measure in SAP is not reflected in QMPS, the production planners end up making planning decisions on outdated data. The effects of outdated time data and efficiency measure in QMPS could have several effect on the production planning. If QMPS has cycle times that are significantly longer than the actual times, a running efficiency measure that is too low, or a resetting time that is too long, the planning system will assume that the production will require more time for the order than it truly will in practice. This means the orders will be completed earlier than planned. This might sound unproblematic, but does create operational issues. As Supply Chain has not planned the next order start until a later time, it might not be possible to start the subsequent order due to material shortages. This results in waiting time, reduced capacity utilization, and the need for rescheduling. If QMPS, on the other hand, has cycle times that are significantly shorter than the actual times, a running efficiency measure that is too high, or a resetting time that is too short, the planning system will assume that the production will require less time than it will in practice. As a result, the production will be delayed which leads to late deliveries and unsatisfied customers. Furthermore, higher inventory levels of input material may arise.

5.3 Alignment between SAP and DU

In the previous chapter, DU was presented as the current system for capturing actual cycle times and registering production disturbances. The system also contain stored planned cycle times, which are used to evaluate speed losses and are intended to correspond to the planned cycle times in SAP. Together with additional data, this information forms the basis for calculating different efficiency measures, such as running efficiency. It is relevant to analyze whether the data in DU correspond to the data in SAP and to assess the magnitude of any differences between them, as these differences can result in incorrect allocation of production costs among products. This became apparent during an interview, where it was stated that responsible departments usually do not follow the SOP regarding updating time data and efficiency measure in SAP, which impacts the reliability of the annual SC process. Furthermore, the process of updating DU following a change in SAP is performed manually, which introduces an additional risk of inconsistencies if SOP is not followed.

A misalignment analysis was conducted for these two systems as well. This analysis does not contain exactly the same number of observations as the one comparing SAP to QMPS since data were not available for all observations in DU. The misalignment rate for cycle times was calculated, and the result is shown in table 5.4. The result shows that there are differences between the systems for all four channels, and that the extent of the inconsistencies varies significantly.

Table 5.4: Misalignment rates for cycle times between DU and SAP

	N	**Misalignment rate**
D01	101	48.51%
D02	138	60.87%
E02	77	62.34%
E04	32	18.75%

To assess the magnitude of the differences between DU and SAP, bar charts were created using the same approach and thresholds as the previous analysis. This means that only observations where the two systems differed is included. The charts are presented in figure 5.5, 5.6, 5.7, and 5.8.

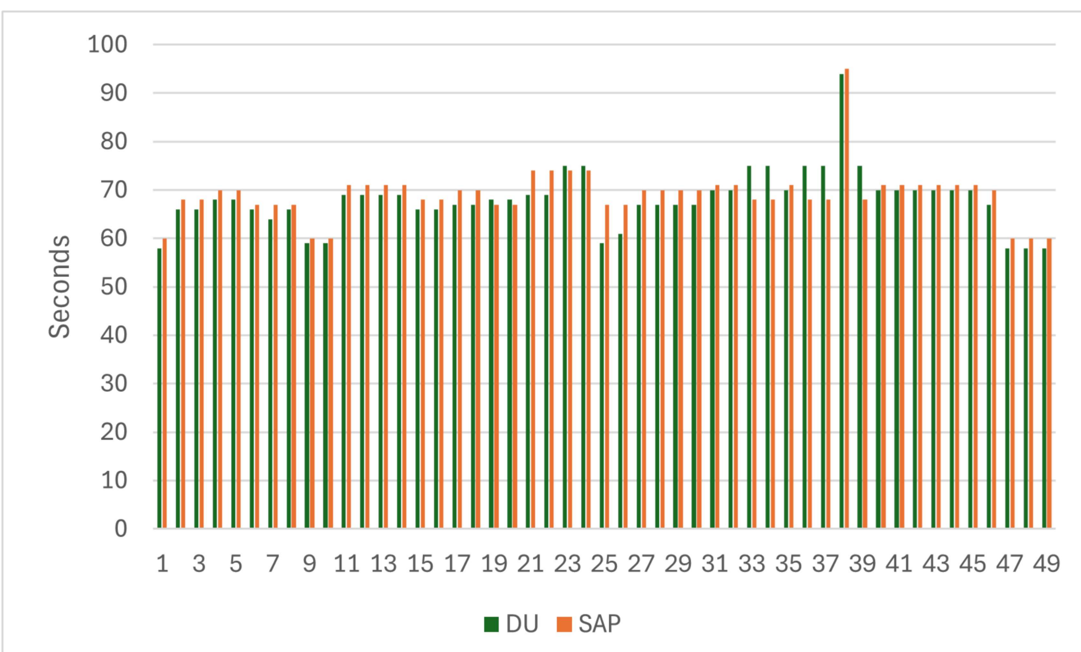


Figure 5.5: Cycle times for material families in D01

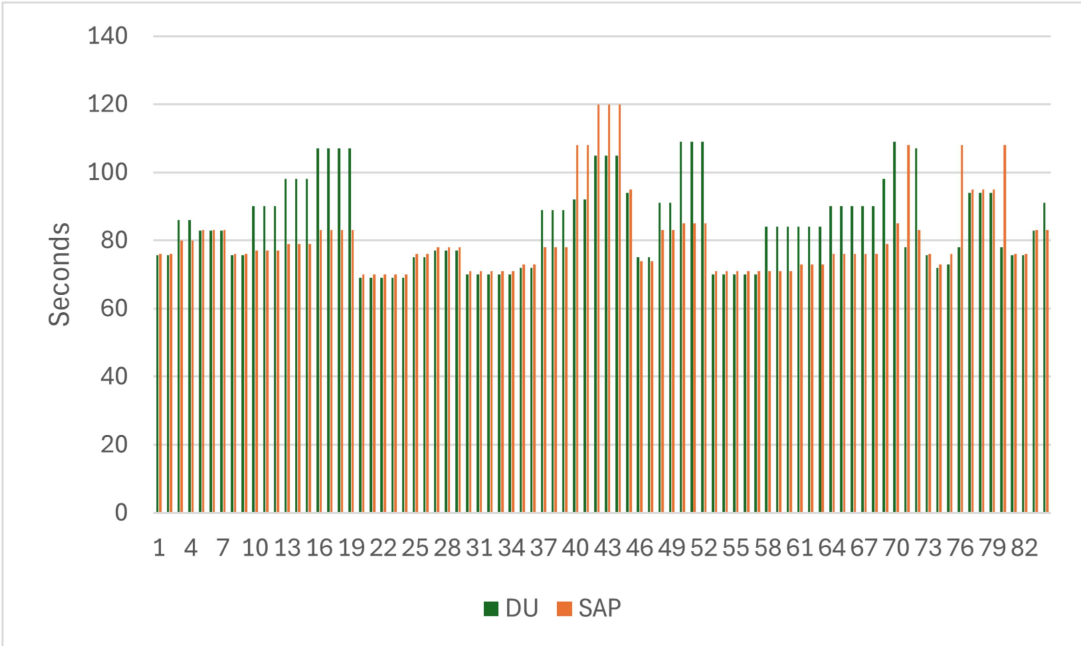


Figure 5.6: Cycle times for material families in D02

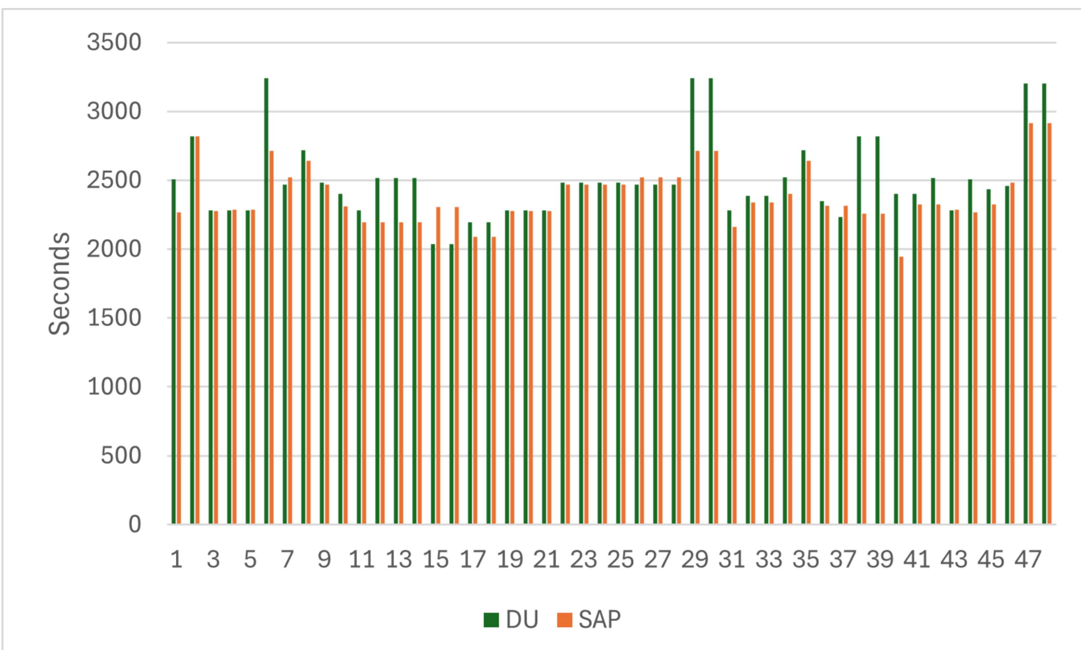


Figure 5.7: Cycle times for material families in E02

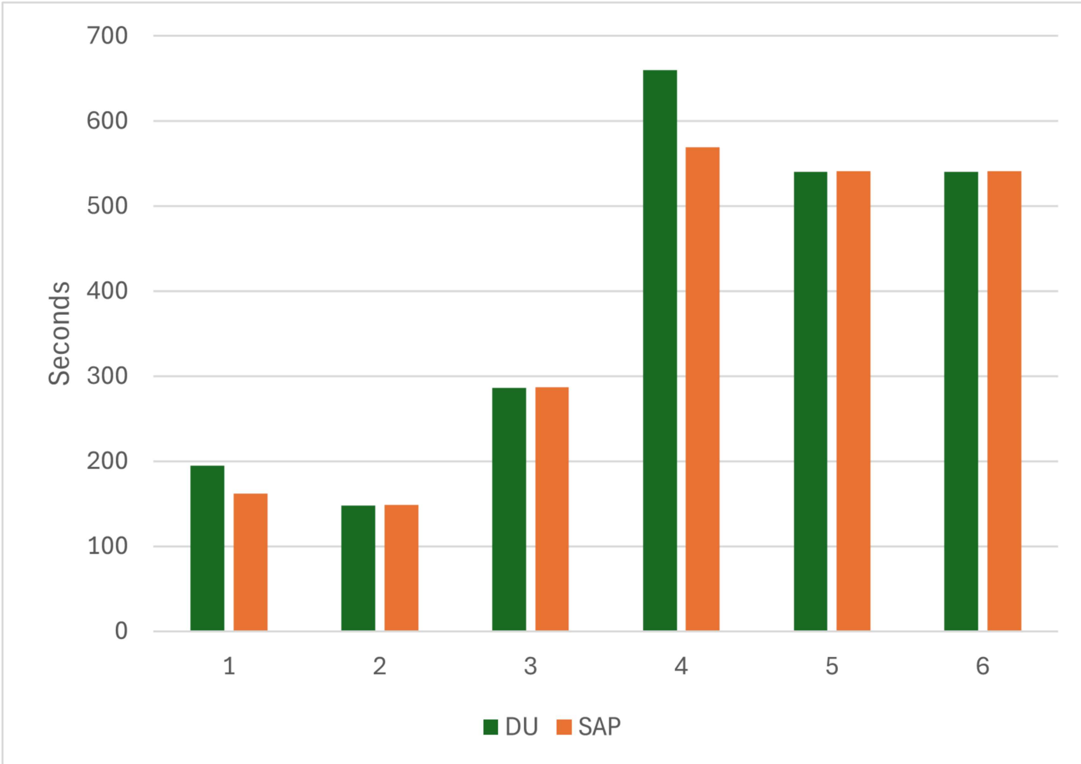


Figure 5.8: Cycle times for material families in E04

Analysis of the charts shows that the majority of the differences were minimal, accounting for 61%, while noticeable and large differences represented 28% and 11% respectively. The minimal differences showed no consistent pattern indicating that either SAP or DU was systemically higher or lower. For the noticeable and large differences in the channel E02, the cycle time in DU was observed to be consistently higher than the corresponding value in SAP. In contrast, for channel D02, which accounted for the largest amount of noticeable and large differences, no systematic pattern could be identified regarding which system reported the higher value.

Running efficiency is not a defined measure in DU. The only efficiency measure defined in DU is OEE. To obtain the running efficiency measure, the definition described in previous chapters was applied, where effective hours are divided by production hours. To get an accurate and current running efficiency value, effective and production hours are obtained from the Key Data Report (KDR), which is based on data from DU, for the entire year of 2025. Running efficiency values from DU and SAP are presented in table 5.5.

Table 5.5: Running efficiency difference between DU and SAP

	DU	SAP	Difference (in percentage points)
D01	63.3%	60%	3.3
D02	51.3%	58%	-6.7
E02	59.4%	63%	-3.6
E04	71.6%	67%	4.6

The results show that all four considered channels exhibit differences between SAP and DU regarding running efficiency. No consistent pattern can be identified indicating which system has higher or lower differences. The identified misalignment in both planned cycle times and running efficiency indicates that the systems are not fully synchronized.

5.3.1 Effects of misalignment between SAP and DU

Although the quality of the data in DU cannot be verified, it is assumed in this section to be representative of actual manufacturing conditions in order to assess the effects of misalignment between SAP and DU.

A SC calculation performed on time data and efficiency measure that is not aligned with DU, can lead to an inaccurate allocation of the production cost. If, for example, the cycle time and resetting time is too short and the running efficiency is too high in SAP, it will result in a SC that is very low. A low SC could lead to an increase in the sales of bearings, but has a negative effect on the margins. However, if the cycle and resetting time is too long and the running efficiency is too low in SAP, it will result in a SC that is very high. A high SC will increase the margins of the bearings, but the customer could perceive the price as too high and resulting in deceasing sales. Therefore, the effect of misalignment depends on both the direction and magnitude of the differences between SAP and DU. The examples above represent extreme cases, while actual outcomes may vary depending on the specific differences between SAP and DU. In some cases, differences in opposite direction may offset each other, resulting in a smaller overall impact. Such an example could be a cycle time that is too low combined with a running efficiency that is also too low.

To demonstrate the effect of the scenarios described, VA cost per piece, which constitutes a component of the overall SC calculation, is calculated using equation 4.6. The planned cycle times and running efficiency are obtained from both SAP and DU from the channel D02. For this demonstration, the VA rate is set to 120 EUR per hour and is based on an example from internal documentation provided by the controlling department. The VA cost per piece for of the three defined categories, minimal, noticeable, and large, all of which were selected randomly from the channel D02, is presented in table 5.6. Two percentages per category was used to reflect that cycle time and efficiency can vary independently and sometimes offset each other, resulting in different impacts for similar cycle time difference ratios.

Table 5.6: VA cost per piece for three categories

	Minimal		**Noticeable**		**Large**	
Random observation	#1	#2	#1	#2	#1	#2
Difference ratio	1.33%	1.35%	14.29%	14.1%	38.46%	28.92%
SAP	262	255	414	269	372	286
DU	292	292	409	347	304	417
Difference	**-30 €**	**-37 €**	**5 €**	**-78 €**	**68 €**	**-131 €**

The result shows that five of the six VA cost per piece has a significant difference between the systems. The largest observed difference in VA cost per piece was that the one based on DU was 45.8% larger than SAP, while the smallest difference between the systems was 1.2%. The sample size of six VA cost per piece out of 84 mismatches in D02 is too small to indicate a pattern on which system has the smaller or larger value.

Although this may not initially appear to be a major issue, the large production volumes at SKF imply that an inaccurate VA cost per piece may not reflect actual manufacturing conditions. This can lead to significant financial consequences, such as lower margins, loss on sold bearings, or reduced sales volumes. To show this, the VA cost per piece has been multiplied by the 2025 production volume for the corresponding material families, and the results are presented in Table 5.7.

Table 5.7: Financial consequence by VA cost per piece

	Minimal		**Noticeable**		**Large**	
Random observation	#1	#2	#1	#2	#1	#2
Difference	-30 €	-37 €	5 €	-78 €	68 €	-131 €
Volume 2025	10434	3424	2236	4650	7966	8054
Financial consequence	-313 020 €	-126 688 €	11 180 €	-362 700 €	541 688 €	-1 055 074 €

5.4 Alignment between SAP, QMPS, and DU

This section presents a combined analysis of all three systems: SAP, QMPS, and DU. While the previous sections analyzed the systems pairwise, a combined analysis provides a more comprehensive understanding and picture of the overall data consistency and allows for the investigation of whether discrepancies occur across all systems, as well as the identification of any patterns. All three systems should contain time data and efficiency measures that are consistent. However, based on the previous findings and identified shortcomings in adherence to SOPs, misalignment is expected.

To determine whether any differences exist between the three systems in regards to cycle times, bar charts comparing cycle times for material families in SAP, QMPS, and SAP were created. These bar charts are shown in figure 5.9, 5.10, 5.11, and 5.12. An analysis of the charts showed that the system alignment of cycle times for channel E04 were consistent across all three systems, apart from a small number of identified differences. In contrast, the three remaining channels show considerably larger differences in the alignment of cycle times. The figures also showed that there is no apparent pattern regarding which system differs from the others. In some cases, none of the systems are aligned.

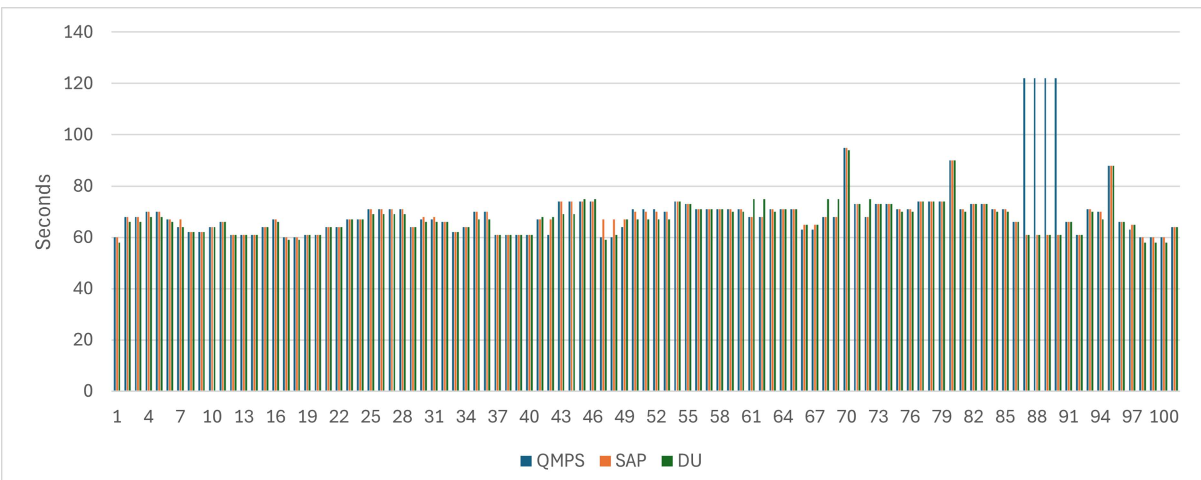


Figure 5.9: Cycle times for material families in D01

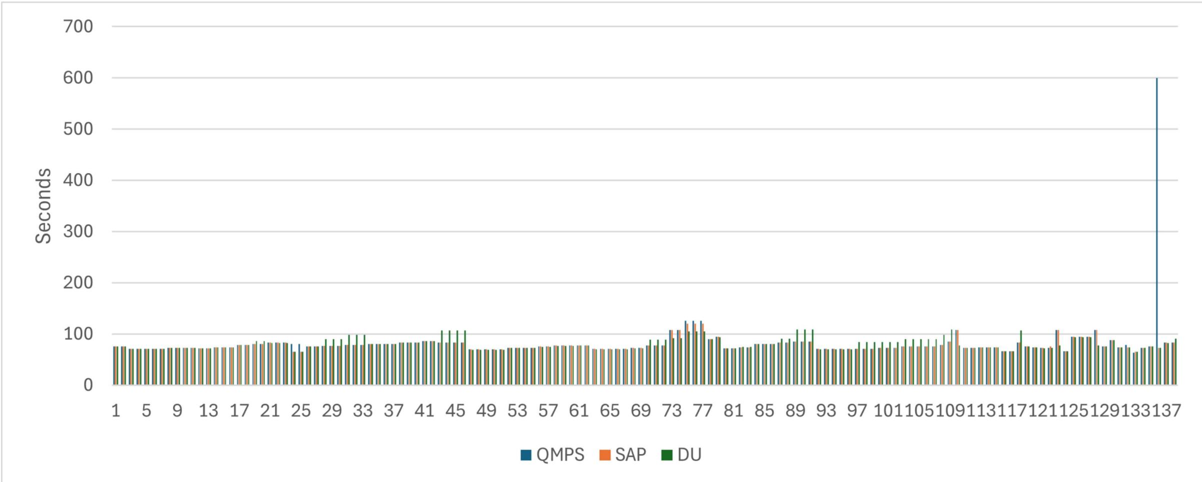


Figure 5.10: Cycle times for material families in D02

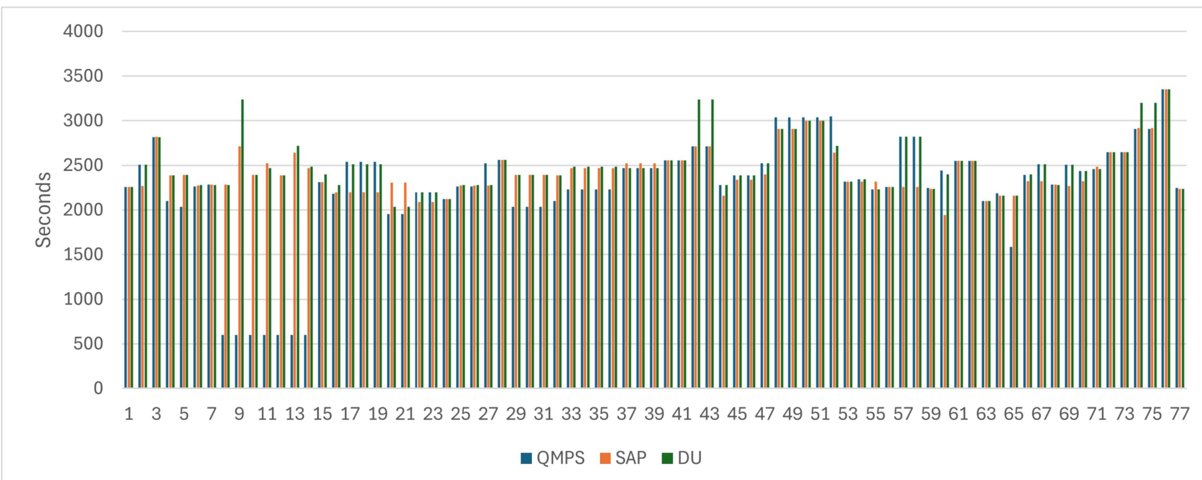


Figure 5.11: Cycle times for material families in E02

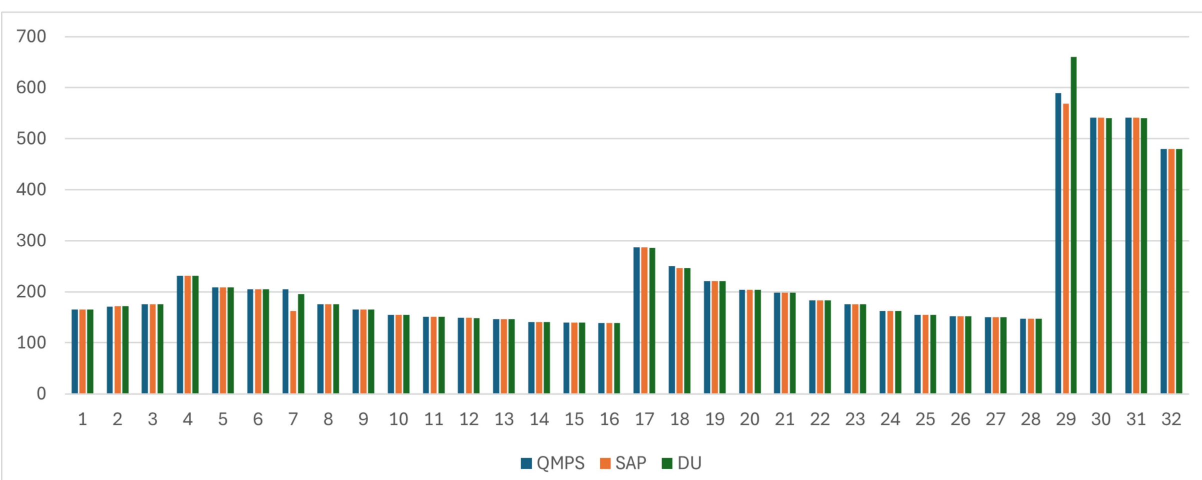


Figure 5.12: Cycle times for material families in E04

The running efficiency values for the three systems is presented in table 5.8. As the table shows, running efficiency is also not aligned across the systems. Only in one instance, for the channel E04, the efficiency value is aligned for two out of the three systems.

Table 5.8: Running efficiency misalignment between QMPS, SAP and DU

	QMPS	**SAP**	**DU**
D01	66%	60%	63.3%
D02	60%	58%	51.3%
E02	64.5%	63%	59.4%
E04	67%	67%	71.6%

Taken together, the results confirm that misalignment is not limited to specific system pairs, but reflects a broader lack of consistency in the data environment. The absence of a clear pattern regarding which system deviates suggests that inconsistencies are not caused by a single type of error but rather weaknesses in the current way of working across multiple aspects. This highlights the relevance of designing a revised SOP supporting reliable TDM.

6

Future state

The analysis of existing SOPs in relation to the current state revealed several fundamental shortcomings related to TDM. These shortcomings form the basis for the proposed future state, which aims to address mismatches, misalignment between systems, unclear definitions and terminology, unreliable determination of time data, and a lack of clearly defined responsibility. This chapter proposes a revised SKF SOP, along with a step-by-step implementation process to ensure that the identified shortcomings are addressed and that new issues related to TDM are not introduced.

6.1 Future state systems and databases

This section presents the new systems and databases required to enable and support the proposed future state. SAP and QMPS, as described in SKF's SOP, remain part of the future state.

Factbird

As mentioned in chapter 1, SKF is currently implementing a MIS across its three TVO's in Gothenburg, replacing the current disturbance reporting and performance evaluation system, DU. The new MIS, Factbird, provides real-time visibility and data-driven insights into production, supporting fast and informed decisions. This is achieved by collecting and integrating data from sensor counters and connected PLCs in the production, allowing data from the production to be visualized digitally. In DU, operators manually report disturbances by entering both the type of stop and the duration of the stop. As many disturbances often end up being registered at the end of the shift, the information often becomes highly dependent on memory and poses a risk of data inaccuracy. The new MIS also requires operators to classify the disturbance type, but the duration of each stop is automatically recorded which reduces the reliance on memory and eliminates the estimation of the stop length. When classifying the stops, the operators select from a set of predetermined stop categories in a user-friendly operator interface that reduces the required effort to report, which helps ensure that stop classifications are performed accurately. As a result, Factbird is expected to provide a more reliable basis for efficiency measures and improvements thanks to the improved accuracy and traceability of disturbance data, as mentioned in chapter 1. In addition, Factbird captures operational data in real time and is therefore able to record other production metrics, including actual cycle and resetting times for all variants in the different production cells and channels. A crucial prerequisite for the validity of the efficiency measures is that the operators manually start new batches in time. This ensures that the measured actual cycle times are compared against the correct planned time, allowing for accurate quantification of speed losses, which is a part of the efficiency calculations. The future state chapter assumes that Factbird is fully implemented and operational across all channels in all three TVOs in Gothenburg.

IT/OT database

As part of the implementation of Factbird, a new database, which we hereafter refer to as IT/OT database, was created. The purpose of the IT/OT database is to store the correct and most up to date values for planned cycle times. This approach allows data to be updated and managed without directly affecting SAP, which could have consequences for other parts of the organization, such as Controlling and Supply Chain. A new database was created as Factbird is not designed to function as a master database, and SKF do not want to use it for that purpose.

6.2 Proposed design of time data and efficiency measures

This section presents a new approach to the determination and definition of time data and efficiency measures, as well as the assignment of accountability and responsibility, aiming to address the previously identified shortcomings.

6.2.1 Cycle time

Determination

As previously mentioned, Factbird records several production metrics for each material family batch, including cycle time for each produced unit, stops, and scrap and rework. Factbird therefore enables a straightforward comparison between planned cycle times and actual cycle times captured from production. This can be used to identify which cycle times in the IT/OT database are correctly determined, and consequently, which ones require re-evaluation. The comparison between planned and actual times can be performed by using Factbird's metric "machine cycle time while running". This measure filters out all disturbances and interruptions, such as micro stops, longer stops, and resets from the total actual cycle time in Factbird. This makes it possible to obtain cycle time for when the process is operating under steady-state conditions, and thereby allowing actual and planned cycle times to be easily compared. If there is a deviation, it is most definitely caused by a process change or that the initial planned cycle time was wrongly determined. It therefore needs to be re-determined.

The study mainly proposes two different time determination methods to be used at SKF. One of the methods is based on calculation, while the other method utilizes Factbird as a supporting tool. The choice of time data determination method depends on two factors: the available time and the required accuracy.

The first method is based on the machine speed specified by the equipment supplier, combined with additional automated handling times, such as robot motions. This approach results in a planned machining time derived from the nominal machine speed, while automated handling times account for activities such as loading and unloading of the product. In addition, recurring activities, such as tool dressing, are incorporated into the planned cycle time based on their known frequency and duration. These elements are simulated in a Computer-aided Manufacturing software, which results in a planned cycle time of the bottleneck machine. This method is feasible because the behavior of machines and robots is largely deterministic under stable operating conditions.

The other method uses the recorded metric "machine cycle time while running", to determine planned cycle times. For the data to be reliable, production should be observed and it should be verified that the process is operating as designed before setting the planned time. If, for example, machine parameters have been changed, these should be reset to their intended settings and the comparison should be performed again to assess whether the deviation remains. The recorded metric under these verified conditions can then be used as the new planned cycle time.

It is also worth mentioning a third method, which is the quickest and easiest, but also the least reliable. This method should be avoided, but could be used if the analysis shows a abnormally large deviation which requires a quick temporary fix of the planned cycle time. The method also involves using the metric "machine cycle time while running" to directly update the planned cycle time, without observing the production process. Although this approach may help reduce large deviations until an alternative method can be performed, it involves a large risk of embedding losses into the planned cycle time, thereby creating a mismatch. For example, the production may be operating at reduced speed on purpose which could result in an excessively long planned cycle time.

Definition
If the first method is selected as the determination method, it is essential to ensure that all three components are included in the planned time. Otherwise, the planned time will not meet SKF's required definition. The second and third methods will automatically apply the correct definition, as Factbird does not classify loading, unloading, or dressing as disturbances. Consequently, these activities are included in both the actual and planned cycle times.

Responsibility
To clarify ownership beyond responsibility, accountability from the RACI framework, described in the Frame of Reference chapter, is introduced in the future state. The study suggests that production managers should be accountable for the cycle times. Manufacturing Reliability will be responsible department for analyzing differences between planned and actual cycle times, determining the appropriate time data determination method, and updating the newly established planned times in the IT/OT database and subsequently in SAP

6.2.2 Efficiency

Determination
As mentioned earlier in this chapter, no manual determination of efficiency measures is required, as Factbird captures these automatically. However, as previously noted, accurate planned cycle times remain a prerequisite, as incorrect speed losses are obtained otherwise.

Currently, only OEE is measured automatically in Factbird. This study suggests that running efficiency should be measured automatically as well. Having automated measurement would eliminate the need for manual calculations by those responsible for updating efficiency in the planning system, thereby reducing the workload and the risk of human errors, and supporting a more data-driven approach.

Defintion
The study suggests that the term "efficiency" be replaced with "running efficiency" in the ERP and planning systems to avoid unnecessary confusion between the different efficiency definitions. This change reduces the risk of entering OEE values instead of running efficiency in the ERP system which was shown to be an issue in the current state, potentially due to the use of the term "efficiency". OEE and running efficiency should also be clearly differentiated in Factbird and the IT/OT database to reduce the risk of confusing them.

Responsibility
The study suggest that the production manager should be accountable for the efficiency measure. Manufacturing reliability will be the responsible department for performing the updates in the IT/OT database with the correct efficiency measures.

6.2.3 Resetting time

Determination
The resetting time in SKF's databases and systems was found to most likely represent actual times rather than planned times. However, forthcoming improvement suggestions require planned times as a basis. Therefore, planned resetting times for all material families must be defined using an appropriate time determination method. Given the large number of material families at SKF, the method must be sufficiently time efficient to ensure it will be applied to all material families. However, as it forms the basis for production planning and the SC process, a sufficiently high level of accuracy is required. This highlights a trade-off between cost and accuracy.

In the frame of reference chapter, Almström (2024) mentions three options for determining planned times: comparison and estimation, predetermined time systems such as MTM-1 and SAM analysis, and calculation and simulation. Comparison and estimation is a time efficient method but often results in approximate times with limited accuracy. Furthermore, it is influenced by factors such as the operator's relationship to the manager and the company (Almström, 2024). Calculation and simulation require dedicated models or software, which involves both a time and financial investment. The predetermined time system MTM-1 has high precision but has the downside of being time consuming to learn and apply. However, SAM analysis offers a more appropriate trade-off between time efficiency and accuracy among the evaluated alternatives and has therefore been selected as the method for determining planned resetting times in this study. For channels where resetting is performed automatically, which currently applies to only one channel, the planned time was already available, meaning that this step does was not required.

In the future, emerging approaches for the automated creation of MTM analyses could potentially be used for this purpose instead. As mentioned in the frame of reference chapter, examples of such methods include artificial intelligence- and virtual reality-based approaches developed by Borsdorf et al. (2022) and Benter et al. (2026). These methods have the potential to reduce analysis effort and limit the need for expert knowledge, while providing sufficiently accurate time data as the technologies continue to develop.

Once planned resetting times are available, continuous analysis between planned and actual cycle times can be carried out. Factbird enables analysis of planned and actual resetting times, allowing large deviations where actual times differ significantly to be identified and investigated. As part of the investigation, the next identical reset should be observed or the operator that performed the reset be consulted. This to determine whether the deviation is caused by random variation or a process change. If the deviation is due to random variation, no action is required, whereas a process change necessitates the determination of a new planned time. SAM analysis will continue to serve as the time data determination method.

Definition

As previously mentioned in the current state chapter, three different definitions of resetting time have been identified. To avoid having the planned resetting times defined with different definitions, the responsible departments must be instructed that all SAM analyzes have to be performed using the definition by Zandin (2001), which is presented in the frame of reference. The correct definition is crucial since SAP and QMPS require this definition to perform accurate production planning and SC process. This is also the definition used for actual resetting times in Factbird, and it is therefore required to ensure that the analysis between planned and actual times is performed correctly. This study suggests that these three different definitions should be distinguished using different terminology. This reduces the risk that an incorrect definition is applied, which in turn helps ensure consistency and accuracy.

Responsibility

The study suggest that the production manager should be accountable for the resetting times. Manufacturing Reliability will be responsible department for analyzing differences between planned and actual resetting times, performing the SAM analyses and updating the newly established planned times in the IT/OT database and subsequently in SAP.

6.3 Further improvements in the future state

Building on the identified shortcomings, this section presents additional improvements that become feasible through the introduction of the MIS and IT/OT database.

Resetting efficiency

In the current state, SKF's systems and databases contain a single resetting time intended to reflect the actual resetting time. This differs from how cycle times are represented in the same system, where a planned cycle time is adjusted using a running efficiency factor to reflect the actual cycle time. Having accurate planned times and representative actual times available would enable the implementation of a resetting efficiency measure.

The study suggests that resetting efficiency be displayed in Factbird alongside OEE and running efficiency, enabling visualization of resetting efficiency over different time periods. This would also allow each channel to have its own resetting efficiency. In the frame of reference, Almström (2024) discusses performance rating, which serves as the basis for resetting efficiency. The equation used to calculate the resetting efficiency is presented in equation 6.1.

$$\text{Resetting efficiency} = \frac{\text{Planned Resetting Time per time period}}{\text{Actual Resetting Time per time period}} \tag{6.1}$$

Implementing a resetting efficiency serves two main purposes. First, the resetting efficiency obtained from Factbird can easily be updated in systems and databases to improve the accuracy and reliability of production planning and SC processes. The resetting efficiency obtained from Factbird is a more data-driven approach for updating the resetting time to reflect actual conditions, rather than just updating it based on estimation. Second, resetting efficiency provides a clear indicator of whether the performance of the resets has improved or worsened.

Resetting visibility

Although all resets, except for one channel, are carried out manually by an operator, the planned or target resetting time is generally not known to them. Because of this, the study proposes that Factbird incorporate a display in the operator view showing either the remaining planned reset time or the additional time spent on resetting. This can be implemented using a countdown, a progress bar, or a similar visual indicator, provided it clearly shows the process and whether it is ahead of or behind the planned time standard. In line with lean visual control principles presented by Liker (2003), this provides the operators with immediate visual feedback and a clear benchmark during resetting, helping to ensure proper execution and reduce variation in actual resetting times.

IT/OT database

The study suggests that the IT/OT database should store more than just planned cycle times and should also store planned resetting time, running efficiency, OEE, and resetting efficiency. This collects all data in a single database instead of spreading it across multiple databases and systems. This reduces the need to search for data across multiple systems and databases, thereby saving time. The IT/OT database also serves as a buffer where all time data and efficiency measures can be updated without impacting production planning or the SC process.

6.4 Management of time data and efficiency measures

In the frame of reference chapter, Almström (2024) describes a method that companies can use in order to minimize the mismatch between planned and actual times and maintain the quality of time standards over time. This can be achieved by working with constant analyzes and continuous improvements. How this method will be applied to SKF's systems is illustrated in figure 6.1 and described in this section. In practice, additional systems are involved, such as interactions between Factbird and SAP through a complex system architecture. However, these elements are beyond the scope of this study and are not included in the figure to maintain clarity and emphasize the key aspects.

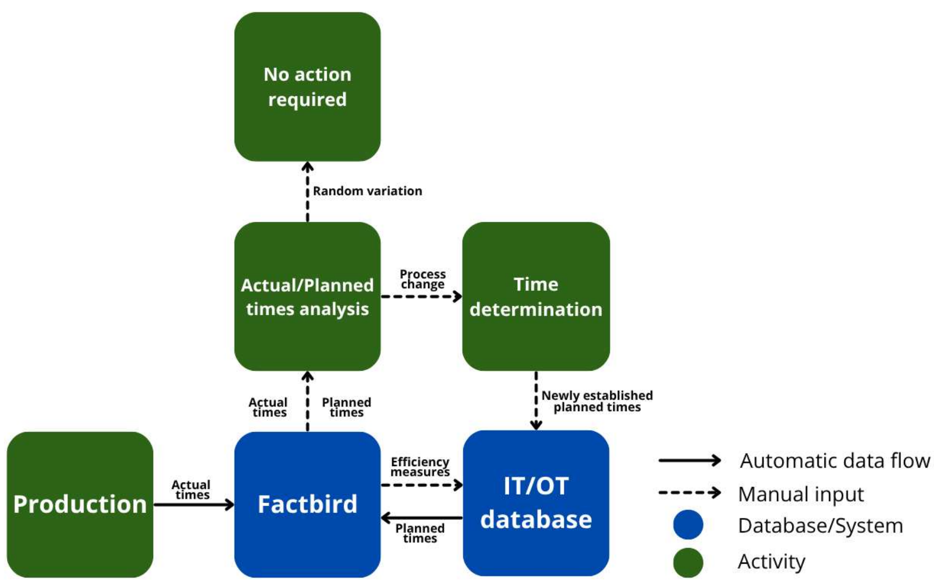


Figure 6.1: Data flows connecting systems and activities

The constant analyzes compares the recorded metric "machine cycle time while running" with the planned times. Factbird will be used for the constant analyzes, as it it receives both actual times from the production and planned times from the newly established IT/OT database. As shown in figure 6.1, Factbird receives information through an automatic data flows from both production and the IT/OT database. Production data into Factbird is updated in real time, while data from the IT/OT database is imported into Factbird at the start of each new batch. This gives an first indication if there is a difference between the planned and actual times that have to be further investigated. If further investigation into the mismatch is required, the following question should be addressed: 'Is the difference between actual and planned time due to a process change or random variation?'. If the answer is random variation, no action is required. However, if the answer is process change, a appropriate action should be taken. As shown in figure 6.1, the latter response implies that a new planned time must be established using an appropriate time data determination method. The process of continuously analyzing and determining appropriate time data differs depending on whether the time relates to a cycle or a resetting, as described in section 6.2. The analysis should be performed continuously, but at least annually and prior to the SC process, to ensure it is based on correct time data and efficiency measures. This is supported by Almström (2024) who states that a revision once a year is a reasonable compromise between precision and cost. The figure also shows that the new planned time have to be manually updated in the IT/OT database, which is done by the department responsible for determining it. This should be done simultaneously as a new planned time is established.

The IT/OT database also consists of OEE, running efficiency, and resetting efficiency. As shown in figure 6.1, these measures will be received from Factbird and updated manually into the IT/OT database, which is performed by the department responsible for efficiency. The efficiency measures in the IT/OT database should be updated annually, prior to the SC process, using measurements from the previous year. This ensures that the time frame is long enough to remove the impact of large stops, for example weeks of material shortage.

The previous chapter demonstrated that the systems and databases are not aligned. Figure 6.2 illustrates how these systems and databases will be connected to ensure alignment. SAP will be updated with planned cycle times, planned resetting times, running efficiency, and resetting efficiency from the IT/OT database. Since the measures stored in SAP directly affects both SC and Supply Chain's planning parameters, SKF requires that updates are performed manually by a responsible with SAP authorization. This manual approach ensures that data is entered in the correct format, aligned with the time data and efficiency measure structured in SAP, and validated before being released. SAP should be updated simultaneously as the IT/OT database, which means annually and prior to the SC process. SAP and QMPS will have an automatic data flow between them, which means that as soon as SAP is updated these changes will be updated in QMPS.

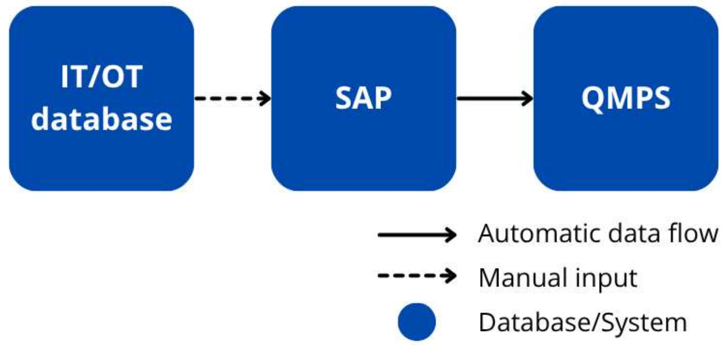


Figure 6.2: Data flows connecting systems

The proposed data flows connecting systems and activities, presented in figure 6.1 and 6.2, are not currently implemented at SKF and will need to be realized through a gradual implementation process. The study proposes a step-by-step list outlining the process required for successful implementation. Once implemented, updating and performing the activities should follow the proposed frequencies outlined in this section.

- Analyze all of the planned cycle and resetting times to minimize the mismatch of the data stored in the new IT/OT database.
- Update the IT/OT database with OEE, running efficiency, and resetting efficiency.
- Update SAP with data from the IT/OT database, subsequently automatically updating QMPS.
- Continuously repeat the step-by-step list to maintain the quality of time standards over time.

7

Discussion

The purpose of this thesis was to investigate how SOPs at SKF can be designed to support reliable TDM. The analysis of existing SOPs in relation to the current state revealed challenges related to time data and efficiency measures definitions, determination, alignment of data across systems, and responsibility and accountability. Based on these findings, the thesis proposes an updated SOP that establishes revised definitions, determinations, clarifies accountability and responsibility, and introduces a more standardized way of working. This chapter discusses these findings in relation to the research questions and relevant literature.

7.1 Research question 1 and 2

The first and second research questions examine how SKF's SOPs are currently designed and adhered to, and what effects this has on reliable TDM. The questions are addressed within the same subsection, as these aspects are closely interrelated.

A comparison between the SOP and actual work practices revealed that, although a formal SOP exists, it is not consistently followed in practice. The findings from the current state presented in Chapter 5 indicate that interview responses varied across respondents and that, when the SOP was not followed, the process carried out instead could differ significantly. Several factors contributing to this lack of adherence were identified, including limited awareness of the SOP, time constraints, insufficient expertise, unclear accountability and responsibility, and the acceptance of practices such as comparison and estimation. As a result, procedures are often bypassed in favor of faster, experience based approaches. This indicates that the SOPs does not function as a standardized way of working but rather as reference documents applied inconsistently across the organization.

Kuhlang et al. (2014) defines TDM as the determination, usage, and administration of time standards. The findings from this study indicate that the shortcomings related to both the SOP design and adherence to it negatively affect all three of these aspects of TDM.

The lack of adherence is particularly evident in the determination of planned times. The current state analysis indicates that comparison and estimation are the most commonly used methods for determining planned times. According to Almström (2024), these methods often result in time data being approximate and lacking accuracy. Their acceptance as "good enough" reflects a practical trade off between efficiency and accuracy, where minimizing workload and maintaining operational processes are prioritized over establishing reliable time standards. While this approach may reduce workload in the short term, it weakens the reliability and consistency of time standards determination. The findings also suggest that the determination process is dependent on individual experience and knowledge rather than standardized procedures. This creates a risk within the organization, as the quality of time standards becomes dependent on specific individuals rather than on a consistent organizational process. Such dependence reduces both repeatability and reliability within TDM.

Beyond affecting the determination of time standards, the lack of adherence also influences how time data is administered and maintained. The absence of clearly defined accountability within SKF's SOP, combined with the inconsistent adherence to formally designated responsibilities in practice, contributes to the misalignment identified in the current state. This became particularly evident during the interviews, where conflicting perceptions regarding ownership and responsibility for time data were observed across departments. The quantitative analysis on mismatch further strengthens these findings. It showed that the channel that was least aligned exhibited a misalignment rate of 77.92% between SAP and QMPS. These results demonstrate that the current organizational structure and associated work practices are insufficient for maintaining synchronized and reliable time data across systems and databases. Since updates are dependent on manual communication and coordination between departments, the process becomes vulnerable to delays, misunderstandings, and inconsistent execution. As a result, the administration and maintenance of time standards are not conducted in a structured or systematic manner.

These issues align with the theory presented in chapter 2, which identifies that there are three principal causes contributing to mismatches between actual times at the shop floor and the planned times stored in databases and systems (Almström & Winroth, 2010). These causes are operation times being defined incorrectly from the beginning, additional allowance times to handle disturbances becoming permanent and accumulating over time, and operation times being rarely updated. The findings from this study indicate that two out of the three causes are present at SKF. Planned times are frequently determined using comparison and estimation based methods and updates are performed sporadically rather than continuously. The identified mismatches have significant operational implications. If the planned times stored in systems do not reflect actual production conditions, the reliability of production planning and SC calculations is reduced. The quantitative analysis demonstrated that discrepancies between systems could result in substantial deviations in value-added cost calculations, which indicates that unreliable time standards not only affect production planning but also financial decision-making. Consequently, the usage of time standards throughout the organization becomes less reliable.

Overall, the findings indicate that shortcomings in both the design of the SOP and its lack of adherence at SKF contribute to unreliable TDM. Inconsistent procedures, unclear accountability and responsibility, insufficient synchronization between systems, and reliance on comparison and estimation practices reduce the accuracy, consistency, and traceability of time standards throughout the organization. As a result, the reliability of production planning and cost calculations is negatively affected.

7.2 Research question 3

The last research question examines how SKF should design their SOPs to better support reliable TDM. The findings indicate that full adherence to the current SOPs alone may not be sufficient to ensure reliable TDM. This suggests that the existing SOP cannot fully support reliable TDM, highlighting the need for a revised approach. Consequently, the identified shortcomings in both the SOP design and the current state define the areas that need to be addressed when designing a future state.

The proposed future state was therefore developed to address these identified shortcomings by introducing more accurate determination methods, improved definitions of time standards, and routines for continuous updating and synchronization of data between systems. Many of these improvements are enabled by the MIS, which supports multiple determination methods, facilitates continuous comparison between planned and actual times, and improves synchronization across systems and databases. Compared to the current state, where updates are largely dependent on manual communication and coordination between departments, the future state introduces a more systematic and data-driven approach to TDM. Consequently, the proposed future state is expected to significantly reduce the mismatches and inconsistencies identified in the current state analysis.

However, although these technical improvements address several shortcomings, the findings also indicate that technological solutions alone are insufficient to ensure reliable TDM. One of the most significant issues identified in the current state was that no department had clear accountability for TDM. Interview responses demonstrated conflicting perceptions regarding ownership and responsibility for time standards, which contributed to inconsistent updating and maintenance of time data across systems. This implies that the MIS alone cannot eliminate mismatches and inconsistencies if the identified organizational shortcomings remain unresolved. This aligns with Hedman and Almström (2017), who argue that achieving high-quality time data requires more than technological solutions and emphasizes the importance of a well-structured TDM organization.

To address these organizational shortcomings, the proposed future state establishes clearer accountability and responsibility regarding the determination, definition and continuous updating of time standards. Responsibility for performing activities is assigned to a specific departments, while accountability is assigned to another department which focuses on monitoring and ensuring that these activities are carried out. This structure is inspired by the RACI responsibility assignment framework and aims to reduce vagueness regarding accountability and responsibility of time data. Consequently, if the responsible department fails to perform the required activities, the accountable department is expected to follow up and ensure adherence to the SOP. Compared to the current state, where responsibilities were inconsistently interpreted and followed, the proposed structure creates a more systematic and continuously maintained TDM. This aligns with Imran et al. (2021), who argue that successful digital transformation requires not only technological implementation, but also organizational structures that support clear responsibilities, communication, and decision-making.

The proposed future state therefore demonstrates that reliable TDM is not solely dependent on technological solutions, but also on organizational structures, clearly defined accountability and responsibilities, and continuous procedural adherence. Although the MIS enables improved data collection, synchronization, and analysis, the findings from the current state indicate that organizational practices and operational priorities strongly influence whether SOPs are consistently followed in practice. Consequently, the successful implementation of the future state depends not only on the introduction of new technological solutions, but also on organizational acceptance, and continuous adherence across departments. Without sufficient organizational support, there is a risk that informal and experience-based practices similar to those identified in the current state will continue despite the introduction of improved systems and procedures.

Overall, the proposed future state addresses the major shortcomings identified in both the existing SOP and the current operational practices by introducing clearer ownership, more reliable determination methods, improved synchronization between systems, and continuous updating of time standards. Together, these changes create improved conditions for reliable TDM and are expected to reduce the mismatches and inconsistencies identified in the current state. However, since the implementation of the future state was outside the scope of this study, it is not possible to empirically verify whether the proposed changes will fully eliminate these issues in practice. Consequently, although the future state is grounded in relevant theory and designed to address the identified shortcomings, the practical effectiveness of the proposed changes remains dependent on successful organizational implementation and continuous adherence to the revised procedures.

7.3 Reflection on methodological approach

The case study approach enabled an in-depth understanding of TDM within SKF in Gothenburg, capturing the complexity of interactions between systems, departments, and SOPs. However, this depth comes at the expense of transferability. As the study focuses on a specific part of the organization and its production environment, the findings may not be directly transferable to other parts of SKF or to other companies. Variations in organizational structures and production environments further limit the applicability of the results. Nevertheless, due to shared processes, systems, and organizational practices within SKF globally, the findings may be more applicable across SKF than to other companies. Consequently, while the findings may be relevant to contexts with similar characteristics, they should be interpreted with caution when applied to other settings.

SKF's SOPs are based on internal documents. However, as time constraints limited the scope of document analysis, not all potentially relevant documents could be reviewed. This creates a risk that additional document analysis could yield findings that differ from those presented in this study. Despite this limitation, a substantial number of internal documents were reviewed, and the findings were largely consistent across them. This suggests that additional data collection would likely yield similar patterns, although this cannot be guaranteed. The reliance on interviews introduces potential bias, as interviewees may present their work in a more structured or favorable manner than it occurs in practice, or their responses may be influenced by their roles and experience. Although efforts were made to mitigate this through the use of 19 semi-structured interviews and cross-validation with quantitative data, the risk of bias cannot be entirely eliminated. The qualitative analysis, based on the Gioia methodology, involves interpretation by the researchers. The grouping of 1st-order concepts into 2nd-order themes and aggregate dimensions provides a structured framework to guide this process. However, the analysis remains inherently subjective, as different researchers may interpret the same qualitative data differently. Consequently, even when applying the same methodological framework, the findings may vary depending on the researchers' interpretations and judgments.

The inclusion of quantitative data from systems such as SAP, QMPS, and DU enabled validation of the issues identified in the qualitative analysis, particularly regarding misalignment and mismatch. This strengthens the study by providing measurable evidence to support the qualitative findings. However, the reliability of these analyses depends on the assumption that accurate and relevant data were extracted from the systems.

The proposed future state is largely based on the qualitative and quantitative data collected in this study. However, as previously discussed, these data sources have inherent limitations, which may also influence the outcome of the proposed design of the future state. Consequently, the future state should not be regarded as the only possible solution, nor necessarily the optimal one for addressing the identified issues. Furthermore, the proposed solution could have been discussed in greater depth with interview participants to capture their perspectives and reactions, which may have contributed to a more comprehensive evaluation.

7.4 Future research

Based on the findings and limitations of the study, several areas for future research can be identified. Future research could further investigate whether the technical capabilities required for the proposed solution can be implemented in practice as intended. In this study, the technical feasibility of the proposed solution was based on expert knowledge within SKF. A few examples of such capabilities include the possibility of automatic updates between SAP and QMPS, as well as the MIS's ability to measure running efficiency and reset times.

Future work could also explore the use of cycle time and efficiency data at a more detailed level within databases and systems. Currently, cycle times are defined for entire material families, regardless of potential differences between different variants. However, Factbird can provide cycle time for the final variant level, which could improve the accuracy of both planning and costing by better reflecting the actual processes. Similarly, running efficiency is currently defined at channel level, even though it may vary between different material families due to factors such as differences in raw material quality from different suppliers.

Another area for future research is to evaluate the proposed solution following potential implementation. This study does not assess the long term effects, which would be necessary to determine whether the proposed solution leads to improved adherence to SOPs and increased reliability of data. This is especially important as the findings of this study have shown that the current SOP are not consistently followed in practice, meaning that intended improvements may not be realized if similar behavioral patterns persist. While this study primarily focuses on organizational structure, previous research highlights leadership and culture as important factors influencing performance outcomes of digital transformation (Imran et al., 2021). These aspects have not been addressed in this study but may play a critical role in ensuring successful implementation. If the proposed solution does not lead to improved adherence in practice, further research should investigate the underlying causes and identify measures to ensure consistent application.

Future research could also examine the transferability of the findings to other contexts, especially where similar MIS are used. As the study is based on a single case, the findings are limited to the specific context of SKF in Gothenburg. Further studies could therefore investigate whether similar challenges can be observed and whether similar solutions are relevant in other industrial contexts.

Furthermore, this study focuses solely on investigating how accurate and up-to-date time data and efficiency measures can positively influence SC calculation and production planning. However, as mentioned in section 2.4, these factors can also have a positive impact on four additional areas. Further research could therefore explore how accurate and up-to-date time data and efficiency measures, affect these four areas at SKF and identify which departments stand to benefit from them. For example, as mentioned in chapter 4, SC also serves as the foundation for calculating several other cost concepts. One of these concepts is used for profitability analysis and may potentially serve as a basis for decision-making. The effects of these cost concepts being based on an inaccurate SC were not examined within the scope of the study. Further research could therefore investigate how improvements in SC propagate to related cost concepts and affect decision making processes.

8

Conclusion

This master's thesis investigated how SOPs at SKF can be designed to support reliable TDM. The case study, conducted at SKF's three TVOs in Gothenburg, revealed both technical and organizational challenges affecting the reliability of TDM. The findings from the analysis demonstrate that, although SOPs exist, they are not consistently followed in practice. As a result, time data and efficiency measures are often determined using comparison and estimation, leading to mismatches across systems. This, combined with unclear definitions, insufficient synchronization between systems, a lack of clearly defined responsibilities, and the absence of accountability, results in unreliable TDM. Consequently, the reliability of both production planning and SC calculations is reduced. To address these challenges, a revised SOP was proposed. The future state introduces improved and more accurate methods for determining time data and efficiency measures, supported by the use of a MIS and a centralized IT/OT database. It enables continuous comparison between planned and actual times, establishes clearer and more consistent definitions, and improves synchronization between systems. In addition, it defines both responsibility and accountability to ensure that time data and efficiency measures are continuously updated and maintained.

In conclusion, the study demonstrates that reliable TDM requires the alignment of technological capabilities with well-defined organizational structures. While the proposed future state provides a basis for improving data quality and system alignment, its success ultimately depends on organizational acceptance and consistent adherence in practice. These findings highlight that reliable TDM is not only a technical challenge but fundamentally an organizational one.

References

Almström, P., Andersson, C., Öberg, A. E., Hammersberg, P., Kurdve, M., Landström, A., Shahbazi, S., Wiktorsson, M., Windmark, C., Winroth, M., & Zackrisson, M. (2017). *Sustainable and resource efficient business performance measurement systems - the handbook* (Handbook). Chalmers University of Technology. Gothenburg, Sweden.

Almström, P. (2024). *Time data management: A handbook*. Nordic MTM Association.

Almström, P., & Winroth, M. (2010). Why is there a mismatch between operation times in the planning systems and the times in reality. *Proceedings of APMS 2010*.

Banks, J., Carson, J. S., Nelson, B. L., & Nicol, D. M. (2014). *Discrete-event system simulation* (5th ed.). Pearson Education Limited.

Bellgran, M., & Säfsten, K. (2010). *Production development: Design and operation of production systems*. Springer-Verlag. https://doi.org/10.1007/978-1-84882-495-9

Benter, M., Neumann, M., & Kuhlang, P. (2026). Automated derivation of mtm analyses from vr data using mtmmotion® – process evaluation and comparison with manual analysis. *Procedia Computer Science*, *277*, 30–39. https://doi.org/10.1016/j.procs.2026.02.044

Borsdorf, A., Nöhring, F., & Kuhlang, P. (2022). Automatisierte erstellung von mtm-analysen: Ergebnisse einer machbarkeitsstudie zur ki-gestützten, textbasierten datenauswertung. *ZWF Zeitschrift für wirtschaftlichen Fabrikbetrieb*, *117*(10), 651–654. https://doi.org/10.1515/zwf-2022-1124

Cadle, J., Paul, D., Hunsley, J., Reed, A., Beckham, D., & Turner, P. (2021). Technique 117: Raci matrix. In *Business analysis techniques: 123 essential tools for success* (3rd ed.). BCS, The Chartered Institute for IT.

Chen, T.-C. T. (2026). *Advances in cycle time management* (1st ed.). Springer Nature. https://doi.org/10.1007/978-3-032-06911-5

Creswell, J. W. (2014). *Research design: Qualitative, quantitative, and mixed methods approaches* (4th ed.). SAGE Publications.

Factbird. (n.d.). *Factbird: Manufacturing intelligence suite*. Retrieved March 19, 2026, from https://www.factbird.com/

Freivalds, A., & Niebel, B. W. (2009). *Niebel's methods, standards, and work design* (12th). McGraw-Hill.

Gioia, D. A., Corley, K. G., & Hamilton, A. L. (2012). Seeking qualitative rigor in inductive research: Notes on the Gioia Methodology. *Organizational Research Methods*, *16*(1), 15–31. https://doi.org/10.1177/1094428112452151

Hastilow, N. K., & Young, R. I. (2012). Understanding ‘manufacturing intelligence’: A precursor to interoperable manufacturing systems. In R. Poler et al. (Eds.), *Enterprise interoperability v: Shaping enterprise interoperability in the future internet* (pp. 49–57). Springer. https://doi.org/10.1007/978-1-4471-2819-9_5

Hedman, R., & Almström, P. (2017). A state of the art system for managing time data in manual assembly. *International Journal of Computer Integrated Manufacturing*, *30*(10), 1060–1071. https://doi.org/10.1080/0951192X.2017.1305501

Hedman, R., Subramaniyan, M., & Almström, P. (2016). Analysis of critical factors for automatic measurement of oee. *Procedia CIRP*, *57*, 128–133. https://doi.org/10.1016/j.procir.2016.11.023

Imran, F., Shahzad, K., Butt, A., & Kantola, J. (2021). Digital transformation of industrial organizations: Toward an integrated framework. *Journal of Change Management*, *21*(4), 451–479. https://doi.org/10.1080/14697017.2021.1929406

Kjellsdotter Ivert, L. (2012). *Use of advanced planning and scheduling (aps) systems to support manufacturing planning and control processes* [Doctoral dissertation]. Chalmers University of Technology [Chalmers Research Portal]. https://research.chalmers.se/en/publication/162616

Korstjens, I., & Moser, A. (2018). Series: Practical guidance to qualitative research. part 4: Trustworthiness and publishing. *European Journal of General Practice*, *24*(1), 120–124. https://doi.org/10.1080/13814788.2017.1375092

Kuhlang, P., Erohin, O., Krebs, M., Deuse, J., & Sihn, W. (2014). Morphology of time data management – systematic design of time data management processes as fundamental challenge in industrial engineering. *International Journal of Industrial and Systems Engineering*, *16*(4), 415–432.

Liker, J. K. (2003). *The Toyota Way*. McGraw-Hill Education. https://doi.org/10.1036/9780071435635

Milani, F. (2019). Future state analysis. In *Digital business analysis* (pp. 237–250). Springer International Publishing. https://doi.org/10.1007/978-3-030-05719-0_13

Nakajima, S. (1988). *Introduction to TPM: Total productive maintenance*. Productivity Press.

Olsson, H., & Sörensen, S. (2021). *Forskningsprocessen: Kvalitativa och kvantitativa perspektiv* (4th ed.). Liber.

Pruzan, P. (2016). *Research methodology: The aims, practices and ethics of science*. Springer. https://doi.org/10.1007/978-3-319-27167-5

Quintão, C., Andrade, P., & Almeida, F. (2020). How to improve the validity and reliability of a case study approach. *Journal of Interdisciplinary Studies in Education*, *9*(2), 264–275. https://doi.org/10.32674/jise.v9i2.2026

Rojas-Cuevas, I.-D., & Caballero-Morales, S.-O. (2025). *Bottleneck analysis* (J. L. García Alcaraz, G. Cortés Robles, & A. Realyvásquez Vargas, Eds.). Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-70984-5_11

Saunders, B., Sim, J., Kingstone, T., Baker, S., Waterfield, J., Bartlam, B., Burroughs, H., & Jinks, C. (2018). Saturation in qualitative research: Exploring its conceptualization and operationalization. *Quality & Quantity*, *52*(4), 1893–1907. https://doi.org/10.1007/s11135-017-0574-8

SKF. (2026). *About SKF*. Retrieved February 26, 2026, from https://www.skf.com/group/organisation/about-skf

Skinner, W. (1974). The focused factory. *Harvard Business Review*, *52*(3), 113–121.

Soares, C., Pereira, G., Ramos, J., Ramalho, R., Santos, A. S., Varela, L., Bastos, J., & Ávila, P. (2025). Recent developments in enterprise resource planning: A literature review. In J. Machado, J. Trojanowska, E. Ottaviano, M. A. Xavior, P. Valášek, & Y. Basova (Eds.), *Innovations in mechanical engineering iv* (pp. 360–367). Springer. https://doi.org/10.1007/978-3-031-93554-1_32

Stenbacka, C. (2001). Qualitative research requires quality concepts of its own. *Management Decision*, *39*(7), 551–555. https://doi.org/10.1108/EUM0000000005801

Taherdoost, H. (2022). How to conduct an effective interview: A guide to interview design in research study. *International Journal of Academic Research in Management*, *11*(1), 39–51. https://hal.science/hal-03741838

Tang, J., Dai, Z., Jiang, W., Wu, X., Zhuravkov, M. A., Xue, Z., & Wang, J. (2024). A comprehensive review of theories, methods, and techniques for bottleneck identification and management in manufacturing systems. *Applied Sciences*, *14*(17), 7712. https://doi.org/10.3390/app14177712

Woodside, A. G. (2010). *Case study research: Theory, methods and practice*. Emerald Publishing Limited.

Zandin, K. B. (Ed.). (2001). *Maynard's industrial engineering handbook* (5th ed.). McGraw-Hill Education.

DEPARTMENT OF TECHNOLOGY MANAGEMENT AND ECONOMICS
DIVISION OF SUPPLY AND OPERATIONS MANAGEMENT
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2026
www.chalmers.se

CHALMERS
UNIVERSITY OF TECHNOLOGY