FACULTY OF ECONOMICS TUL

Master Thesis

Standardization of production process in global manufacturing company

Study programme: N0413A050030 International Management

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Thesis Supervisors: doc. Ing. Jakub Dyntar, Ph.D.

Department of Business Administration and Management

Liberec 2025

FACULTY OF ECONOMICS TUL

Master Thesis Assignment Form

Standardization of production process in global manufacturing company

Name and surname:	**Bc. Petr Nohýnek**
Identification number:	E23000491
Study programme:	N0413A050030 International Management
Assigning department:	Department of Business Administration and Management
Academic year:	2024/2025

Rules for Elaboration:

1. Description of a current state of a manifacturing process at different locations.
2. Standardization of a manifacturing process.
3. Optimization of idle time.
4. Redistribution of work due to an automation.
5. Digitalization of a manufacturing process.

Scope of Graphic Work:
Scope of Report: 65
Thesis Form: printed/electronic
Thesis Language: english

List of Specialised Literature:

- HOLT, P. *The Simplicity of Lean: Defeating Complexity, Delivering Excellence*, Management Impact Publishing, 2019, 250 p., ISBN: 978-9462763227.
- RUSHTON, A., CROUCHER, P., BAKER, P. *Handbook of Logistics and Distribution Management*, Kogan Page, 2017, 912 p., ISBN 074947677X.
- SINEK, S. *Start With Why: How Great Leaders Inspire Everyone To Take Action*, Penguin, 2018, 246 p., ISBN 978-0-241-95822-3.
- ŌNO, T. *Toyota production system: Beyond large-scale production*, Productivity Press, 2019, 176 p., ISBN 0-915299-14-3.
- WAHAB, A. Lean Manufacturing and sustainable performance with a moderation of organizational culture, *South Asian Journal of Operations and Logistics*, 1(2), 30-52, 2022. DOI 10.57044/SAJOL.2022.1.2.2209

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Date of Thesis Assignment: November 1, 2024
Date of Thesis Submission: August 31, 2026

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Standardizace výrobního procesu v globální výrobní společnosti

Anotace

Tato diplomová práce se zabývá optimalizací, standardizací a návrhem digitálního řešení za účelem zefektivnění procesu prodeje balení ve společnosti Knorr-Bremse. Řešený problém je analyzován strukturovaným způsobem pomocí metodiky 5W1H, PDCA cyklu řízení projektů a nástrojů štíhlé výroby. Práce se zaměřuje na tři různé pobočky společnosti. Optimalizace byla dosažena využitím hodnotové analýzy, která identifikovala kroky nepřidávající hodnotu a odhalila plýtvání, jež bylo následně eliminováno. U výrobních linek NG4 a LAA2 byla rovněž provedena optimalizace layoutu. Po implementaci nového procesu byl tento proces standardizován. Pro další zvýšení efektivity je navržena digitalizace procesu pomocí chytrých čteček čárových kódů. Díky optimalizaci bylo dosaženo roční úspory ve výši 14 065,3 EUR a potenciálního zvýšení ročního zisku firmy o 609 826,98 EUR. Na závěr je doporučeno zavedení navrženého řešení i v dalších pobočkách společnosti Knorr-Bremse po celém světě.

Klíčová slova

Prodej balení, výrobní proces, štíhlá výroba, optimalizace, standardizace, digitalizace

Standardization of production process in global manufacturing company

Annotation

This diploma thesis focuses on the optimisation, standardisation, and design of a digital solution to streamline the process of the sale of packaging at Knorr-Bremse. The problem is analysed in a structured manner using the 5W1H methodology, the PDCA project management cycle, and lean manufacturing tools. The thesis addresses the issue across three different company branches. Optimisation was achieved through the use of value analysis, which identified non-value-adding steps and uncovered waste that was subsequently eliminated. Additionally, layout optimisation was carried out for the NG4 and LAA2 production lines. Following the implementation of the new process, standardisation was established. For further improvement, the digitalisation of the sale of packaging process using smart barcode scanners is proposed. As a result of the optimisation, an annual cost saving of €14,065.30 was achieved, along with the potential to increase the company's annual profit by €609,826.98. Finally, it is recommended that the proposed solution be implemented in other Knorr-Bremse branches worldwide.

Key Words

Sale of packaging, production process, Lean manufacturing, optimisation, standardisation

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List of Abbreviations and Symbols

ADB	Air Disc Brake
AG	Aktiengesellschaft (Corporation limited by shared ownership)
AI	Artificial intelligence
CSR	Corporate Social Responsibility
CZK	Czech Crown
DMS	Daily Management System
EPS	Electronic Steering Pump
EUR	Euro
IT	Information Technology
KB	Knorr-Bremse
KLT	Kleine Ladung Transporter (Small Transporting Box)
MES	Manufacturing Execution Systems
NVA	Non-Value Added
OE	Original Equipment
OEE	Overall Equipment Effectiveness
OS	Operating System
PDCA	Plan-Do-Check-Act project management cycle
PMO	Operations & Production Manager
Power BI	Power Business Intelligence
PUL	Production Unit Leader
RFID	Radio Frequency Identification
SAP	System Analysis Program
SIPOC	Supplier, Input, Process, Output, Customer map
TUL	Technical University of Liberec

VA	Value Added
VE	Value Engineering
VSM	Value Stream Maping

1 Introduction

This diploma thesis aims to deal with the problem of the sale of packaging. The sale of packaging is an end-of-line process repeated with every full box of finished products. This process is being bottlenecked for cycle time reduction efforts, causing one of the TOP downtimes of each production line and leading to the failure to meet the Overall equipment effectiveness (OEE) target. This problem appears across several Knorr-Bremse locations; therefore, this thesis aims to develop a best practice solution to apply to other locations.

To reach this best practice solution, tools of Lean management are going to be used. Using these tools, this process can be simplified and standardised across several Knorr-Bremse locations. A further digitised solution is going to be designed for even better efficiency of this process. To solve the problem with the sale of packaging, the methodology has been established to standardise problem-solving efforts across different subsidiaries.

The thesis is structured into five main chapters to systematically address the research objective. The first chapter outlines the goal of the thesis, providing a clear definition of the problem and the motivation behind the study. In the second chapter, the theoretical background is presented, focusing on Lean management principles, project management methodologies, and the role of digitalisation in modern production systems. Chapter three describes the problem-solving process, detailing the practical analysis conducted at three selected Knorr-Bremse locations. It includes the identification of inefficiencies and the application of Lean tools to develop standardised procedures. The fourth chapter presents the results and discussion, highlighting key findings, implementation outcomes, presentation of potential savings, and potential for digital integration to further reduce downtime and streamline operations. Finally, chapter five provides the conclusion, summarising the main insights, contributions of the thesis, and recommendations for future work.

2 Goals of Thesis

This thesis aims to develop a standardised production process across various subsidiaries of Knorr-Bremse AG by leveraging Lean management principles and project management methodologies. The main objective is to harmonise operational workflows and reduce process variability between international production sites, thereby improving overall efficiency, quality, and responsiveness within the organisation.

Through the systematic implementation of lean tools such as value stream mapping, Power BI data reports, and others, this thesis will identify process inefficiencies, sources of waste, and recurring downtimes. A key focus will also be placed on the standardisation of the process. Another goal is to design digitalised solutions that align with lean philosophies to further optimise process performance. By doing so, the thesis seeks to bridge traditional lean practices with modern digital technologies.

Furthermore, specific, measurable objectives will be established to guide the transformation process at the subsidiary level. These will include setting up a goal for each area of research. The outcome of this research is intended to provide a scalable and replicable framework that supports continuous improvement and operational excellence across Knorr-Bremse's global production network.

2.1 Goal of Thesis in KB Liberec, Czech Republic

The first focus area of this thesis is Knorr-Bremse's subsidiary in Liberec, Czech Republic. This subsidiary has an issue with the sale of packaging, generating downtimes. These downtimes lead to not fulfilling OEE targets each shift. According to the Power BI report based on data collected by the Daily Management System (DMS), the sale of packaging appears three times out of the 6 highest downtimes of the whole production plant. The Power BI report also shows, that the downtime is distributed accros all shifts, that means, that the problem is repetitive. The process of the sale of packaging can't be eliminated; therefore, it needs to be optimised, standardised, and further improvements in terms of digitisation need to be established.

2.1.1 Goal for the Brakechamber Production unit in KB Liberec

In Figure 1 can be seen how the goal for brakechamber lines in the Liberec subsidiary has been set.

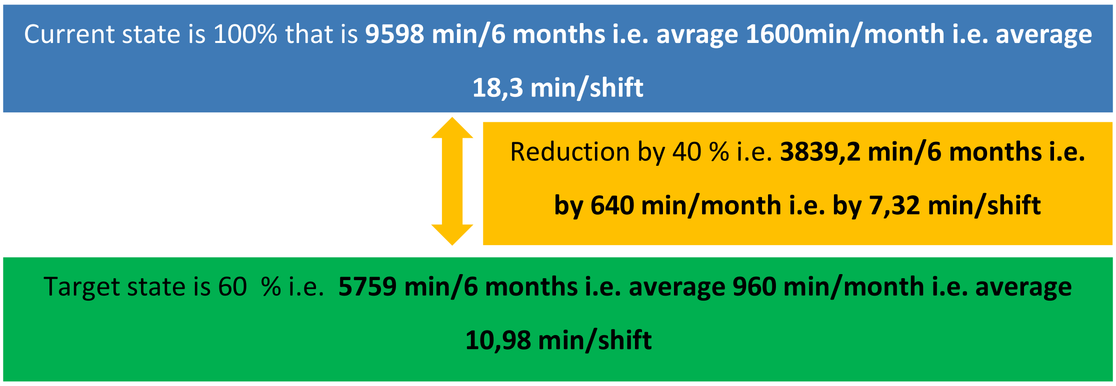


Figure 1: Goal for the Sale of packaging on Beakechamber lines in KB Liberec

Source: Own

The goal is to reduce the downtime on brakechamber lines by 40 % using the redistribution of work and digitising the process. Main tasks that need to be sorted are: redistribution of work, unification and standardisation of work across brakechamber lines, and later to the other Knorr-Bremse subsidiaries, if needed, layout changes are also made for streamlining the process of sale of packaging. After changes have been successfully implemented, there is space for improvement in terms of digitalisation. That can lead to further speeding up of the process of the sale of packaging.

2.1.2 Goal for the Machining Production unit in KB Liberec

Another focus area that needs a goal to be set is the Machining area in KB Liberec. As for the brakechamber lines, there is also a need to establish a goal for this area. Because there are two different issues, there is a need to set a specific goal for each problem. In Figure 2 can be seen how the goal has been set for the sale of packaging appearing in the machining area of KB Liberec.

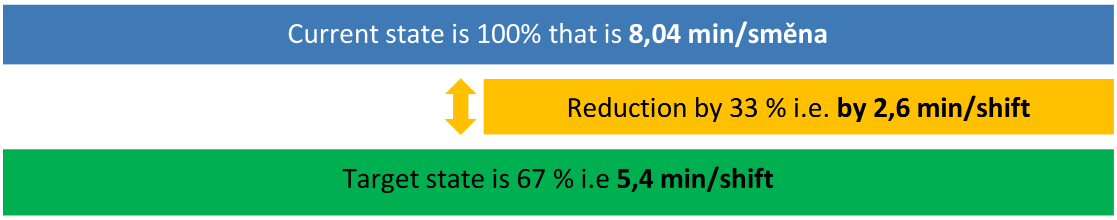


Figure 2: Goal for the sale of packaging in the machining area in KB Liberec

Source: Own

Main tasks for the machining area are to improve the process of the sale of packaging by purchasing barcode scanners, installing SAP on the computers next to the machines, and creating a standard. This helps to remove waste in the form of motion. There is also space for further improvement by digitising the process of the sale of packaging.

The third goal for the Liberec subsidiary of Knorr-Bremse that needs to be established is also for the machining area. This goal is for improving the reporting of work at the end of each shift. In Figure 3 can be seen how the goal has been set. The goal is to reduce time spent on reporting work at the end of each shift by 49 % by implementing changes for the sale of packaging.

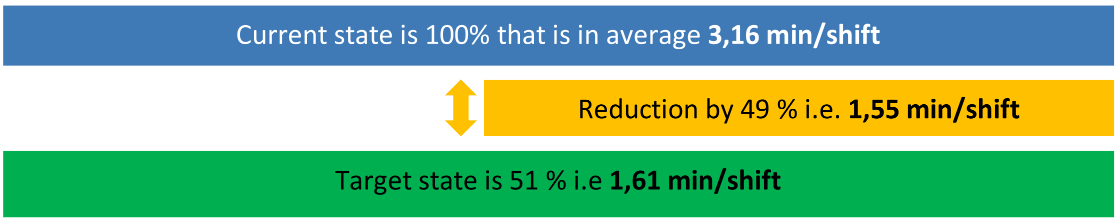


Figure 3: Goal for the reporting of work at the end of each shift at the Machining area in KB Liberec

Source: Own

2.2 Goal of Thesis in KB Lisieux, France

The second focus area of this thesis is Knorr-Bremse's subsidiary in Lisieux, France. In Figure 4 can be seen how the goal for the brakechamber line LAA2 in Lisieux has been set.

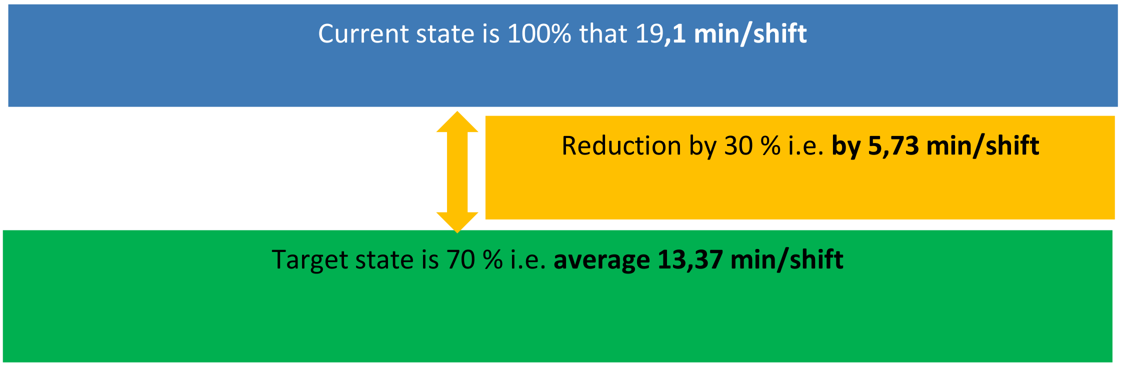


Figure 4: Goal for the Sale of packaging on the brakechamber lines in KB Lisieux

Source: Own

The goal is to reduce downtime on the brakechamber line LAA2 by 30 % using the redistribution of work, a change in layout, and digitising the process. Main tasks that need to be sorted are: Redistribution of work, unification, and standardisation of work across Knorr-Bremse subsidiaries. After these changes are implemented, there is space for improvement in terms of digitalisation. That can lead to further speeding up the process of the Sale of packaging.

2.3 Goal of Thesis in KB Namegawa, Japan

The third focus area of this thesis is Knorr-Bremse's subsidiary in Namegawa, Japan. Figure 5 shows how the goal for the machining area in Namegawa has been set.

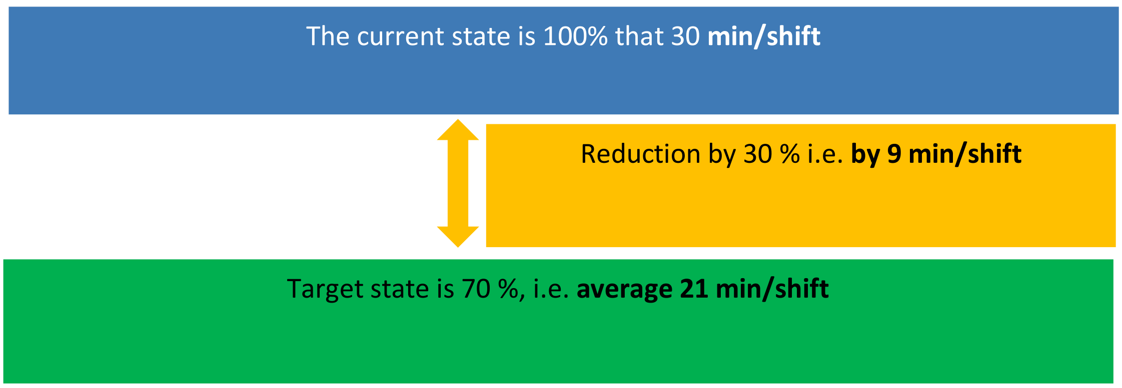


Figure 5: Goal for the sale of packaging on the machining area in KB Namegawa

Source: Own

The goal is to reduce the process time of the sale of packaging by 30 % using a change in the packaging procedure and digitising the process. Main tasks that need to be sorted are: design of new process, unification and standardisation of work across Knorr-Bremse subsidiaries. After these changes are implemented, there is space for improvement in terms of digitalisation. That can lead to further speeding up the process of the sale of packaging.

3 Theoretical background

In any academic research project, having a strong theoretical foundation is crucial. It helps guide the study and offers a clear way to approach and explore the research questions. It provides the key concepts and perspectives needed to fully and clearly understand the topic.

The main goal of this section is to introduce and discuss the important theories, models, and academic viewpoints that relate to the research topic. By placing the study within the wider academic conversation, this framework not only explains the ideas behind the research but also shows how the work contributes to the field. It ensures the study builds on existing knowledge while pointing out the gaps it aims to fill.

The theory section doesn't just summarise what's already known but also lays a strong and clear foundation for the research that follows. By connecting theory with practice, this thesis hopes to make a meaningful contribution to both academic knowledge and real-world applications.

3.1 Managing International Manufacturing Operations

Managing international manufacturing operations involves the orchestration of complex processes across multiple geographical locations, aiming at optimising efficiency and achieving strategic objectives. As globalisation continues to shape economic landscapes, manufacturing firms increasingly engage in cross-border production to leverage benefits such as cost savings, market access, and resource availability. Central to this process is the consideration of various factors such as supply chain management, knowledge networks, risk management, and technological advancements.

One of the foremost aspects of managing international manufacturing operations is the formulation of a robust strategy that aligns with the firm's overarching business objectives. According to Stanislavyk et al. (2024), standardising core operational activities while tailoring marketing and product strategies to local conditions is crucial for manufacturers operating on an international scale. This dual approach allows firms to maintain efficiency while also catering to the unique demands and preferences of local markets.

Moreover, risk management emerges as an integral component of this strategic framework, particularly in light of the varied and often unpredictable factors that affect international operations. Manufacturing firms are exposed to a multitude of risks, including geopolitical instability, supply chain disruptions, and fluctuating market dynamics. Consequently, organisations must incorporate risk assessment frameworks that analyse potential threats and devise contingency plans to minimise their impact (Stanislavyk et al., 2024). Effective risk management not only protects organisational assets but also supports strategic decision-making in an uncertain environment.

The integration of supply chains across different countries presents both challenges and opportunities for international manufacturers. Research by Golini et al.(2017) highlights that effective supply chain integration enhances product flow and information sharing, which are essential for meeting customer demands swiftly and accurately. The ability to manage resources and collaborate with suppliers enhances overall supply chain performance, thereby supporting operational efficiency.

In addition to integration, resilience has become a pivotal focus in international manufacturing strategies. As noted by Fleisch and Dzengelevski (2024), organisations are increasingly seeking to build resilient supply chains that can withstand disruptions while maintaining continuity in production processes. A resilient manufacturing strategy involves configuring networks and operational structures to facilitate rapid responses to changes in demand or supply availability. This adaptability is especially crucial in industries vulnerable to technological advancements and competitive pressures.

Knowledge management plays a vital role in optimising international manufacturing operations. According to Man et al. (2018), effective knowledge management practices within supply chain networks significantly enhance organisational learning capabilities, contributing to better adaptability to industry trends and improved process outcomes. By fostering a culture of sharing insights and expertise among employees and stakeholders, firms can better adapt to shifts in industry trends and enhance process improvements.

In international operations, the dissemination of knowledge across geographic boundaries is particularly important. Firms operating globally can leverage diverse perspectives and localised experiences to refine their manufacturing processes, innovate product designs, and enhance customer relations. Tools and practices that support real-time information sharing and collaboration across teams can lead to improved decision-making and operational effectiveness.

In summary, effectively managing international manufacturing operations entails a multifaceted approach that encompasses strategic planning, supply chain integration, knowledge management, risk mitigation, and the adoption of advanced technologies. As manufacturers navigate the complexities of globalisation, embracing flexibility and resilience will be paramount for sustaining competitiveness. By harmonising these elements, organisations can optimise their manufacturing processes and achieve sustainable growth in the ever-evolving global economy. The next chapter is going to add to this topic, how industrial engineering helps in the international operations of production companies.

3.2 Industrial Engineering

Industrial engineering plays a critical role in the operations of international companies by enhancing efficiency, productivity, and responsiveness to global market dynamics. In an increasingly interconnected world, where firms compete based on entire supply chains rather than individual entities, the contributions of industrial engineering become paramount. Efficient management of production processes, resource allocation, and quality control fosters an environment where companies can thrive amid unfavourable conditions, such as those introduced by global disruptions like the COVID-19 pandemic.

To begin with, the essence of industrial engineering in international businesses lies in its capacity to optimise demand chain performance. Towill and Childerhouse (2011) emphasise that possessing industrial engineering competence allows companies to be better prepared for external changes, which is crucial for roles ranging from commodity suppliers to integrated specialists in demand chain management. This readiness is complemented by the ability to adapt business models that incorporate elements such as product/service features and decision-making structures, which Baber and Ojala (2020) highlight as essential during the pandemic. The changing nature of operations necessitates that enterprises evolve their frameworks to ensure resilience and continuity during periods of volatility.

The internationalisation of firms, especially small and medium-sized enterprises, is heavily influenced by their strategies and market orientations. For instance, research by Saarenketo et al. (2021) shows that entrepreneurial orientation significantly impacts foreign market entry, which is essential in contexts where firms seek to expand their operational footprint internationally. Furthermore, entrepreneurial commitment is equally critical, as demonstrated by Javalgi and Todd’s (2011) analysis, indicating that a solid commitment to internationalisation, combined with leveraging human capital, enhances international success for Indian SMEs.

In examining how globalisation and various external pressures affect industrial operations, Meyer and Thein (2014) discuss the implications of adverse home country institutions, focusing on how international sanctions can shape multinational enterprises' strategies and operations. Such frameworks provide insight into how firms navigate complexities while mitigating risks associated with differing regulatory environments across nations. Additionally, organisational culture also plays a significant role; research by Siagian et al. (2017) underscores that aligning business process re-engineering efforts with the organisational culture is vital for firms, impacting overall performance and operational effectiveness.

The discussion around business process re-engineering and intellectual capital efficiency further expands our understanding of industrial engineering's role. Effective business process re-engineering can significantly enhance productivity in international environments, as articulated in Roy’s et al. (2021) work about integrity management within the construction and engineering sectors. Effective management of third-party relationships, combined with a deep understanding of industry dynamics, allows companies to streamline processes and increase service delivery efficiency, proving essential for competitiveness (Roy et al., 2022).

Moreover, rapid technological advancements underpin industrial engineering's evolution and its application across sectors. The advent of Industry 4.0, characterised by the integration of IoT and cloud computing, has redefined operational landscapes in manufacturing. As noted by Wang et al. (2016), smart factories utilize data analytics and control engineering to enhance process coordination, thereby optimizing supply chain performance. The notion that competition extends from individual firms to entire supply networks highlights the need for robust systems that manage data and processes across borders effectively (George & Pillai, 2019).

Finally, embedding sustainability into industrial practices is becoming increasingly vital, with a growing emphasis on integrating the Sustainable Development Goals into business strategies. Battaglia et al. (2020) suggest that aligning with Sustainable Development Goals not only fosters enduring operational strategies but also enhances competitive advantage in global markets characterised by increasing consumer awareness and regulatory pressures. Thus, a holistic approach involving industrial engineering principles offers a pathway to achieving sustainable and resilient business operations within international contexts. The next chapter is going to describe how Lean management falls into the activities of international operations.

3.3 Lean management

Lean management integrates into the field of industrial engineering, and it has gained prominence globally, particularly in the context of managing international companies. This management philosophy, originating from the Toyota Production System, focuses on minimising waste while maximising productivity and efficiency. Lean principles are becoming increasingly relevant in diverse industries, supporting companies in improving operational processes and enhancing overall strategic alignment across international operations.

The foundation of lean management in industrial engineering lies in its emphasis on value creation and waste elimination. Lean principles advocate for a customer-centric approach where organisations aim to deliver greater value through enhanced quality while simultaneously reducing costs (Teich & Faddoul, 2013). The focus on continuous improvement necessitates a deep understanding of workflows and processes, empowering employees to identify inefficiencies and propose solutions (Turgay et al., 2023). This philosophy aligns closely with the objectives of industrial engineers, who utilise various methodologies, such as just-in-time and total quality management, to streamline operations and enhance productivity (Furlan et al., 2011).

Further exploration indicates that successful lean implementation is intricately linked to organisational culture and leadership (Rajpurohit, 2019). As illustrated in the work of Bortolotti et al. (2015), successful lean organisations exhibit strong leadership commitment and an organisational culture that fosters collaboration across different divisions. Leadership plays a pivotal role in aligning the collective efforts of an organisation towards lean initiatives, ensuring that all employees understand both the objectives and their roles in achieving them. This alignment is crucial for international companies, where operations span multiple countries and cultures, necessitating a unified approach to lean management.

In an increasingly digital landscape, integrating Industry 4.0 technologies with lean practices presents unique opportunities for international firms. According to Mncwango and Ramdass (2023), the gradual incorporation of Industry 4.0 technologies enhances lean practices by offering new tools for data collection and process monitoring, thus improving efficiency and adaptability. The synergy between digitalisation and lean management not only optimises resource use but also enables real-time insights into operations, facilitating informed decision-making processes essential for managing global supply chains effectively (Sony, 2018). Digital lean management has the potential to foster innovation by providing advanced analytics for ongoing improvement initiatives, thus allowing companies to remain competitive in dynamic markets (Hamzeh et al., 2021).

Moreover, the principles of lean management are not solely confined to manufacturing environments, they extend to areas such as service operations and supply chain management as well. For instance, the application of lean principles in the hospitality sector exemplifies how these strategies can yield enhanced operational performance through efficiency and customer satisfaction (Linder et al., 2020). Lean practices can refine processes in service delivery, resulting in improved customer experiences critical for international brands aiming for consistency across their global operations (Vienažindienė & Čiarnienė, 2013).

International companies must also navigate challenges inherent in lean transformation efforts. Research by Maware and Parsley (2022) highlights that organisations often encounter obstacles such as resistance to change, lack of adequate training, and insufficient leadership support when attempting to implement lean practices across varied cultural contexts. The implications of these challenges are substantial, underscoring the need for tailored solutions that consider the nuances of local markets while striving to maintain a cohesive operational strategy. With the basics of the lean management theoretical background can dive more into the problematics of lean production.

3.3.1 Lean production

Lean production, commonly referred to as lean manufacturing, is a systematic approach to production that emphasises the elimination of waste while maximising value for the customer. Originating from the Toyota Production System in the mid-20th century, lean production has evolved into a widely adopted methodology across various industries, including automotive, healthcare, construction, and food production (Sahoo, 2019). The core philosophy of lean production is to create more value for customers with fewer resources by streamlining processes and enhancing efficiency. At its essence, lean production focuses on identifying and eliminating non-value-added activities, which are defined as any processes or steps that do not contribute to the value perceived by the customer. This includes various forms of waste, such as overproduction, waiting times, excess inventory, unnecessary motion, defects, and underutilised talent (Singh et al., 2018). By systematically addressing these areas of waste, organisations can create a more efficient production flow that aligns closely with market demand, thereby enhancing overall operational efficiency (Kaban, 2023). With the basic overview, letś dive more into the history of lean production.

3.3.1.1 Lean Production History (Toyota Production System)

Lean Production, also known as Lean Manufacturing, has a rich history that originates primarily from post World War II Japan and was later formalised and popularised globally.

The history of lean production, primarily derived from the Toyota Production System, reflects an evolution stemming from the need for more efficient production techniques compared to traditional mass production methods. Lean manufacturing emphasises the continuous elimination of waste, thereby enhancing efficiency and effectiveness within the production process (Abolhassani & Jaridi, 2016; Holweg, 2006; Lin et al., 2022). This historical development can be traced back to the mid-20th century in Japan when Toyota's innovative strategies offered a stark contrast to the assembly line practices epitomised by Henry Ford in the early 20th century (Holweg, 2006; Radnor & Johnston, 2012).

The foundation of lean principles centres around the goal of maximising value while minimising waste. The term "lean production" was popularised by Womack, Jones, and Roos in their landmark book, "The Machine That Changed the World," which analysed the Toyota production system and showcased its superior performance in comparison to traditional manufacturing systems (Holweg, 2006; Melton, 2005). The principles of just-in-time production and autonomation (jidoka) are key components of the Toyota production system framework, both striving to improve product quality and reduce lead times through efficient resource utilisation (Lin et al., 2022). This holistic approach not only redefined automotive production but also influenced numerous industries beyond manufacturing, extending its virtues to healthcare and service operations (Shah et al., 2008; Wickramasinghe & Wickramasinghe, 2017).

With these basics of Lean Production, specific tools can be described. These tools are used in most of the production companies all around the world. According to Wahab (2022), tools such as value stream mapping and Kaizen are essential for sustainable performance.

3.3.2 Lean tools

This section provides a brief overview of key Lean tools used to enhance efficiency, reduce waste, and improve overall process performance. These tools—such as 5S, Value Stream Mapping, Kaizen, Kanban, PDCA Lean project management, and more are designed to support continuous improvement and create more value with fewer resources. Each tool plays a specific role in identifying inefficiencies, streamlining workflows, and fostering a culture of problem-solving and innovation. According to Wahab (2022)

3.3.2.1 The 7 Types of Waste in Lean Management (Muda)

Lean management, originally developed within the context of manufacturing, is a methodology aimed at enhancing efficiency by reducing waste and adding value for customers. The concept of "waste" or "muda" is central to lean thinking, representing any activities that consume resources without providing value. Lean management practitioners strive to identify and eliminate these wastes to improve operational efficiency and effectiveness across various sectors, including manufacturing and healthcare. Specifically, the identification of the seven types of waste is pivotal in helping organisations streamline processes and foster continuous improvement.

The seven types of waste, identified by Taiichi Ohno (2013), are fundamental in the quest for operational excellence. They include the following:

1. **Overproduction:** This occurs when more products or services are produced than are required to meet customer demand, leading to excessive inventory that ties up resources. Overproduction can be particularly costly, as it incurs additional costs related to storage, handling, and potential obsolescence. Effective lean practices advocate for just-in-time production to align output closely with actual customer demand (Hallam & Contreras, 2016).
2. **Waiting:** During processes, delays caused by waiting for materials, equipment, information, or approvals can significantly slow down operations. This type of waste not only extends lead times but also contributes to employee frustration and potential loss of focus (Isfahani et al., 2019). Lean methodologies emphasise process synchronisation and flow management to minimise waiting times and improve throughput.
3. **Transport:** Unnecessary movement of products or materials between locations does not add value to the end product and only serves to increase costs and time. Transport waste can often be minimised through improved layout design, optimising material flow, and reducing handling steps related to transportation (Aij & Teunissen, 2017).

4. **Extra Processing:** This type of waste occurs when unnecessary steps are taken in a process that do not add value. Often a result of poor process design or lingering historic practices, extra processing represents an inefficiency that should be continuously evaluated and streamlined through approaches like value stream mapping (Vanichchinchai, 2021).
5. **Inventory:** Excess inventory represents not only capital tied up in unsold products but also costs associated with storage and handling, as well as the risk of obsolescence. This waste can be mitigated through just-in-time inventory systems and better demand forecasting methods that align production closely with actual consumption (Isfahani et al., 2019).
6. **Motion:** Inefficient movements by employees or equipment during operational processes contribute to wasted time and effort. Motion waste can arise from poor workplace design or layouts that require unnecessary walking or reaching. Ergonomic principles are often integrated into lean practices to help minimise this waste (Sari et al., 2023).
7. **Defects:** This type of waste is manifested when products or services are not delivered to the required quality standards, necessitating rework, repairs, or returns. Eliminating defects is crucial not only for reducing waste but for enhancing customer satisfaction. Lean encourages practices such as root cause analysis and proactive quality management to minimise defects (Xie et al., 2022).

While the concept of muda originated in manufacturing, its principles have been widely adopted across various industries, including healthcare, education, and service sectors. For example, studies have indicated that the application of lean management in hospitals significantly alleviates waiting times, enhances service quality, and boosts patient satisfaction outcomes (Isfahani et al., 2019).

In the healthcare context, minimising waiting times, transport, and overproduction can lead to improved patient care. For instance, lean methodologies have been successfully applied to reduce patient wait times and enhance the efficiency of healthcare delivery systems (Régis et al., 2019; Marín-García et al., 2021). The identification and elimination of waste not only lead to operational improvements but also contribute to better health outcomes for patients.

To effectively eliminate waste in processes, organisations often use various strategies and tools grounded in lean principles. These may include:

- **Value Stream Mapping**: This tool visually represents the flow of materials and information through processes, allowing teams to identify waste and areas for improvement systematically (Marín-García et al., 2021).
- **5S Methodology**: This organisational technique emphasises sorting, setting in order, shining, standardising, and sustaining to create an efficient and productive workplace (Vanichchinchai, 2021).
- **Kaizen Events**: These are focused improvement workshops designed to tackle specific areas of waste or quality issues by engaging teams in brainstorming and solution development (Aij & Teunissen, 2017).

Successful implementation of lean principles requires a cultural shift within organisations that encourages employee involvement, empowerment, and commitment to continuous improvement (Zahari et al., 2019). Engaging employees in identifying waste, suggesting improvements, and participating actively in lean initiatives fosters a collaborative environment that enhances productivity.

3.3.2.2 5S methodology

The 5S methodology, originating from Japan, is a widely recognised framework aimed at improving workplace organisation and efficiency. The term "5S" derives from five Japanese words: Seiri (Sort), Seiton (Set in order), Seiso (Shine), Seiketsu (Standardise), and Shitsuke (Sustain). As a cornerstone of Lean manufacturing, it seeks to eliminate waste, enhance productivity, and encourage a culture of continuous improvement within organisations. (Kanabar et al., 2024).

The 5S framework was first formalised by Takashi Osada in the 1980s, who sought to apply systematic approaches to the work environment that could reduce clutter and improve overall effectiveness (Verma & Jha, 2019). The adoption of 5S in various sectors, ranging from traditional manufacturing to healthcare and educational institutions, highlights its versatility and effectiveness. For instance, research indicates substantial improvements in workplace organisation and performance when 5S principles are implemented in educational settings, reducing costs and enhancing service delivery (Mukoma et al., 2023). Holt (2019) elaborates that the 5S framework serves as a foundational practice for implementing Lean principles in various industries. By systematically organising the workspace, 5S not only removes waste but also establishes standards that promote a culture of continuous improvement. The introduction of 5S in an organisational context ensures that employees are equipped with clear procedures that enhance their performance and workplace satisfaction.

1) **Seiri (Sort)**: This initial step involves identifying and separating necessary items from unnecessary ones, thereby reducing clutter and improving space utilisation. This process emphasises the need to keep the workspace focused on essential tools and materials that directly contribute to operational outputs.
2) **Seiton (Set in order)**: After sorting, the next step organise the remaining items logically and efficiently, ensuring that tools and equipment are easily accessible. An effective organisation can reduce search times and facilitate smoother workflows, positively affecting employee morale and efficiency.
3) **Seiso (Shine)**: This stage focuses on cleaning the workplace and maintaining equipment to ensure a safe and pleasant working environment. Regular cleaning routines not only support aesthetic improvements but also help in identifying maintenance issues before they escalate, thus leading to better operational reliability.
4) **Seiketsu (Standardise)**: Once the first three steps are established, organisations need to standardise practices and procedures to maintain the newly organised condition. This involves creating documented procedures and standards that reinforce the benefits achieved by the initial stages.
5) **Shitsuke (Sustain)**: The final step emphasises the importance of sustaining the gains from the first four stages and embedding the 5S principles into the organisational culture. Continuous training, audits, and leadership support are essential to ensure long-term success in maintaining an efficient and organised workspace.

The implementation of the 5S methodology has been associated with numerous benefits across various sectors. A significant impact observed includes enhanced employee productivity due to minimised time spent searching for tools and materials (Mazur et al., 2024; Singh et al., 2014). Furthermore, studies indicate that a well-structured, clean, and organised workplace leads to higher employee morale and lower turnover rates (Worthington & Heaton, 2021). Moreover, the 5S principles contribute to improved safety standards, reducing workplace accidents and enhancing compliance with regulatory requirements.

Continuously applying 5S can also bring financial benefits by reducing waste associated with inefficient processes and increasing operational throughput.

3.3.2.3 Value stream mapping

Value stream mapping is another widely used lean tool to analyse, design, and manage the flow of materials and information. It uses standardised symbols to show streams and information flows. Items are mapped as adding value or not adding value for the customer. (Mukherjee, 2023)

Initially developed within the Toyota Production System, Value stream mapping was used to visualise material and information flows in manufacturing environments. Over time, its application has expanded into various domains, including software development, healthcare, and service industries. In manufacturing, the method aids in identifying inefficiencies at different handoff points in the production line, while in knowledge work, it highlights delays and communication gaps that reduce productivity. (Mukherjee, 2023) In Figure 6 can be seen how the Value Stream map looks in practice.

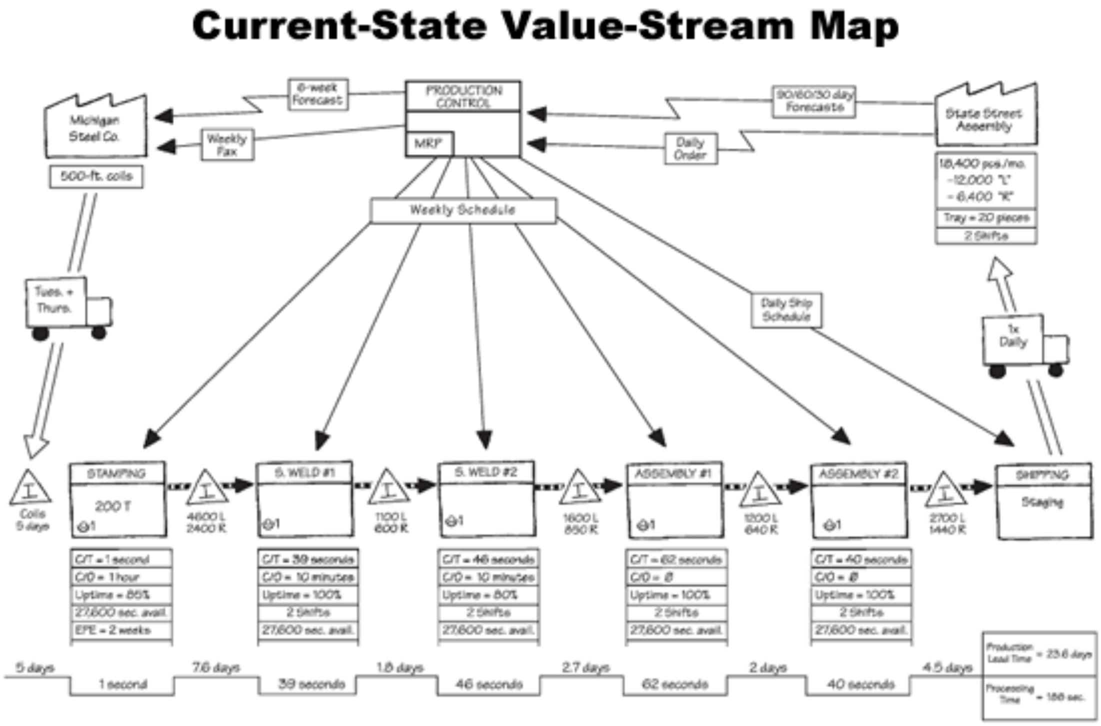


Figure 6: Value stream mapping example

Source: (Lean Enterprise Institute, 2023)

Value stream mapping supports both product flow, focusing on process steps to complete a deliverable, and customer flow aimed at fulfilling end-user expectations. By using simple sketches before formalisation, organisations can tailor the mapping process to their needs without incurring unnecessary complexity. (Mukherjee, 2023)

However, value stream mapping should be applied thoughtfully. Excessive or poorly executed mapping can itself become a source of waste. Best practices include balancing the level of effort with expected returns, involving cross-functional teams, and being aware of resistance due to fear or uncertainty during the mapping process. (Mukherjee, 2023)

Value stream mapping is especially effective in uncovering the seven types of waste defined by lean methodology: overproduction, inventory, motion, defects, over-processing, waiting, and transport. In knowledge-based work such as software development, these take the form of partially completed work, extra features, relearning, handoffs, delays, task switching, and defects. These types of waste are going to be described in section **2.2.3** ***The 7 Types of Waste in Lean Management*** (Mukherjee, 2023)

Ultimately, Value stream mapping enables organisations to identify inefficiencies, align processes with customer needs, and foster a culture of continuous improvement. (Mukherjee, 2023)

3.3.2.4 Kaizen

Kaizen, originating from Japan, translates directly to "continuous improvement." It is a philosophy that emphasises the necessity of incremental enhancements to processes, products, and workplace culture. Developed in the mid-20th century, Kaizen became integral to Japan's post-war economic revival, primarily because it relied on the collective input of all employees, from top management to shop floor workers, to identify areas for improvement. The term was notably popularised by Masaaki Imai in his 1986 book "Kaizen: The Key to Japan's Competitive Success," highlighting its role in enhancing productivity and quality within organisations. (Suárez-Barraza et al., 2011)

At its core, Kaizen revolves around the idea that small, ongoing positive changes can lead to significant improvements over time. This principle is founded on the belief that every employee has valuable insights that can contribute to better performance. In the manufacturing context, the application of Kaizen has been demonstrated to reduce waste and enhance efficiency significantly. A case study noted how its systematic application could lead to considerable cost savings alongside reductions in cycle times and improved quality. (Medina et al., 2024)

Moreover, Kaizen's principles extend beyond manufacturing into various industries, including services and education, emphasising their flexibility and applicability. For example, in the field of education, Kaizen has been employed to revamp graduate programs by focusing on incrementally improving course delivery and student engagement, aligning with the broader objectives of continuous improvement (Emiliani, 2005).

Central to the Kaizen philosophy is its reliance on systematic methodologies, including tools such as the Plan-Do-Check-Act (PDCA) cycle, which provides a framework for testing changes and assessing outcomes (Medina et al., 2024). This tool is described in more detail in Chapter ***3.4.2 The PDCA Cycle in Project Management.*** Furthermore, the emerging concept of "Digital Kaizen," integrating modern technologies like artificial intelligence, demonstrates Kaizen's adaptability to contemporary challenges within Industry 4.0 contexts. Here, the goal is to harness technological enhancements while simultaneously empowering human workers, rather than replacing them, reflecting the foundational ethos of Kaizen that emphasises human involvement in continuous improvement processes (Bajić et al., 2023).

The implementation of Kaizen is not without challenges. Cultural barriers and resistance to change can hinder its success, particularly in environments that are not naturally aligned with its principles (Carneiro et al., 2023). Organisations must foster an internal culture that encourages openness and minimises fear of failure, enabling employees to suggest and implement changes freely. Qualitative studies indicate that successful Kaizen practices lead to improved efficiency, reduced operational costs, and enhanced employee morale, showcasing their potential for transformative effects on organisational performance (Hailu et al., 2023).

In conclusion, Kaizen is more than a set of tools; it is a comprehensive philosophy that champions small, consistent changes facilitated by the collective efforts of all employees. Its historical roots in Japan's economic recovery underscore its effectiveness and significance across various domains. As organisations continue to navigate the complexities of modern business environments, the principles underlying Kaizen will likely remain relevant and critical for achieving sustained improvement and competitiveness.

3.3.2.5 SIPOC

The SIPOC (Suppliers, Inputs, Process, Outputs, Customers) map serves as a valuable tool in lean management, offering a structured approach to visualize a process from its inception to conclusion. Developed within the framework of Lean Six Sigma, SIPOC helps organisations clarify the essential elements of a process and facilitates continuous improvement initiatives by mapping the relationships among different components.

The SIPOC diagram is divided into five key components, clearly delineating the key elements of any process:

- **Suppliers**: These are the external entities or stakeholders that provide the necessary materials, information, or services needed for the process. Identifying suppliers is critical in understanding where inputs originate and ensuring they meet quality and delivery standards (Gutiérrez et al., 2016).
- **Inputs**: This category includes all the resources, data, and materials that are required to execute the process. Inputs are vital for determining the initial conditions necessary for successful process execution (Prashar, 2020).
- **Process:** This is the sequence of activities or steps that transform inputs into outputs. The process should be clearly defined and mapped to allow for a comprehensive understanding of how value is created (Prashar, 2020).
- **Outputs**: Outputs are the results produced by the process, which could be products, services, or information delivered to customers. Understanding outputs is essential for measuring process effectiveness and ensuring that customer needs are met (Dempsey et al., 2021).
- **Customers**: These are the individuals or organisations that receive the outputs. Identifying customers helps organisations better understand their requirements and expectations, leading to improvements in process design and delivery (Mishra & Sharma, 2014).

In manufacturing, SIPOC contributes to quality improvement initiatives by clarifying the relationships among components within production processes. Organisations can map supplier interactions alongside product specifications, ultimately aiming to reduce defects and improve efficiency (Fullerton et al., 2014). The identification of customers will allow manufacturers to tailor output to meet customer expectations effectively.

Moreover, SIPOC is often utilised as a preliminary step in the DMAIC (Define, Measure, Analyse, Improve, Control) methodology within Six Sigma projects. Although primarily a part of Six Sigma, it complements lean principles by fostering the identification and elimination of waste at an early project stage (Prashar, 2020; Kumar et al., 2021).

In conclusion, the SIPOC map is an essential tool in lean management, providing a structured framework for visualising processes and understanding their components. By facilitating better communication, defining project scope, and identifying areas for improvement, SIPOC enhances the effectiveness of process management initiatives across diverse industries. Its application in healthcare and manufacturing exemplifies its versatility, allowing organisations to align processes with customer needs and operational efficiency. As organisations continue to seek efficiencies in their operations, adopting the SIPOC approach will be pivotal in driving continuous improvement and achieving strategic objectives.

3.3.2.6 Spaghetti diagram

The spaghetti diagram is a visual representation used in process mapping that highlights the flow of materials, information, or people within a workspace. Named for its resemblance to a tangled plate of spaghetti, this tool is particularly useful in identifying waste within a process, such as excessive movement or inefficient workflows. By mapping out the physical layout and movements associated with a process, organisations can better understand and improve their operations, ultimately leading to enhanced efficiency and reduced costs.

The structure of a spaghetti diagram involves a simple floor plan or layout of the workspace on which all movements and paths are traced. Elements represented in the diagram typically include:

- **Workstations**: Locations where tasks are performed or items are processed.
- **Material Flow**: The path taken by materials, tools, or products as they move between different workstations.
- **Information Flow**: The movement of data or communication necessary for the operation.
- **Employee Movement**: Paths taken by employees as they perform their duties.

The primary purpose of a Spaghetti Diagram is to visualise the flow of materials and information in a way that identifies redundancy, congestion, and other inefficiencies. The visual nature of the diagram facilitates discussions around process improvements and helps teams identify opportunities for streamlining workflows.

Spaghetti Diagrams find applications in various settings, particularly in manufacturing, healthcare, and service industries. One common use is in manufacturing environments, where the tracking of material movement can reveal inefficiencies due to excessive travel distances or unnecessary handling of items. For example, a Spaghetti Diagram can show how far workers must walk to fetch tools or materials, enabling organisations to reorganise workstations for more efficient layouts.

Moreover, in service industries, Spaghetti Diagrams help organisations streamline communication flow among team members and departments, ensuring that information is shared efficiently and effectively.

The Spaghetti Diagram offers numerous advantages, including:

- **Waste Identification**: By visually representing movement and flow, organisations can easily identify areas of waste, including unnecessary transportation, waiting times, or redundancies.
- **Enhanced Communication**: The visual nature of the diagram facilitates discussions among team members, promoting a shared understanding of the process and encouraging collaborative problem-solving.
- **Data-Driven Decision-Making**: Insights drawn from Spaghetti Diagrams allow organisations to make informed decisions about process improvements and workspace layout changes, ultimately leading to better operational performance.

In conclusion, the Spaghetti Diagram is an essential lean tool that provides organisations with a visual method for analysing and improving process flows. By highlighting waste in movement and facilitating discussions around operational efficiencies, Spaghetti Diagrams enable managers and teams to design streamlined workflows that enhance productivity. As a result, organisations can achieve significant improvements in efficiency and service levels, making Spaghetti Diagrams a valuable component of any continuous improvement initiative. (Hys, M., & Domagała, M.,2018)

3.4 Project management

Project management is a specialized domain derived from key management principles, aimed at guiding a project team to achieve specific goals and deliverables. Encompassing a variety of techniques, tools, and knowledge areas, project management has evolved into a structured discipline that provides a roadmap for the planning, execution, and evaluation of projects. One notable methodology prevalent within project management is the Plan-Do-Check-Act (PDCA) cycle, renowned for its effectiveness in promoting continuous improvement and achieving project objectives.

3.4.1 Overview of Project Management

Project management involves the application of knowledge, skills, tools, and techniques to project activities to meet project requirements (Cojoacă et al.,2023). Central to the discipline are the project's objectives, be they related to scope, quality, time, cost, risk, or stakeholder satisfaction. The Project Management Institute (PMI) has developed standardised guidelines and frameworks, such as the PMBOK Guide, which outline best practices and methodologies for executing projects efficiently (Taraba, 2018). Organisations increasingly recognise the strategic importance of project management in achieving their operational goals, leading to the adoption of more formalised processes and methods (Alvarez-Dionisi, 2016).

The selection of project managers, those who orchestrate the processes and lead project teams, is critical. Their leadership competencies significantly influence project success, necessitating a thorough assessment process during recruitment (Xie et al., 2023). A well-rounded project manager integrates technical knowledge with interpersonal skills, enhancing team collaboration and stakeholder engagement (Lloyd-Walker et al., 2016).

3.4.2 The PDCA Cycle in Project Management

The PDCA cycle, also referred to as the Deming Cycle, is an iterative four-step management method used for continuous improvement of processes, products, or services (Shinoda, 2019). Each stage serves a distinct role in ensuring that project activities align with desired outcomes.

- **Plan**: This initial phase involves identifying goals, defining processes, and determining the required resources. During this stage, project managers analyse data, anticipate potential challenges, and develop strategies to mitigate risks (Chen & Zhang, 2024). By establishing a detailed plan, teams can create a structured approach that outlines objectives, deliverables, timelines, and resource allocations (Zhao et al., 2017).
- **Do:** In the Do phase, the project team implements the plans created in the previous step. It is a vital stage where execution takes place, and teams are tasked with following through on their assigned responsibilities. Ensuring that all team members are aware of their performance metrics and expected contributions is essential for maintaining accountability during execution (Chen & Zhang, 2024).
- **Check**: This stage involves reviewing project progress and outcomes against the established objectives. Performance metrics and key indicators are used to assess whether the project is on track and adhering to quality standards (Xie et al., 2024). Evaluating results during this phase allows for the identification of deviations from the original plan and facilitates timely adjustments. Effective monitoring enables project managers to identify and remove obstacles that hinder progress and to reassess priorities as needed (Rylander & Simpson, 2019).
- **Act**: Based on insights garnered from the Check phase, the Act phase focuses on institutionalising the improvements or modifications deemed necessary. If the project outcomes align with expectations, successful practices are standardised; if the results indicate shortcomings, corrective actions are initiated (Chen & Zhang, 2024). The objective is to close any gaps between actual performance and projected outcomes, promoting a cycle of continuous improvement.

3.4.2.1 Significance of PDCA in Project Management Practice

The structured approach of the PDCA cycle fosters an environment of continuous improvement within project management. Organisations that adopt PDCA typically experience enhanced quality of deliverables, improvement in team dynamics, and greater alignment with client expectations (Xie et al., 2024). Moreover, the iterative nature of PDCA supports adaptive project management approaches, allowing for flexibility in adjusting project plans to evolving circumstances (Chen et al., 2022).

Furthermore, PDCA serves as a bridge integrating various project management methodologies. For instance, it complements traditional methodologies like Waterfall, as well as contemporary Agile frameworks, by providing a clear foundation for planning, executing, and reviewing project components (Taraba, 2018). This adaptability makes PDCA relevant across multiple sectors, from engineering projects to healthcare initiatives, where maintaining quality and efficiency is paramount.

3.4.2.2 Challenges and Best Practices in Applying PDCA

Despite the benefits of PDCA, organisations may encounter challenges during its implementation. Common obstacles include resistance to change, inadequate training in PDCA methodologies, and difficulty fostering a culture that embraces continuous improvement (Sun, 2023). To counteract these challenges, organisations should invest in training programs aimed at enhancing team capabilities in PDCA execution. Engaging stakeholders in the planning stage can also foster buy-in and participation, cultivating a shared commitment to project success (Xie et al., 2024).

Moreover, integrating technology can augment the effectiveness of the PDCA application. Utilising project management software that supports data collection and performance tracking streamlines the Check phase, ultimately driving more efficient decision-making (Zhao et al., 2017). By leveraging technology and bolstering team skills, organisations can create robust PDCA frameworks that enhance their overall project management capacities.

The theoretical foundation of project management, particularly through methodologies like the PDCA cycle, emphasises the importance of systematic planning, execution, evaluation, and adaptation. As organisations strive for improved project outcomes and operational excellence, leveraging PDCA as a continuous improvement tool becomes increasingly pertinent. By engaging in iterative processes, organisations not only enhance their project management competencies but also position themselves for long-term success in a competitive landscape.

In conclusion, effective project management underpinned by PDCA fosters a culture of utilization, striving for excellence in deliverables and stakeholder satisfaction, ensuring that project teams are responsive to challenges and proactive in their approach.

3.5 Digitalisation in Manufacturing (Industry 4.0)

The integration of digitization and automation in the manufacturing sector has gained significant relevance in the context of Industry 4.0, symbolizing the digital transformation of manufacturing processes and highlighting the important role of advanced technologies such as the Internet of Things (IoT), artificial intelligence (AI), and cloud computing. This transformation aims to enhance productivity and efficiency while optimising operations through data analytics and real-time reporting, particularly utilising platforms such as Power BI.

Automation encompasses a diverse array of technologies, including robotics, computer-aided manufacturing, and flexible manufacturing systems (Ratnasingam et al., 2019; Salim et al., 2020). As noted by Ng and Kanagasundaram, automated technologies enable manufacturers in high-wage economies to offset labour costs and achieve faster returns on investment due to increased production rates (Ratnasingam et al., 2019). This observation is consistent with the findings of Iyer et al. (2024), who identified that trends such as Big Data and AI are shaping the future of automated manufacturing, promising substantial benefits across various sectors. Such an environment necessitates effective data management and visualisation tools, with Power BI emerging as a pivotal solution for reporting operations and decision-making processes within these automated systems.

Furthermore, the transition toward automation is driven by the need for enhanced operational performance and sustainability. A study focusing on manufacturing firms in Saudi Arabia indicated that automation positively impacts operational performance and profitability (Alharbi, 2024). This performance boost is largely attributed to data from IoT-enabled devices, which facilitate real-time monitoring and control of manufacturing processes (Tanaya, 2024). Liao (2020) discusses the necessity of a high level of automation in semiconductor manufacturing, emphasising the importance of real-time data collection and processing to improve coordination among manufacturing components.

The potential of digitisation and automation becomes even more pronounced when integrated with cloud computing technologies. Tanaya (2024) elaborates on how the shift from traditional Distributed Numerical Control systems to models like MTConnect enhances data exchange in automated manufacturing setups, promoting efficiency and integrated reporting. By leveraging cloud-based platforms, manufacturers can enhance collaboration across various departments and integrate reporting systems into unified dashboards, streamlining the analysis and dissemination of manufacturing performance metrics (Kergroach, 2017).

Moreover, the application of advanced analytics in manufacturing not only drives productivity but also fosters an agile operational framework. According to Azman and Ahmad (2023), the strategic incorporation of automation and robotics is projected to drive the evolution of smart manufacturing, emphasising the importance of aligning technological advances with strategic planning to bolster global competitiveness. This agility enables manufacturers to adapt to market fluctuations while maintaining high productivity levels, a synergy further enhanced by comprehensive data analytics capabilities provided through platforms like Power BI.

Additionally, it is crucial to consider the human aspect in the integration of automation. Although automation significantly alters the manufacturing landscape, as highlighted by Moniz and Krings (2016), human involvement remains critical in overseeing and interacting with automated systems. This interaction necessitates careful design and implementation of human-robot collaborations to maximise efficiency while addressing challenges associated with workforce dynamics. Insights from Oliff et al. (2018) on the essential role of human factors in collaborative manufacturing environments underscore the need for a balanced approach that includes human oversight in automated processes.

In conclusion, the convergence of digitisation and automation within manufacturing heralds a new era centred on data-driven decision-making and operational efficiency. The role of Power BI in facilitating comprehensive reporting and analysis is crucial, as it serves as an essential tool in visualizing complex datasets generated by automated manufacturing processes. As industries continue to embrace these technological advancements, it is imperative to remain vigilant regarding the interplay between automation, human factors, and the continuous evolution of operational strategies.

Despite the many advantages of digitisation, challenges such as the need for skilled personnel, cybersecurity risks, and the initial investment in new technologies can impede adoption. They emphasise the importance of strategic planning and investment in digital capabilities to fully leverage the potential benefits of digitisation in logistics and distribution. (Rushton, 2017)

3.6 Problem solving

Problem-solving is a fundamental skill in various fields, including business management, engineering, and social sciences. Effective problem-solving techniques are essential for analysing issues, making informed decisions, and designing effective solutions. One renowned approach used in problem-solving is the 5W1H analysis, a method that utilises six fundamental questions: What, Why, Who, Where, When, and How. This analytical framework, often called the Kipling Method due to its association with Rudyard Kipling, is a versatile tool for dissecting complex problems and improving clarity. (Benaddi et al., 2022).

From the perspective of a team leader within the context of Sinek's (2018) methodology, utilising the 5W1H framework allows leaders to articulate their vision more clearly, addressing essential elements that guide decision-making and action. For instance, when a leader articulates the 'What' of their mission, they define the goals; the 'How' conveys the methods by which these goals will be achieved, while the 'Who' identifies the key stakeholders involved. This structured inquiry enables leaders to foster a sense of shared purpose and engagement among their teams.

The 5W1H framework offers a comprehensive methodology for approaching problem-solving by encouraging thorough exploration of the context and underlying factors of an issue. By systematically addressing each question, analysts and decision-makers can comprehensively categorize the problem and its implications, leading to well-rounded solutions.

- **What** refers to the identification of the problem at hand—understanding the nature of the issue and its ramifications.
- **Why** seeks to uncover the reasons behind the problem's occurrence, which is crucial for identifying root causes.
- **Who** involves in determining the stakeholders affected by the problem or those responsible for addressing it.
- **Where** contextualizes the problem within a specific location or environment, which can influence its severity and the effectiveness of potential solutions.
- **When** implies the timeline related to the issue, including when it occurred and the urgency of addressing it.
- **How** examines the methods by which the problem can be solved, exploring available options and strategies for resolution (Benaddi et al., 2022).

When applied thoughtfully, the 5W1H method promotes critical thinking and can help define objectives that align interventions with desired outcomes, ensuring that solutions address the core of the problem rather than just its symptoms (Prasad & Kumar, 2022).

In business management, the 5W1H framework can be instrumental when analysing corporate social responsibility (CSR) initiatives. By utilising 5W1H, organisations can dissect CSR projects to determine their effectiveness and alignment with corporate values. For instance, answering the "What" can reveal the specifics of a CSR initiative, while "Why" uncovers its purpose—whether it aims to enhance community relations or improve sustainability practices (Prasad & Kumar, 2022).

Moreover, businesses can leverage this framework in crises. For example, during a product recall, teams can use 5W1H to evaluate the scope of affected products (What), ascertain reasons for the recall (Why), identify implicated departments (Who), localize affected markets (Where), determine the timeline for action (When), and outline the steps required to mitigate further issues (How). This structured approach provides clarity and a strategic plan of action, enhancing decision quality in high-stress moments (Benaddi et al., 2022).

Incorporating 5W1H into broader frameworks such as SWOT analysis can bolster problem-solving effectiveness by providing a foundation of information to feed into ongoing assessments (Helms & Nixon, 2010). For example, when performing a SWOT analysis, the insights gained from answering the 5W1H questions can inform the identification of strengths, weaknesses, opportunities, and threats. The integration of these distinct methods fosters a more dynamic approach to understanding complex business challenges.

Additionally, the 5W1H framework has relevance in the domain of public services. It aids in the assessment of innovation efforts by targeting key areas that impact service delivery, thereby ensuring a comprehensive view of the operational context (Benaddi et al., 2022). In the context of technological advancement, such as cloud computing and the Internet of Things, the 5W1H can guide organisations in understanding service integration challenges, resulting in better data interoperability and application outcomes in public services (Gim et al., 2018).

The 5W1H analysis serves as a powerful tool for problem-solving, fostering a systematic exploration of issues that can yield effective solutions across various domains, including business, public service, and technology. Its structured approach ensures that all critical aspects of a problem are considered, making it a valuable addition to organisational strategies aimed at tackling complex challenges. By enhancing the depth of analysis through the 5W1H method, businesses and institutions can cultivate a proactive problem-solving orientation that leads to sustainable and effective outcomes.

As organisations continue to navigate increasingly complex environments, the 5W1H framework will remain an indispensable asset, equipping decision-makers with the necessary inquiries to dissect problems thoroughly and develop actionable strategies.

3.7 Daily Gemba (Daily Management System)

For daily gemba, Knorr-Bremse uses a tool of the Daily Management system. Daily Management Systems (DMS) in production companies are structured meetings designed to enhance operational efficiency, accountability, and continuous improvement. These systems are crucial for monitoring daily activities, optimising resource allocation, and ensuring that production processes align with strategic objectives. The primary purpose of a DMS is to facilitate real-time decision-making and problem-solving, enabling organisations to respond swiftly to challenges and opportunities in the production environment (Kim & Kim, 2011).

One of the key components of a DMS is the integration of material management systems that are based on daily scheduling. This approach allows production companies to synchronise their material flow with daily operational needs, ensuring that resources are available when required, thus minimising downtime and maximising productivity. The implementation of such systems is essential for maintaining an efficient production line, as they provide a structured method for tracking inventory levels, scheduling deliveries, and managing supplier relationships (Kim & Kim, 2011).

In addition, the use of data-driven approaches within DMS can lead to substantial improvements in production efficiency. For instance, integrating data analytics into daily management practices enables organisations to identify trends, forecast demand, and optimise their production schedules accordingly (Zhong et al., 2017). This data-centric approach not only enhances decision-making but also supports the continuous improvement of production processes by providing insights into performance metrics and operational bottlenecks (Zhong et al., 2017).

Furthermore, the adoption of advanced technologies such as RFID systems for real-time manufacturing operation management exemplifies how DMS can enhance operational efficiency in production environments. These systems allow for accurate tracking of materials and products throughout the production cycle, thereby reducing errors and improving inventory management (Liu et al., 2015). The real-time visibility provided by such technologies is crucial for maintaining production flow and ensuring that resources are utilised effectively (Liu et al., 2015).

The core components of a Daily Management System (DMS) in production companies are essential for fostering an environment of continuous improvement, operational efficiency, and effective problem-solving. These components typically include visual management tools, standardised work processes, daily accountability meetings, and performance metrics, all of which contribute to a culture of transparency and responsiveness in production environments.

One of the fundamental aspects of a DMS is the use of visual management tools, such as huddle boards or visibility walls. These tools display key performance indicators (KPIs) and other relevant data in a manner that is easily accessible to all employees. This visibility allows teams to quickly assess performance and identify areas needing attention (Winner et al.,2022). Visual management not only enhances communication but also fosters a sense of ownership and accountability among team members, as they can see the direct impact of their work on overall performance.

Standardised work is another critical component of a DMS. It involves defining and documenting the best practices for each task within the production process. This standardisation ensures that all employees are aligned in their approach, which minimises variability and enhances quality (Hung et al., 2022). By having clear guidelines, production companies can maintain consistency in operations, which is vital for achieving high-quality outputs and meeting customer expectations.

Daily accountability meetings, often referred to as "stand-up meetings," are integral to the DMS framework. These brief gatherings allow teams to discuss progress, address any issues, and plan for the day ahead. Such meetings promote a culture of continuous improvement by encouraging employees to share insights and collaborate on problem-solving (Hung et al., 2022). This daily rhythm not only keeps everyone informed but also empowers employees to take initiative in resolving challenges as they arise.

The use of performance metrics is crucial for evaluating the effectiveness of the DMS. These metrics provide quantitative data that can be analysed to identify trends, measure progress, and inform decision-making (Zhang et al., 2017). By regularly reviewing performance data, production companies can make informed adjustments to their processes, ensuring that they remain agile and responsive to changing conditions in the market.

Modern DMS frameworks often incorporate advanced technologies such as Manufacturing Execution Systems, Power BI, and other data analytics tools. These technologies facilitate real-time monitoring of production processes, enabling companies to optimise resource allocation and improve overall efficiency (Zhang et al., 2017). The integration of such systems supports a data-driven approach to management, allowing for timely interventions and strategic planning.

Introducing a Daily Management System (DMS) into a company often faces major obstacles, especially when there is a lack of understanding about the true need for such a system. The two biggest challenges that a company can face are resistance to change and Data overload for employees. These two challenges are described in more detail in the following paragraphs.

One of the most significant challenges in implementing a DMS is resistance to change among employees. Many workers may be accustomed to existing processes and may view the introduction of a DMS as an additional burden rather than a beneficial tool. This resistance can stem from a lack of understanding of the system's benefits or fear of increased scrutiny on their performance (Kim & Kim, 2011). Overcoming this resistance requires effective change management strategies, including comprehensive training and clear communication about the advantages of the new system (Perez & Sheikh, 2023).

While DMS relies heavily on data for decision making, the sheer volume of information generated can lead to data overload. Employees may struggle to filter through excessive data to identify actionable insights, which can diminish the system's effectiveness (Zeng & Zhang, 2013). Organisations must establish clear guidelines on data management and prioritise key performance indicators (KPIs) to ensure that employees focus on the most relevant information (Zhong et al., 2017).

The implementation of a Daily Management System (DMS) in production companies represents a transformative approach to achieving operational excellence. By integrating structured frameworks such as visual management tools, standardised work processes, daily accountability meetings, and advanced technologies, DMS fosters a culture of transparency, continuous improvement, and responsiveness. These elements ensure that organisations can align daily operations with strategic objectives, optimise resource utilisation, and enhance decision-making through real-time data insights.

Despite its benefits, implementing a DMS is not without challenges. Resistance to change among employees and the risk of data overload are significant barriers that must be addressed through effective communication, training, and data prioritisation. Overcoming these obstacles is essential to unlocking the full potential of DMS in driving productivity, minimising inefficiencies, and adapting to the ever-changing demands of the market.

In conclusion, a well-designed and effectively implemented DMS serves as a vital tool for production companies striving to maintain a competitive advantage. By embedding this system into their daily operations, organisations can build a foundation for sustained growth, agility, and long-term success.

3.8 Role of standardisation in the context of a globally operating manufacturing company

The concept of standardisation plays a pivotal role in globally operating manufacturing companies, acting as a fundamental driver for efficiency, quality, and competitiveness. Standardisation refers to the process of establishing and implementing agreed-upon norms and protocols that govern various dimensions of manufacturing processes, including materials, dimensions, and operational procedures. The significance of standardisation increases in the context of global supply chains, where products and services need to meet uniform criteria to facilitate international trade and interoperability.

One of the primary benefits of standardisation in manufacturing is the enhancement of operational efficiency. According to Zelbst et al. (2012), the use of technologies like RFID can streamline processes, leading to significant improvements in manufacturing effectiveness and efficiency, contributing to operational performance.

Furthermore, Schumacher et al. (2023) emphasise that standards help manufacturers develop and create markets for their products by coordinating consensus on definitions, specifications, and best practices, which is particularly critical for industries characterised by global supply chains. The implications are profound, as standardised practices not only reduce variability but also mitigate risks associated with product quality and compliance across different jurisdictions.

In addition to operational efficiency, standardisation contributes to sustainability in manufacturing practices. Thawornsujaritkul and Boonnual (2024) indicate that lean management practices leverage standardised procedures to enhance sustainability across industrial operations by reducing waste and optimising resource use. Lean principles can serve as a reference point for developing robust standards that align environmental performance with business objectives. Moreover, the establishment of specific standards addressing sustainability can guide manufacturers in minimising resource consumption while promoting long-term ecological balance, which has become a critical imperative in today’s manufacturing landscape.

The ongoing evolution of manufacturing technologies necessitates a strong emphasis on standardisation, particularly regarding interoperability among various systems. Lee et al. (2013) highlight the necessity for standard data representations that facilitate seamless integration and exchange of manufacturing data, ultimately improving the interoperability of diverse systems within manufacturing environments. This is particularly relevant in the context of adopting advanced digital technologies such as IoT and Industry 4.0 paradigms, where heterogeneous systems must communicate effectively to optimise productivity and resource utilisation.

Moreover, the impact of environmental regulations on manufacturing innovation can be mediated through standardised approaches. Research by Zhu et al. (2019) indicates that the design and implementation of environmental regulations play a critical role in fostering technological innovation. By establishing specific standards, manufacturers can align their processes with environmental goals while maintaining flexibility in operational execution. Consequently, this balance between compliance and innovation is essential for companies that operate on a global scale, where varying regulations can complicate operations.

Adherence to international standards not only fosters compliance but also enhances a company's reputation and credibility within the global market. For automotive manufacturers, as discussed by Abatan et al. (2024), adhering to rigorous Environmental Health and Safety practices ensures operational legality and aligns production with societal expectations, thereby reinforcing the importance of strict standards in driving corporate responsibility.

The landscape of standardisation in manufacturing is continuously evolving, with new standards emerging that address unique challenges presented by technological advancements, such as additive manufacturing and automation. García-Dominguez et al. (2020) assert that the rapid development of technologies in additive manufacturing has resulted in a pressing need for clear and applicable standards that consider specific processes and materials. This ongoing dialogue emphasises the importance of adaptive standardisation practices that keep pace with innovations within the manufacturing sector.

To summarise, standardisation is a critical mechanism through which globally operating manufacturing companies can enhance efficiency, sustainability, and compliance. As industries navigate increasingly complex global supply chains, the establishment and adherence to uniform standards will be fundamental in ensuring that operations remain competitive, responsible, and aligned with both market demands and regulatory frameworks.

4 Problem description, methods, and data

This is an introduction to the section about the description of the problem, methodology, and input data of this diploma thesis. The section will present the Knorr-Bremse company and individual locations that are analysed to address the issue related to the sale of packaging.

The methodology is going to be established to reach the desired goal set in Chapter **1.1 Goal of Thesis**. Later, using this established methodology, data about the problem of the sale of packaging is collected using a Power BI report, production data, and time snapshots. Then SIPOC analysis for each time snapshot is created with inputs and outputs of each analysed step, also each step is evaluated by value analysis. Chapter **5 Results and Discussion** presents the results and discussion, detailing the implementation of corrective measures and the benefits they brought.

First, a specific problem in each of Knorr-Bremse's subsidiaries is described. For a subsidiary in Liberec methodology is established and later used for improving the processes of the sale of packaging in other locations.

4.1 Introduction of the Knorr-Bremse company

Knorr-Bremse is a globally running company employing around 32,000 people, operating in 30 different countries with 100 locations. The company is divided into two main divisions: commercial vehicles and rail. For this diploma thesis, the main focus is on the division of commercial vehicles. The company was founded in 1905 by George Knorr in Berlin and started with the development and production of air brakes for trains. Knorr-Bremse is currently one of the leading suppliers for the whole train and commercial vehicles industry. (Knorr-Bremse,2025).

4.1.1 Introduction of Knorr-Bremse Liberec, Czech Republic

The Czech location of Knorr-Bremse has a long history of production of braking systems for commercial vehicles. Between 1968 and 1991 company operated as

Autobrzdy, producing Air Braking Components for commercial vehicles. The biggest customers were AVIA, KAROSA, LIAZ, and TATRA. In 1991 started production of components for Knorr-Bremse and in 1993, Autobrzdy for commercial vehicles was fully merged by Knorr-Bremse. In 2009, Knorr-Bremse relocated its production from Hejnice to the Liberec Industria Zone Nord. Currently, Knorr-Bremse's subsidiary in Liberec operates in two halls, H5 and H7. Hall H5 is dedicated to serial production for aftermarket and OE customers. In H7 hall, Knorr-Bremse refurbishes old Knorr-Bremse components such as Air Disc Brake callipers, compressors, and more. The company's Liberec subsidiary employs around 450 employees, and the annual revenue from production is around 130 million euros. This makes Knorr-Bremse Liberec one of the biggest employers in the Liberec region. (Knorr-Bremse, 2025)

4.1.2 Introduction of Knorr-Bremse Lisieux, France

The Lisieux facility focuses on the production and development of brakechambers and air compressors for commercial vehicles. With approximately 450 employees, the site contributes significantly to Knorr-Bremse's overall success. The subsidiary generates an estimated annual revenue of around 250 million EUR, highlighting its economic importance. Its strategic location in France allows for efficient distribution and collaboration with key clients across Europe. Additionally, the Lisieux site is actively involved in innovation and technological advancements within the braking system industry. (Knorr-Bremse, 2025)

4.1.3 Introduction of Knorr-Bremse Namegwa, Japan

Japanese subsidiary of Knorr-Bremse is focusing on the development of brake control and wheel end areas, driver assistance systems and the fourth level of automated driving. Another focus area of Japan's subsidiary is the production of brake lining, brakechambers, Brake discs and electronic power steering (EPS). (Knorr-Bremse,2025)

The First Methodology is established to reach the desired goal set in Chapter **1.1, Goal of Thesis**. Later, using this established methodology, data about the problem of the sale of packaging is collected. On chosen production lines problem of the sale of packaging is solved by using work redistribution, standardisation, and, if needed, also a change in layout. These changes and improvements are validated using Power BI reports, and at the end of each, savings are calculated.

4.2 Methodology establishment

This section of the diploma thesis deals with the establishment of methodology, which is going to be used during the project. Each section will be managed using the PDCA project management cycle.

First of all, data needs to be gathered as much as possible. For that tool of Knorr-Bremse's Daily Management System has been used. For visualisation of the data from the DMS company uses a Power BI report. Not all locations and production areas use this digitised solution for the collection and visualisation of data, hence tool of time snapshot and production database is used for detailed insights into each analysed process.

With the gathered data problem is described in more detail using the 5W1H analysis. This structured approach helps to systematically analyse the issue, ensuring a comprehensive understanding of its scope, causes, and impact. By answering key questions, a clear function can be created for developing effective solutions in the next phases of the PDCA cycle. For each line tool of the SIPOC map is used, where every Time snapshot is broken down in more detail with inputs and outputs of each step, and value analysis is created.

With value analysis, most Non-Value-Added (NVA) steps are eliminated, leading to the creation of a new, optimised process design. This redesigned process enhances efficiency, reduces waste, and improves overall performance before moving into the implementation phase. This new process is being discussed with each Production Unit Leader (PUL) and Logistics representative for discussion. After the discussion, feedback points are implemented in the newly proposed process.

The newly designed process is then tested by operators, allowing for real-time feedback and necessary adjustments. If modifications are required, they are incorporated to optimise the process. Once finalised, the new process is implemented, and operators receive proper training across all shifts to ensure smooth adoption and efficiency.

The next phase focuses on monitoring and validating process changes to ensure they achieve the desired improvements. Key performance indicators (KPIs) are tracked, and data is analysed to assess effectiveness. Any deviations or inefficiencies are identified, allowing for further refinements if needed. This step ensures the sustainability and long-term success of the implemented process.

The final two steps in the methodology are standardisation of the process and calculation of savings. Standardisation ensures that the improved process is documented, consistently followed, and maintained across all shifts. The calculation of savings evaluates the financial impact of the changes, quantifying cost reductions and efficiency gains to demonstrate the success of the process improvements.

4.2.1 Problem description

Effective project management requires a structured approach to problem-solving, ensuring continuous improvement and efficiency. One widely recognised methodology for this process is the **PDCA (Plan-Do-Check-Act) cycle**, which provides a systematic framework for identifying, analysing, and addressing issues.

The sale of packaging is an operation at the end of the production process, when the operator (finisher) of the last station after the production of all pieces, writes off the full package into the SAP system, then the logistics worker receives a signal about the produced packages for loading through the E-KANBAN application. This application is running in cooperation with the SAP system. Then the package is loaded and taken to the warehouse. The problem with the sale of packaging is appearing on several lines in Knorr-Bremse Liberec, mainly in the Brakechamber production unit. According to the data based on the DMS (Daily Management System), the sale of packaging is one of the TOP 3 downtimes of the given lines. The intention is not to eliminate this downtime, but to reduce it so that lines are not slowed down or stopped.

On the other lines in KB Liberec, the sale of packaging is already optimised, so it is not necessary to address it further.

For the Machine shop area, the sale of packaging is the process by which the operator writes off full packages of manufactured pieces in the SAP system. The logistics operator moves around the workroom at regular intervals, so he does not receive a signal via the E-KANBAN application, but receives a visual signal to take the finished gitterbox away using a posted sales note on the gitterbox. Currently, machine shop operators have to go to one place to sell packages, creating waste in the form of movement. The current state is also a limit for the planned three-machine operation, where one operator will operate 3 machines (currently one operator operates 2 machines) - this fact is based on the project "Optimisation of the machine shop". Another potential on the machine shop after the SAP system is going to be instaled into the computers is the reporting of work at the end of shift, where operators must enter the following information: Machine ID, Number of OK parts made, Number of NOK parts made, order quantity, number of order and signature that confirms the handover of shift. The job reporting is also done on one central computer and there is wastage in the form of movement and wastage in the form of waiting.

Problem observation and analysis are going to be discussed in more detail for each line of the Brakechamber area in KB Liberec. For analysis of the problem observation, there will be used tool of time snapshot.

In Knorr-Bremse’s subsidiary in Lisieux, France problem appears similar to that in Liberec on the Brakechamber line LAA2. The problem appears after the last finished product, where the end-of-line operator needs to write off produced production. Data about finished packagings is then displayed to the manipulant who takes the finished box to the warehouse. According to the production data, the Sale of packaging is one of the TOP3 LAA2’s line downtimes. This line also has an inconvenient layout; therefore, a layout change is needed.

In Knorr-Bremse’s subsidiary in Namegawa, Japan problem also appears as in Liberec, but in the Machine shop area. A Problem appears with each finished product. Finished products are put into KLT boxes and written off into the SAP system individually, which causes a slowdown of the production process. These KLT boxes are stacked on the pallet ale later taken to the warehouse by a logistics worker. By changing writing of production into the SAP from one box to whole palet, can be saved time and waste of overprocessing.

For the problem description, the 5W1H method is going to be used. This is a widely used tool for the description of the Problem, and it's a core tool of the Problem-Solving methodology.

4.2.1.1 Description of the problem using the 5W1H method

Effective problem-solving requires a structured approach to fully understand the nature of an issue and identify its root causes. The 5W1H methodology — **What, When, Where, Who, When, How** is a powerful tool for breaking down problems and ensuring a thorough analysis. This method helps to define all aspects of a problem systematically, enabling the development of targeted and sustainable solutions.

By addressing these six key dimensions, the 5W1H methodology ensures that no critical factors are overlooked during the problem-solving process. It provides a clear framework for asking the right questions and gathering relevant information, which is essential for making informed decisions. The approach also promotes clarity and structure, allowing teams to align on the problem description and collaborate effectively on resolving the issue.

In this section, the focus will be on the application of the 5W1H method as a fundamental tool for problem description and analysis. Its role in fostering a deeper understanding of challenges, facilitating better communication, and supporting precise decision-making will be discussed, emphasising the importance of a systematic approach in addressing problems in complex environments.

First, the focus will be on high runner Brakechamber lines NG4, OBC4, and OBC3. These lines are very important for meeting customer demand for brakechambers. Each downtime is a big loss in terms of money; therefore, these lines are first where the 5W1H analysis has been made. In Table 1 can be seen 5W1H analysis in the Brakechamber area.

Table 1: 5W1H Analysis of the Sale of packaging on Brakechamber lines in KB Liberec
Source: Own

What?	Stopping the production line due to the sales of packaging.
When?	When finishing operator needs to sell a full box of the product.
Where?	Last station of every Brakechamber line in the Liberec production plant of Knorr-Bremse
Who?	Finishing operator
Why?	Between 1.10.2023 and 31.3.2024, this downtime appeared on Brakechamber lines **524 times** and lasted in total **9598 min**, average downtime for Sale of packaging was **1600 min/month i.e., 18,3 min/shift**
How?	After finishing the last OK product.

After defining the 5W1H analysis, the problem can be broken down into individual lines. For data collection has been chosen new tool in the Knorr-Bremse company DMS report using Microsoft's Power BI tool. Thanks to the data size of the problem can occur.

The second important area to be standardised is Machining in KB Liberec. Machining and ADB line are together the second production unit where Knorr-Bremse produces on Machining machines Brake callipers, Brake calliper carriers, and later some of these Brake callipers are assembled on the ADB (Air Disc Brake) line. In the Machining area, there is no standard for "Sale of packaging"; therefore, this area falls under this project. In Tabel 2 can be seen 5W1H analysis for Machining area.

Table 2: 5W1H Analysis of the Sale of packaging at Machining area in KB Liberec
Source: Own

What?	Waste in for of movement with each Sales of packaging into the SAP system.
When?	When every package is finished – write-off of finished pieces into the SAP system.
Where?	Each Machine in Machining area in Knorr-Bremse Liberec
Who?	Every operator in Machining area
Why?	Whith every Sale of packaging walk to the computer with SAP system takes up to 45 seconds.
How?	After finishing the last OK product from the box.

During the Analysis of the Machining area, another potential improvement occurred. At the end of each shift, operators need to report their work during the shift into the Shift handover book. The following information, such as: Machine ID, Number of OK parts made, Number of NOK parts made, order quantity, number of orders, and a signature that confirms the handover of shift, needs to be filled into this book. Then all this information is filled into the SAP system. The Problem that occurred was that at the end of each shift, all operators needed to fill this information into the SAP systém, but there was only one central computer with this system. That caused waste in the form of waiting, because operators needed to wait for each other. In Table 3, can be seen 5W1H analysis for Work reporting at the end of each shift.

Table 3: 5W1H Analysis of the Work reporting in Machining area in Liberec

Source: Own

What?	Waste in for of movement with each Sales of packaging into the SAP system.
When?	When every package is finished – write-off of finished pieces into the SAP system.
Where?	Each Machine in Machining area in Knorr-Bremse Liberec
Who?	Every operator in Machining area
Why?	Whith every Sale of packaging walk to the computer with SAP system takes up to 45 seconds.
How?	After finishing the last OK product from the box.

Next, the focus will be on the high runner Brakechamber line LAA2 in KB Lisieux, France. This line is very important for meeting customer demand for brakechambers. For a description of this problem, a 5W1H analysis has been made and can be seen in Table 4.

Table 4: 5W1H Analysis of the Sale of packaging on Brakechamber lines in KB Lisieux

Source: Own

What?	Waste in for of movement with each Sales of packaging into the SAP system.
When?	When finishing operator needs to sell a full box of the product.
Where?	Last station of the line LAA2 in the Lisieux production plant of Knorr-Bremse
Who?	Finishning operator
Why?	Every sale of packaging takes in average 19,1 min.
How?	After finishing the last OK product from the box.

The last issue that needs 5W1H analysis to find the root cause of the slow writing of the production is Machining area in the Japanese subsidiary of Knorr-Bremse in Namegawa. This 5W1H analysis is presented in Table 5.

Table 5: 5W1H Analysis of the Sale of packaging in the Machining area in KB Namegawa

What?	Waste in for of movement with each Sales of packaging into the SAP system.
When?	When finishing operator needs to sell a full box of the product.
Where?	Last station of the line LAA2 in the Lisieux production plant of Knorr-Bremse
Who?	Finishning operator
Why?	Every sale of packaging takes in average 19,1 min.
How?	After finishing the last OK product from the box.

5 Results and discussion

This part of the thesis focuses on how the challenges surrounding the sale of packaging were identified and resolved, using a structured methodology tailored to each subsidiary of Knorr-Bremse. It outlines the step-by-step approach taken to address the issues effectively and ensure consistent improvements across different branches. In addition, this section presents a newly developed digital solution aimed at further streamlining and enhancing the packaging sales process, laying the groundwork for more efficient operations and continuous future improvements.

5.1 Knorr-Bremse Liberec, Czech Republic

This section of the diploma thesis focuses mainly on subsidiary in Liberec, Czech Republic, where the problem is broken down into individual production lines and two specific areas of production. These issues with the sale of packaging are solved, and benefits are calculated at the end of each section.

5.1.1 Brakechamber Lines of KB Liberec

This section of the thesis focuses on individual production lines that will be analysed. The objective is to describe existing issues, identify NVA activities, improve the production process through job redistribution, propose these changes to the Production Unit Leader, and create the standard. The first line to be analysed is the NG4 line, because it is the most important one from the Brakechamber area at KB Liberec.

5.1.1.1 Optimisation of the Sale of packaging on the NG4 line

The first line to be analysed is the NG4 line, one of the most important production lines for Knorr-Bremse Liberec. The company invested 1 million euros in new automation, which required a change in the layout. This change resulted in the sale of packaging becoming the top cause of downtime on the NG4 line.

The following paragraph will describe the current state of the process, which will be optimised later.

According to the data from the NG4 line, the sale of packaging is the TOP1 downtime. According to data from the DMS Power BI report, the sale of packaging represents the most significant downtime on the NG4 line. Figure 7 shows the data Pareto of all downtimes on the NG4 line, where the biggest downtime is highlighted on the left. Different colours in the bar of the graph represent shifts, which means that the sale of packaging is a repetitive problem occurring across all shifts and needs to be solved. The right side of the report shows detailed statistics and the distribution of downtime between shifts.

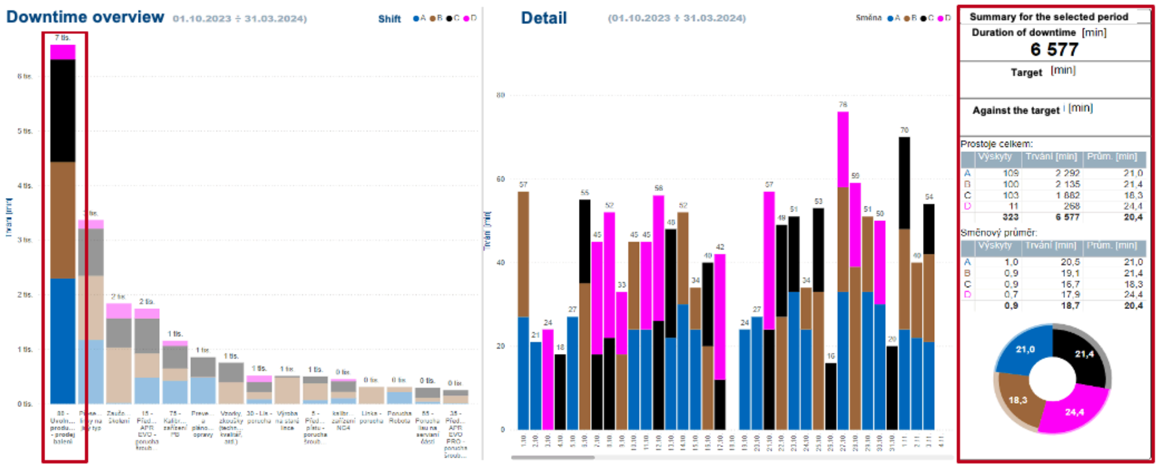


Figure 7: Power BI report of all NG4 line downtimes in the monitored period

Source: Internal source of Knorr-Bremse

In the monitored period between 1/10/2023 to 31/3/2024, downtime of the Sale of packaging occurred 323 times with a total duration of 6577 min. The duration of the Sale of packaging is on average 3:15 min according to time snapshot monitoring. The cycle time of the NG4 line is currently set for 54s. In Figure 8, SIPOC analysis can occur that has been made based on a time snapshot. Using SIPOC analysis, the inputs and outputs of each step were fed into the analysis and all activities has been evaluated if they are Value Added (VA), Value Engineering (VE), that means the activity is needed for the proces but doesn't add any value or Non Value Added (NVA). All this information falls under „P" in the PDCA cycle of project management. In the next section, the project is getting into,, D“ part of the PDCA cycle that stands for,, Do“.

SIPOC Map Sale of packaging NG4

Project title: Optimisation of Sale of Packaging | Revision date:

Mapped by: Petr Nohýnek | Date: 04.01.2024

NVA - Waste | VA | VE

	Inputs	Process Steps	Tim	Valu	Outputs	Foto
1	Sale ticket	Filling up the Sale ticket	0:00:11	VE	Filled Sale ticket	
2	Filled Sale ticket	Putting the Sale ticket into pocket	0:00:05	VE	Sale ticket in the pocket	
3	Sale ticket in the pocket	Walk	0:00:17	NVA	Sale ticket in the pocket	
4	Sale ticket in the pocket	Sale of packaging in SAPu	0:00:27	VE	Sold packaging	
5	Sale ticket in the pocket	Walk	0:00:16	NVA	Sale ticket in the pocket	
6	Sale ticket in the pocket	Placement of pocket on the box	0:00:03	VE	Box with sticked pocket	
7	Last piece	Inserting of last piece to the box	0:00:04	VA	Box of full products	
8	Box of full products	Insert of Interleaf	0:00:05	VE	Box of full products with interleaf	
9	Box of full products with interleaf	Closing of the box	0:00:09	NVA	Closed full box	
10	Tape	Taping of the box	0:00:15	NVA	Taped box	
11	Taped box	Unbraking of the box	0:00:06	VE	Unbrkaed box	
12	Unbrkaed box	Putting the box to dedicated place	0:00:24	NVA	Taken away box	
13	Empty box	Location of new box	0:00:19	NVA	Located empty box	
14	Located empty box	Opening of the box	0:00:03	VE	Open new box	
15	Open new box	Insert of the stopper	0:00:02	VE	New box with stopper	
16	New box with stopper	Opening of the box	0:00:04	NVA	Open new box	
17	Open new box	Straightening of the box	0:00:25	NVA	Straightened new box	
18						
			0:03:15			

Figure 8: SIPOC map based on snapshot on the NG4 line, Analysis of inputs and outputs, Value Analysis

Source: Own

After the SIPOC map has been done for at least two time snapshots, the new process can be established. First, most of the NVA activities need to be removed to improve the process. In SIPOC analysis has been observed that waste of movement is the biggest NVA analysis, based on which there is a need for a layout change. For further anylsis and design of the new layout has been used tool of Spaghetti diagram, which is used for showing the movement of operators in the process. In Figure 9, can be seen layout change for the NG4 line with the Spaghetti diagram. By a layout change, have been saved 30 s for each sale of packaging. The biggest problem with the current layout is that the computer, where the operator of the final station needs to write off finished packaging, is too far from the workstation. The next issue is with the space for boxes, which requires a change in the location of the drop racks.

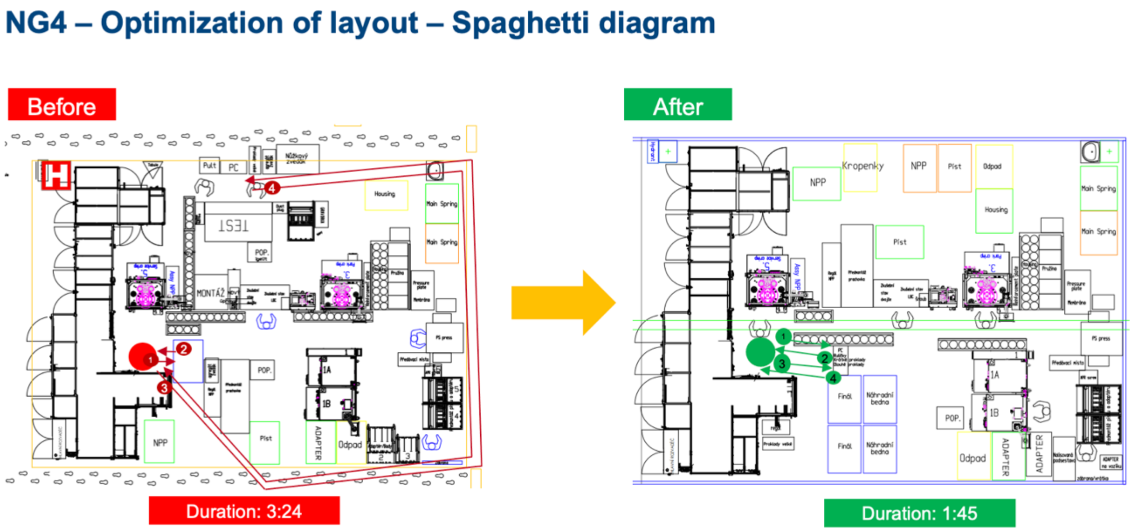


Figure 9: Spaghetti diagram and layout change of the NG4 line

Source: Own (According to the Internal source of Knorr-Bremse)

The outcome of the analysis is the following changes: Change of layout, work redistribution. The analysis revealed that box packing represents the second most time-consuming stage of the process. Therefore, work redistribution has been suggested to the PUL (Production Unit Leader). The redistribution of work concerns the packing of the box, which means for wooden boxes of the final product, putting of lid on top of the box, and for the cardboard box, it concerns sealing the box with tape.

All these steps have been put into the action plan that can be found in Table 6.

Tabulka 5: Action plan for optimisation of the Sale of packaging on the NG4 line in KB Liberec

Source: Own

Line	Action	Required by	Responsible	Status
NG4	Problem description using the 5W1H method	30.01.2024	P. Nohýnek	Done
NG4	Measuring the current state using the time snapshot method	31.03.2024	P. Nohýnek	Done
NG4	Analysis of the current state using: SIPOC map, Value Analysis (VA, VE, NVA)	15.02.2024	P. Nohýnek	Done
NG4	Design of new Process	16.02.2024	P. Nohýnek	Done
NG4	Introduction of PUL and logistics representatives	27.02.2024	P. Nohýnek	Done
NG4	Implementation + layout change	06.04.2024	P. Nohýnek	Done
NG4	Test of the new process + training of operators	16.04.2024	P. Nohýnek	Done
NG4	Standardisation of process – creation of SOS (Standard Operation Sheet)	22.04.2024	P. Nohýnek	Done
NG4	Validation of the process and Saving calculation	17.06.2024	P. Nohýnek	Done

The next step is implementation of changes into the Line. First, there is a need for a layout change, which is the most important change. A layout change was made on the 6th of April 2024. Consequently, started training of operators for the new process with work redistribution. The NG4 line operates on 3 shifts, so all shifts need to be trained.

With the training finished, the project moves to the ,,C" of the PDCA cycle of Project management, where the success of implemented changes are monitored. Standard validation time in KB Liberec is set for 7 weeks. Validation is occured in two ways.

The first way of validation is the random occurrence of the process using the time snapshot method and SIPOC analysis. The Second way is monitoring the downtimes in Power BI Pareto of downtimes using data from DMS. In Figure 10, can be occured change in data comparing data from January 2024 and November 2024. Some minor changes and problems have occurred. For example, operators didn't fill correct time into the DMS report, which meant that in Power BI, the downtime of the sale of packaging occurred higher than it was in reality. After 7 weeks of validation without issue, the process can be Standardised.

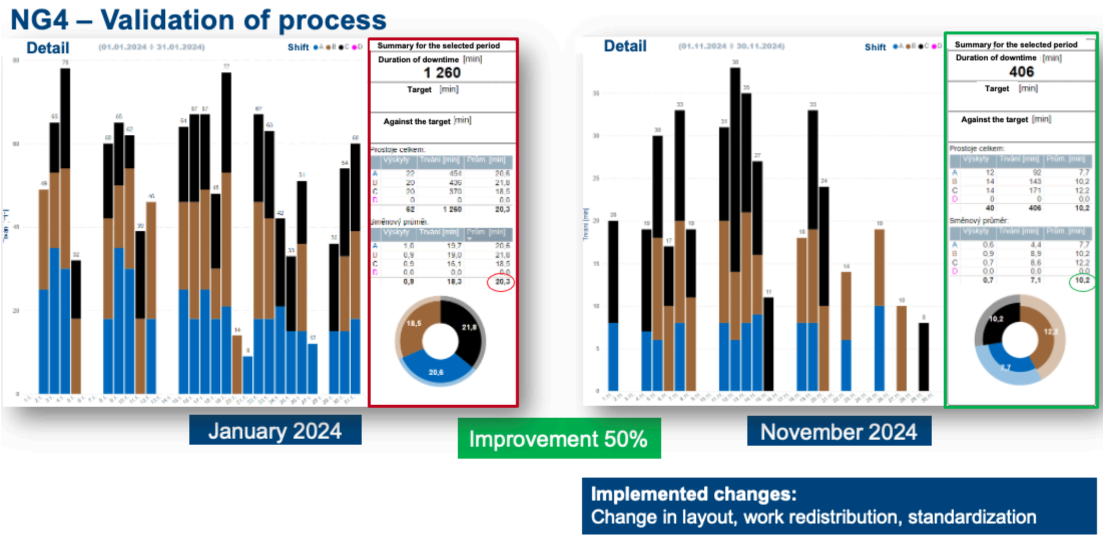


Figure 10: Validation of Process – Change in DMS Power BI data report on the NG4 line in KB Liberec

Source: Own (According to internal source of Knorr-Bremse)

All these changes also bring savings. Which are going to be calculated. All these calculations have been approved by the Controlling department of KB Liberec.

<u>Savings calculation:</u>

Direct wage – 8,9 CZK/min

Duration of downtime before optimisation – 20,3 min/shift

Duration of downtime after optimisation – 12,4 min/shift

Time saving – 7,9 min/shift

Saving per shift -> 8,9*7,9 = 70,31 CZK (2,96€)

Saving per week (15 shifts) -> 70,31*15 = 1054,65 CZK (44,5€)

Saving per year (50 weeks) -> 1054,65*50 = 52 732,5 CZK (2225€)

Total saving per year –> **52 732,5 CZK (2225€)**

C/T of NG4 line – 0,9 min (54 s)

Frequency -> 8 times/shift -> 7,9min/shift

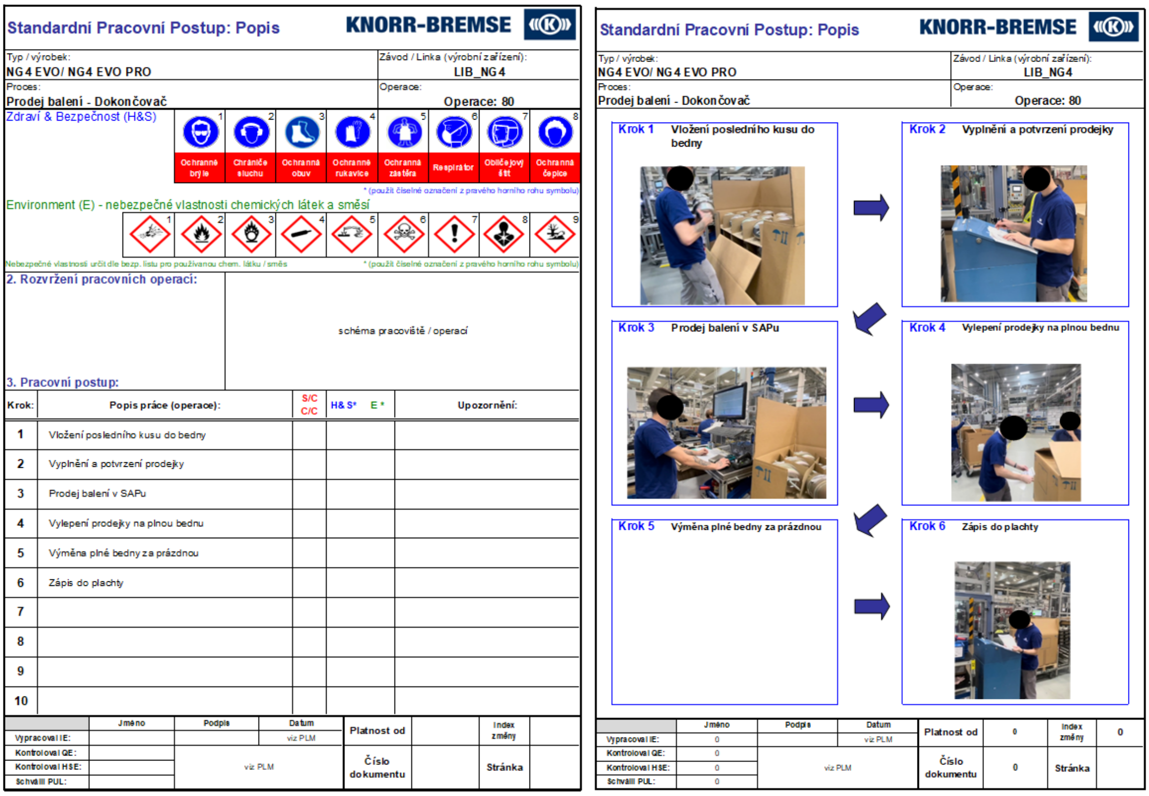
For each Shift can be made 7,9/0,9 = 8,7 pcs more of Products

Per each Week can be made 8,7*15 = 130,5 pcs more of Products

Per Year can be made 130,5*50 = 6525 pcs more of Products

After the calculation of savings, Knorr-Bremse is going to save 52,732,5 CZK (2,225 €) on down times of line NG4 and also going to be able to produce 6,525 pcs of Products more in one year. With the average price of produced goods on the NG4 line, KB could potentially earn 6,525,000 CZK, which is approximately 253,841 EUR.

For the Standardisation of Processes, Knorr-Bremse uses a Standard Operation Sheet, which can be seen in Figure 11.



Standardní Pracovní Postup: Popis — KNORR-BREMSE

Typ / výrobek: NG4 EVO/ NG4 EVO PRO — Závod / Linka (výrobní zařízení): LIB_NG4

Proces: Prodej balení - Dokončovač — Operace: Operace: 80

Zdraví & Bezpečnost (H&S): Ochranné brýle, Chrániče sluchu, Ochranná obuv, Ochranné rukavice, Ochranná zástěra, Respirátor, Obličejový štít, Ochranná čepice

Environment (E) - nebezpečné vlastnosti chemických látek a směsí

2. Rozvržení pracovních operací: schéma pracoviště / operací

3. Pracovní postup:

Krok:	Popis práce (operace):	S/C C/C	H&S* E*	Upozornění:
1	Vložení posledního kusu do bedny			
2	Vyplnění a potvrzení prodejky			
3	Prodej balení v SAPu			
4	Vylepení prodejky na plnou bednu			
5	Výměna plné bedny za prázdnou			
6	Zápis do plachty			
7				
8				
9				
10				

Standardní Pracovní Postup: Popis — KNORR-BREMSE

Typ / výrobek: NG4 EVO/ NG4 EVO PRO — Závod / Linka (výrobní zařízení): LIB_NG4

Proces: Prodej balení - Dokončovač — Operace: Operace: 80

Krok 1 Vložení posledního kusu do bedny

Krok 2 Vyplnění a potvrzení prodejky

Krok 3 Prodej balení v SAPu

Krok 4 Vylepení prodejky na plnou bednu

Krok 5 Výměna plné bedny za prázdnou

Krok 6 Zápis do plachty

Figure 11: Standard Operation Sheet of optimised process on NG4 line in KB Liberec

Source: Own

5.1.1.2 Optimisation of the Sale of packaging on the OBC 4 line

The next very important line for KB Liberec is OBC4. It is the second most important line in the Brakechamber area. This line is automated a lot, yet there is a problem with the sale of packaging, generating downtime on the line. Therefore, optimisation of this process would be a welcome change. For the optimisation of OBC4's sale of packaging has been established action plan, which can be found in Table 7.

Table 6: Action plan for optimisation of the Sale of packaging on the OBC4 line in KB Liberec

Source: Own

Line	Action	Required by	Responsible	Status
OBC4	Problem description using the 5W1H methodics	30.01.2024	P. Nohýnek	Done
OBC4	Measuring the current state using the time time snapshot method	31.03.2024	P. Nohýnek	Done
OBC4	Analysis of the current state using: SIPOC map, Value Analysis (VA, VE, NVA)	22.04.2024	P. Nohýnek	Done
OBC4	Design of new Process	29.04.2024	P. Nohýnek	Done
OBC4	Introduction of PUL and logistics representatives	13.06.2024	R. Konta, J. Najman, P. Nohýne	Done
OBC4	Implementation	28.08.2024	R. Konta, P. Nohýnek	Done
OBC4	Test of new process + training of operators	02.09.2024	P. Nohýnek	Done
OBC4	Standardisation of process – creation of SOS (Standard Operation Sheet)	30.10.2024	P. Nohýnek	Done
OBC4	Validation of process and Saving calculation	16.12.2024	P. Nohýnek	Done

According to data from the Power BI report based on data from DMS, which can be seen in Figure 12, the sale of packaging on line OBC4 is the TOP2 downtime. Different colours in the bars represent various shifts, which means that the problem of the sale of packaging is a repetitive problem occurring across all shifts. The left side of the picture represents all downtimes of the OBC4 line in the selected period, the right shows detailed information and statistics about the downtime of the sale of packaging.

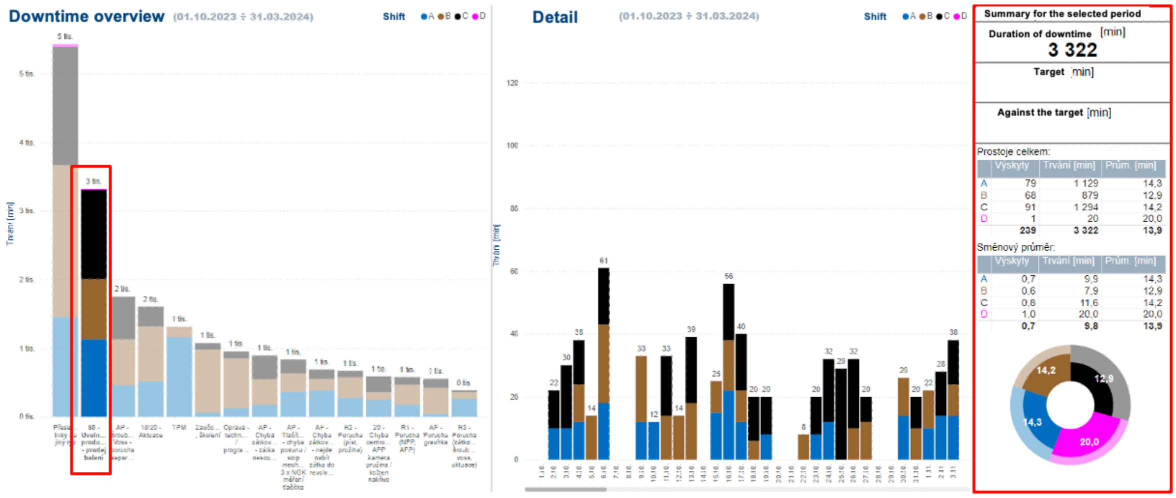


Figure 12: Power BI report of all OBC4 line downtimes in the monitored period

Source: Internal source of Knorr Bremse

In the monitored period between 1.10.2023 to 31.3.2024, this downtime occurred 223 times with a total duration of 3062 min. The cycle time of the OBC4 line is currently set at 30 s, but it can differ between various partnumbers of products. On following Figure 13 can be seen how value analysis has been made using the SIPOC map based on a time snapshot. With the SIPOC analysis inputs and outputs of each step have been identified. Also, using this analysis, all activities have been evaluated (VA, VE, NVA).

SIPOC Map Sale of packaging OBC4

Project title:	Optimisation of Sale of Packaging	Revision date:	
Mapped by:	Petr Nohýnek	Date:	18.10.2023

NVA - waste
VA
VE

	Inputs	Process Steps	Time	Value	Outputs	Foto
1	Calculator	Recalculation of finished pieces	0:00:08	VE	Recalculated box	
2	Recalculated box	Reporting into performance report	0:00:08	VE	Entered performance report	
4	Last produced piece	Inserting of last piece to the box	0:00:09	VA	Full box of finished products	
5	Interleaf	Rech for the interleaf	0:00:06	NVA	Interleaf	
6	Full box of finished products	Checking of the box	0:00:09	VE	Full checked box	
	Interleaf	Insert of interleaf	0:00:02	VE	Box with interleaf	
7	Box with Interleaf	Closing of the box	0:00:03	VE	Closed full box	
7	Closed full box	Unbraking of the box	0:00:05	VE	Unbraked box	
	Unbraked box	Putting the box to dedicated place	0:00:11	NVA	Taken away box	
	Empty box	Location of new box	0:00:10	NVA	Located empty box	
	Located empty box	Braking of the new box	0:00:04	VE	Braked new box	
	Computer with SAP	Sale of packaging in SAP	0:00:10	VE	Sold packaging	
			0:01:25			

Figure 13: SIPOC map based on time snapshot on the OBC4 line, Analysis of Inputs and outputs, Value Analysis

Source: Own

After at least two time snapshots have been created and analysed using the SIPOC map, corrective actions can be developed. First of all, NVA activities need to be eliminated or at least optimised, also VE activities should be optimised. The potential of time saving has been set at 19 % of the current state. This new process is then presented to PUL and the logistics representative for feedback and feasibility. After the process is adjusted according to this feedback, a new process for the sale of packaging can be implemented. Then, at least two time snapshots are made to validate if the new process is effective and lowers the downtime. Later, this downtime is monitored using Power BI. In Figure 14 can be seen how data changed comparing January 2024 (before optimisation) and November 2024 (after optimisation).

Improvement for the line OBC4 is according to the data 15,4 %. This improvement has been achieved by work redistribution and work standardisation. After validation of changes next step is Standardisation. A standard operation sheet is created, and all operators on this line are trained.

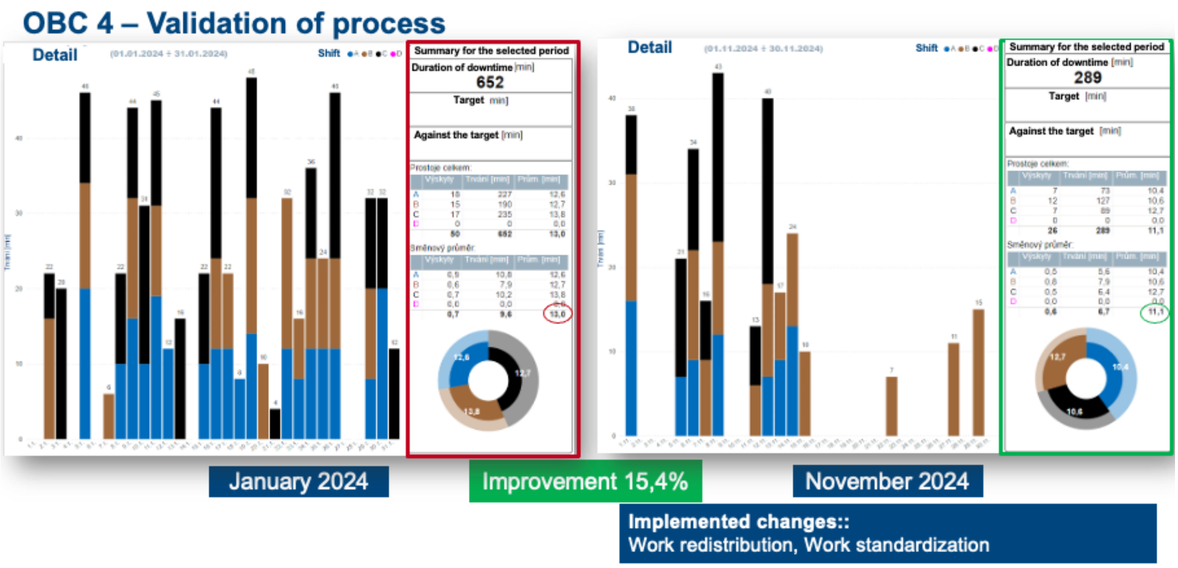


Figure 14: Validation of process – Change in DMS Power BI data report on OBC4 line

Source: Own (Accordin to internal source of Knorr-Bremse)

The next step is a calculation of the savings that have been brought by this improvement. All calculations are verified by Knorr-Bremse's Controlling department.

<u>Savings calculation:</u>

Direct wage – 8,9 CZK/min

Duration of downtime before optimisation – 8,5 min/shift

Duration of downtime after optimisation – 6,9 min/shift

Time saving – 1,6 min/shift

Saving per shift -> 8,9*1,6 = 14,24 CZK (0,6€)

Saving per week (15 shifts) -> 14,24*15 = 213,6 CZK (9€)

Saving per year (50 weeks) -> 213,6*50 = 10 680 CZK (450,63€)

Total saving per year –> **10 680 CZK (450,63€)**

C/T of OBC4 line – 0,5 min (30 s)

Frequency -> 6 times/shift -> 1,6 min/shift

For each Shift can be made 1,6*0,5 = 3,2 pcs more of Products

For each Week can be made 3,2*15 = 48 pcs more of Products

Per Year can be made 48*50 = 2400 pcs more of Products

After the calculation of the savings, Knorr-Bremse is going to save 10,680 CZK (450,63€) on downtimes of the line OBC4 and also going to be able to produce 2400 pcs of Products more in one year. With the average price of produced goods on the OBC4 line, KB could potentially earn 2,400,000 CZK, which is approximately 3, 129 EUR.

5.1.1.3 Optimisation of the Sale of packaging on the OBC 3 line

Another line that needs to be optimised is line OBC3. This line of the Brakechamber area in KB Liberec is not a priority line due to a similar portfolio of products with line OBC4, which is more automized and with a lower cycle time. Line OBC3 is often used for smaller production orders, when line OBC4 has technical problems or is undergoing preventive maintenance. Also, due to lower utilisation, this line is often operated by a reduced number of operators. Therefore, improvement and standardisation of the sale of packaging will help this line. Due to smaller orders that are processed by this line, the problem with the sale of packaging appears more often. In Table 8, can be occure Action plan used for the optimisation of the Sale of packaging on the OBC3 line.

Table 7: Action plan for optimisation of the Sale of packaging on the OBC3 line in KB Liberec

Source: Own

Line	Action	Required by	Responsible	Status
OBC4	Problem description using 5W1H methodics	30.01.2024	P. Nohýnek	Done
OBC4	Measuring the current state using the time snapshot method	31.03.2024	P. Nohýnek	Done
OBC4	Analysis of the current state using: SIPOC map, Value Analysis (VA, VE, NVA)	22.04.2024	P. Nohýnek	Done
OBC4	Design of new Process	29.04.2024	P. Nohýnek	Done
OBC4	Introduction of PUL and logistics representatives	13.06.2024	P. Nohýnek	Done
OBC4	Implementation	06.01.2025	P. Nohýnek	Done
OBC4	Test of the new process + training of operators	07.01.2025	P. Nohýnek	Done
OBC4	Standardisation of process – creation of SOS (Standard Operation Sheet)	10.01.2025	P. Nohýnek	Done
OBC4	Validation of the process and Saving calculation	17.02.2025	P. Nohýnek	Done

According to data from the Power BI report based on data from DMS, which can be seen in Figure 15, the sale of packaging on line OBC3 is TOP4 downtime. Different colours in the graph represent various shifts, which means that the problem of the sale of packaging is a repetitive problem occurring across all shifts. In the monitored period between 1.10.2023 – 31.3.2024, this problem appeared 211 times with a total duration of 3939 minutes. The cycle time of the OBC3 line is currently set to 56 s.

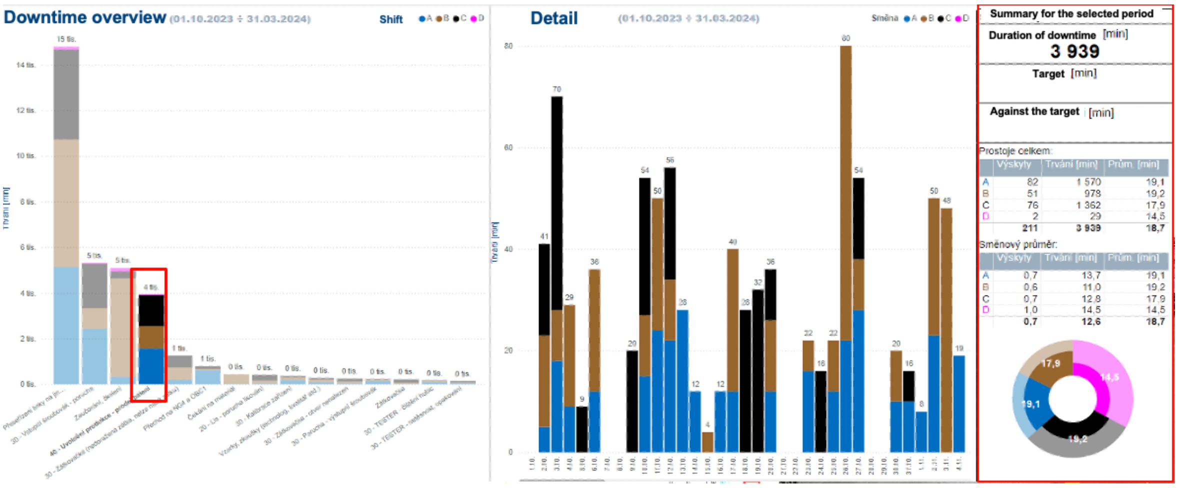


Figure 15: Power BI report of all OBC3 line downtimes in the monitored period

Source: Internal source of Knorr Bremse

On following Figure 16 can be seen SIPOC map based on a time snapshot. Before designing a new process, at least two snapshots have been created and analysed using the SIPOC map. In the Analysis, time snapshots are broken down into individual steps with their inputs and outputs, and evaluated to determine if it is VA, VE, or NVA activity.

SIPOC Map Sale of packaging OBC 3

Project title: Optimisation of Sale of Packaging Revision date:

Mapped by: Petr Nohýnek Date: 12.10.2023

NVA - waste
VA
VE

	Inputs	Process Steps	Time	Value	Outputs	Foto
1	Last produced piece	Inserting of last piece to the box	0:00:04	VA	Full box of finished products	
2	Filled Sale ticket, scanner, PC with SAP	Scanning of sale ticket	0:00:06	VE	PC with SAP	
3	PC with SAP	Sale of packaging in SAP	0:00:08	VE	PC with SAP	
4	Pocket	Removal of pocket	0:00:04	VE	Pocket	
5	Sale ticket, pocket	Putting the Sale ticket into pocket	0:00:04	VE	Pocket wth sale ticket	
6	Pocket wth sale ticket	Placement of pocket on the box	0:00:05	VE	Box with sticked pocket	
	Interleaf	Insert of interleaf	0:00:04	VE	Box with interleaf	
7	Lid	Closing of the box with lid	0:00:05	NVA	Closed full box	
7	Closed full box	Putting the box to dedicated place	0:00:06	NVA	Taken away box	
	New box	Removal of lid on new box	0:00:04	NVA	Lid	
	New box withoud lid	Placement of the new box	0:00:04	NVA	Placed new box	
			0:00:54			

Figure 16: SIPOC map based on snapshot of the OBC3 line, Analysis of Inputs and outputs, Value Analysis

Source: Own

Based on these SIPOC maps new process is designed. Later, this new process is discussed with the PUL and logistics representative. After the discussion process is adjusted and implemented. After implementation, two additional time snapshots are made to see if the desired improvement is achieved. This downtime is later monitored using the Power BI tool. After successful validation of implemented changes Standard Operation Sheet is created.

The last step before validation is a calculation of savings. Same as previous calculations, these calculations are also verified by the Controlling department of Knorr-Bremse Liberec.

Saving calculation:

Direct wage – 8,9 CZK/min

Duration of downtime before optimization – 19,5 min/shift

Duration of downtime after optimization – 14,8 min/shift

Time saving – 4,7 min/shift

Saving per shift -> 8,9*4,7 = 41,83 CZK (1,76€)

Saving per week (15 shifts) -> 41,83*15 = 627,45 CZK (26,47€)

Saving per year (50 weeks) -> 627,45*50 = 31 372 CZK (1 323,73€)

Total saving per year –> **31 372 CZK (450,63€)**

C/T of OBC3 line – 0,93 min (56 s)

Frequency -> 6 times/shift -> 1,6 min/shift

For each Shift can be made 1,6*0,93 = 1,48 pcs more of Products

Per each Week can be made 1,48*15 = 22,3 pcs more of Products

Per Year can be made 22,3*50 = 1 115 pcs more of Products

Due to optimization of the Sale of packaging, Knorr-Bremse can save 31,372 CKZ, which equals 450,63€ per year, and is able to make 1,115 pcs of more products. But these numbers are only potential savings due to lower utilization of the OBC3 line.

With the average price of produced goods on the OBC3 line, KB could potentially earn 545,458 CZK, which is approximately 23,015.1 EUR.

5.1.2 Machining area of KB Liberec

Another area in KB Liberec that is analysed for optimization of the sale of packaging is the machining area. In the machining area, this problem is not associated with downtimes but with the waste of movement, which is an obstacle to the planned 3 machine operation by one operator (currently, one operator operates 2 machines). In the Machining area of KB Liberec are 6 machines operated by 3 operators. Currently, all operators need to go to the table of the Shift leader to write off manufactured pieces, which takes approximately 40 seconds per way. Another problem is qualitative, since operators often swap packagings of produced pieces while writing off, which leads to problems in logistics. Due to the operation on two machines, each operator writes off production ca. 4 times/ shift. This problem is already described using the 5W1H method in chapter **4.2.1.1 Description of the problem using the 5W1H method.** For further analysis time snapshot method is used to give data to the

SIPOC map. In the SIPOC map that can be seen in Figure 17 inputs and outputs of each step are visible, and also all activities are evaluated if they are VA, VE, or NVA.

SIPOC Map Sale of packaging MACH - LIB

Project title: Optimisation of Sale of Packaging | Revision date:

Mapped by: Petr Nohýnek | Date: 13.02.2024

NVA - waste | VA | VE

Inputs	Process Steps	Time	Value	Outputs	Foto
Last piece	Inserting of last piece to the box	0:00:03	VA	Full box of finished products	
Full box of finished products	Closing the box	0:00:04	VE	Closed full box	
Sale ticket	Walk	0:00:14	NVA	Sale ticket	
Sale ticket	Filling up the Sale ticket	0:00:07	VE	Filled sale ticket	
Filled sale ticket	Walk	0:00:16	NVA	Filled sale ticket	
Filled sale ticket, Computer with SAP	Sale of packaging in SAP	0:00:28	VE	Sold packaging	
Pocket	Putting the Sale ticket into pocket	0:00:10	VE	Pocket wth sale ticket	
Pocket wth sale ticket	Walk	0:00:13	NVA	Pocket wth sale ticket	
Pocket wth sale ticket	Placement of pocket on the box	0:00:02	VE	Box with sticked pocket	
		0:01:37			

Figure 17: SIPOC map based on snapshot of the Machining in KB Liberec, Analysis of inputs and outputs, Value Analysis

Source: Own

During the analysis, it was found that each machine in the machining area in KB Liberec has its own computer to display machine performance. These computers, unfortunately, lack a SAP licence. Therefore, it was not possible to write off production on these computers. For the implementation of the new process is also established Action plan, which can be found in Table 9.

Table 8: Action plan for optimisation of the Sale of packaging in the Machining area in KB Liberec

Source: Own

Line	Action	Required by	Responsible	Status
MACH	Problem description using the 5W1H method	30.01.2024	P. Nohýnek	Done
MACH	Measuring the current state using the time snapshot method	31.03.2024	P. Nohýnek	Done
MACH	Analysis of the current state using: SIPOC map, Value Analysis (VA, VE, NVA)	22.04.2024	P. Nohýnek	Done
MACH	Design of new Process	29.04.2024	P. Nohýnek	Done
MACH	Introduction of PUL, logistics representatives and PMO	17.06.2024	P. Nohýnek	Done
MACH	Implementation (purchase and installation of scanners, installation of SAP)	16.10.2024	P. Nohýnek	Done
MACH	Test of the new process + training of operators	17.10.2024	P. Nohýnek	Done
MACH	Standardisation of process – creation of SOS (Standard Operation Sheet)	15.12.2025	P. Nohýnek	Done
MACH	Validation of the process and Saving calculation	16.12.2025	P. Nohýnek	Done

When designing a new process, this information is crucial for desired improvement. For the implementation of the SAP licence into these computers IT department of KB Liberec is contacted. For an easier and faster process also barcode scanners are needed. There are two versions of barcode scanners proposed to the Operations &

Program Manager and PUL, with pros and cons of each solution. This can be seen in Figure 18.

During the analysis, another problem occurs at the end of each shift, when operators need to report their work. The installation of the SAP system on the computers by the machines can also help reduce waste in the form of waiting.

Figure 18: Comparison between barcode scanner solutions

Source: Own (According to the Internal Source of Knorr-Bremse)

An important step is also the calculation of benefits and return on investment, which is divided into two parts, one for the sale of packaging and the second for work reporting at the end of the shift.

5.1.2.1 Calculation of benefits in the Machining area

- Wired barcode scanner – 5,800 CZK (3x 1450 CZK)
- Wireless barcode scanner – 16 350 (3x 5450 CZK)

<u>Calculation of savings for the sale of packaging:</u>

Direct wage – 12,7 CZK/min

Duration of downtime before optimisation – 8,04 min/shift

Duration of downtime after optimization – 5,40 min/shift

Time saving – 2,64 min/shift

Saving per shift -> 12,7*2,64 = 33,53 CZK (1,41€)

Saving per week (15 shifts) -> 33,53*15 = 502,92 CZK (21,2€)

Saving per year (50 weeks) -> 502,92*50 = 25 146 CZK (1 061,01€)

Total saving per year –> 25 146 CZK (1 061,01€)

Total saving for the whole Machinig area – 25 146*3 = 75 438 CZK (3 183€).

<u>Calculation of savings for Work reporting:</u>

Direct wage – 12,7 CZK/min

Duration of downtime before optimization – 3,16 min/shift

Duration of downtime after optimization – 1,61 min/shift

Time saving – 1,55 min/shift

Saving per shift -> 12,7*1,55 = 19,7 CZK (0,83€)

Saving per week (15 shifts) -> 19,7*15 = 295,3 CZK (12,46€)

Saving per year (50 weeks) -> 295,3*50 = 14 763,67 CZK (623€)

Total saving per year –> 14 763,67 CZK (623€). Total saving for the whole Machinig area – 14 763*3 = 44 291 CZK (1 869€).

Total saving with scanners in the Machining area -> **119,729 (5052€) per year**

In the next paragraph detailed overview of Benefits and advantages, disadvantages, costs, and payback follows.

Benefits and advantages:

- Reduction of the sale of packaging time approx 40s per box (160s per operator shift)
- The current process is limited for the planned 3 machine operation
- After the installation of the SAP system on the computers, it's going to be possible to report work for operators at their workplace. Thanks to this time reduction, it's going to be possible to make more products (ca. One rotation of a pallet in the Machine)

Cons

- Higher cost associated with the purchase of the scanners

Cost

- For the whole Machining area, there is a need for purhcasing 4 barcode scanners.
- Cost of wired scanners – 5,800 CZK (1,450 CZK/Pcs)
- Cost of wireless scanners – 16,350 (5,450 CZK/Pcs)

Return

- Wired scanners – 29 shifts = 10 days
- Wireless scanners – 103 shifts = 34 days

Necessary steps for implementation

- Installation of SAP on Computers, activation of unused SAP accounts, and purchase of scanners.

After meeting with PMO, and PUL agreement on purchasing wireless scanners is made. The purchase and installation of the SAP system and barcode scanners happened on the 16th of October 2024, and the next day, training of operators for the new process started. After the first training of operators and their feedback Standard operation sheet is created. In this case, validation of desired improvement means checking if the new process is saving the required time. Validation is made by the random occurrence of the process by the time snapshot method and creation of the SIPOC map. Validation is successfully concluded on the 16th of December 2024.

Standardisation and optimization not only bring savings in time, but also allow KB Liberec to make more pieces. Total saving for only time reduction makes for all areas in KB Liberec saving of 170 222,5 CZK, which equals 7 182,4 EUR. Another benefit is allowing lines to produce more pieces by eliminating bottleneck operations. By this, the Saving can KB Liberec make up to 9 470 500 CZK, which equals 399 599,16 EUR in revenue. These numbers are only potential revenue due to the calculation of full utilization of each machine without any downtimes.

5.2 Knorr-Bremse Lisieux, France

The issue of the sale of packaging is an important consideration in the operational efficiency of the Lisieux subsidiary. In Lisieux, a similar production area is dedicated to manufacturing brakechambers, comparable to the operations at the Liberec plant. Given this similarity, the challenges associated with the sale of packaging can be addressed using a comparable optimisation strategy. If the sale of packaging results in production downtimes, implementing the same improvements as in Liberec could help mitigate these inefficiencies. Streamlining packaging management and ensuring a well-coordinated logistics approach will be crucial in minimizing disruptions. By adopting best practices from the Liberec plant, the Lisieux facility can enhance workflow efficiency, reduce potential losses, and improve KPI's. This optimisation will contribute to smoother production processes and better resource utilization within Knorr-Bremse's European operations.

5.2.1 Optimization of the Sale of packaging in Lisieux, France

In the French subsidiary, the line LAA2 is being analysed for optimization of the Sale of packaging. This line is similar to the Liberec's NG4 line, producing similar products; therefore, similar optimization efforts are implemented for this line. For optimization of the line LAA2 Action plan has been established and can be seen in Table 10.

Table 9: Action plan for optimization of the Sale of packaging on the LAA2 line in KB Lisieux

Source: Own

Line	Action	Required by	Responsible	Status
LAA2	Problem describtion using 5W1H methodics	30.01.2024	P. Nohýnek	Done
LAA2	Measuring the current state using the time snapshot method	31.03.2024	P. Nohýnek	Done
LAA2	Analysis of the current state using: SIPOC map, Value Analysis (VA, VE, NVA)	15.04.2024	P. Nohýnek	Done
LAA2	Design of new Process	16.04.2024	P. Nohýnek	Done
LAA2	Introduction of PUL and logistics representatives	13.06.2024	P. Nohýnek	Done
LAA2	Implementation + Layout change	28.08.2024	P. Nohýnek	Done
LAA2	Test of the new process + training of operators	02.09.2024	P. Nohýnek	Done
LAA2	Standardisation of process – creation of SOS (Standard Operation Sheet)	30.10.2024	P. Nohýnek	Done
LAA2	Validation of the process and Saving calculation	16.12.2024	P. Nohýnek	Done

The French subsidiary also uses data collection using DMS, but doesn't use digital visualisation by Power BI. Therefore, data can only be taken from the production database, and for more detailed analysis only option is creating a snapshot of the process. According to the production data, the Sale of packaging is currently one of the TOP3 downtimes of this line. The cycle time of the LAA2 line is currently set at 63 s, but it can differ between various part numbers of products. In Figure 19, can be occured SIPOC map can occur that has been created based on a time snapshot of the process. With the SIPOC analysis inputs and outputs of each step are identified. Also, using this analysis, all activities have been evaluated (VA, VE, NVA).

SIPOC Map Sale of packaging LAA2

Project title: Sale of packaging   Revision date:

Mapped by: Date: 30.06.2024

NVA - waste
VA
VE

Inputs	Process Steps	Time	Value	Outputs	Foto
Last piece	Inserting of last piece to the box	0:00:06	VA	Full box of finished products	
Interleaf	Insert of interleaf	0:00:04	VE	Box with interleaf	
Box with stopper	Removal of stopper	0:00:03	NVA	Box without stopper	
Lid	Closing of the box with lid	0:00:21	NVA	Closed box	
Formular	Filling up of formular	0:00:10	VE	Filled formular	
Sale ticket	Filling up the Sale ticket	0:00:44	VE	Filled sale ticket	
Filled sale ticket	Walk	0:00:11	NVA	Filled sale ticket	
PC with SAP, Sale ticket	Sale of packaging in SAP	0:00:51	VE	Sold packaging in SAP	
Filled sale ticket	Walk	0:00:11	NVA	Filled sale ticket	
Sale ticket	Placement of sale ticket on the box	0:00:17	VE	Box with sale ticket	
Box with sale ticket	Unbraking of the box	0:00:04	NVA	Unbraked box	
Unbraked box	Putting the box to dedicated place	0:00:18	NVA	Taken away box	
New empty box	Placement of the new box	0:00:08	NVA	New empty box	
Closed empty box	Opening of the box	0:00:06	NVA	Opened emoty box	
Stopper	Insert of the stopper	0:00:04	NVA	Box with stopper	
Box with stopper	Straightening of the box	0:00:12	NVA	Straightened new box	
		0:03:50			

Figure 19: SIPOC map based on time snapshot of the LAA2 line, Analysis of Inputs and outputs, Value Analysis

Source: Own

After the SIPOC map is done for at least two time snapshots, the new process can be established. First, NVA activities need to be removed to improve the process. In the SIPOC analysis can be observed that waste of movement is the biggest NVA activity, based on which there is a need for a layout change. For further analysis and design of the new layout is being used tool Spaghetti diagram is used, which is used for showing the movement of operators in the process. The layout change can be seen in Figure 20.

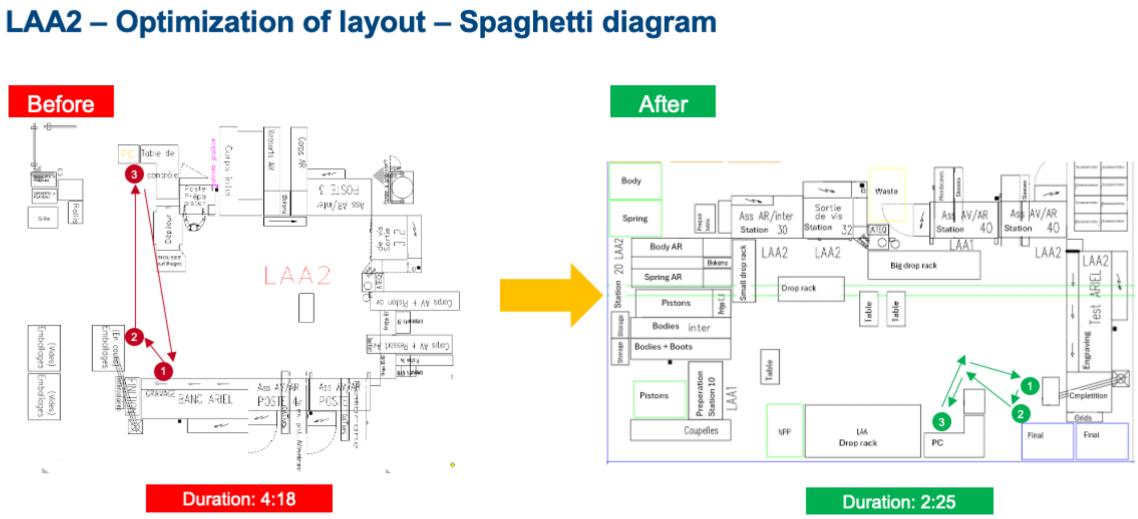


Figure 20: Spaghetti diagram and layout change on LAA2 line

Source: Own (According to internal source of Knorr-Bremse)

Using the SIPOC map potential of 12 % of time saving has been found after redistributing the work and changes in layout.

LAA2 line is not a high-runner line therefore, work redistribution is designed in two scenarios. The first scenario is that if the line is fully occupied, the operator before the last station assists with the Sales of Packaging. In the second scenario, when the line is not fully occupied, the setter or manipulant assists. Steps of the Sale of packaging, which has been redistributed to other workers, are: Change of the full box for an empty box, taping or closing of the full box. It depends on whether it is a cardboard box (needs to be taped) or a wooden box (needs to be closed with a wooden lid).

After implementation, two time snapshots have been made to see if the change brings the desired improvement. Further validation of the process is made using data from the production database. Then the process is standardised and savings are calculated.

Savings calculation:

Direct wage – 0,4 €/min

Duration of downtime before optimisation – 19,1 min/shift

Duration of downtime after optimisation – 9,5 min/shift

Time saving – 9,6 min/shift

Saving per shift -> 0,4*9,6 = 3,84€

Saving per week (15 shifts) -> 3,84*15 = 57,6€

Saving per year (50 weeks) -> 57,6*50 = 2,880€

Total saving per year –> **2880€**

C/T of LAA2 line – 1,43 min (85 s)

Frequency -> 4 times/shift -> 9,1min/shift

Per each Shift can be made 9,1/1,43 = 6,36 pcs more of Products

Per each Week can be made 6,36*15 = 95,4 pcs more of Products

Per Year can be made 95,4*50 = 4770 pcs more of Products

After the calculation of savings, Knorr-Bremse is going to save 2880 € on down times of line LAA2 and also going to be able to produce 4770 pcs of products more in one year. With the average price of produced goods on the LAA2 line, KB could potentially earn 292,841 EUR.

5.3 Knorr-Bremse Namegawa, Japan

Japanese Subsidiary of Knorr-Bremse is focusing on the development of brake control and wheel end areas, driver assistance systems, and the fourth level of automated driving. Another focus area of the Japanese subsidiary is the production of brake linings, Brakechambers, Brake discs, and Electronic Power Steering (EPS). (Knorr-Bremse,2025)

In the Namegwa, Japan area of the Machining has fallen under the focus of this Diploma thesis. This production is similar to the Machining area in Liberec. The Only Difference is that in this subsidiary, KB produces smaller products. For the Machining area in Namegawa, there is no available data. The only option to gather data is to make a time snapshot and from that time snapshot create a SIPOC map. The following Figure 21 shows a SIPOC map. Two time snapshots have been taken for analysis of the process of the sale of packaging.

SIPOC Map Sale of packaging MACH - NAM

Project title: Optimisation of Sale of Packaging
Revision date:
Mapped by:
Date: 20.08.2024

NVA - waste
VA
VE

	Inputs	Process Steps	Time	Value	Outputs	Foto
1	Last piece	Inserting of last piece to the box	0:00:04	VA	Full box of finished products	
2	Kanban lable	Placement of kanban lable	0:00:04	VE	Box with kanban lable	
3	Box with kanban lable	Sale of packaging in SAP	0:00:15	VE	Sold packaging	
4	Box with kanban lable	Putting te box on pallet	0:00:07	VE	Pallet with boxes	
			0:00:30			

Figure 21: SIPOC map based on time snapshot in Machining, Namegawa, Analysis of Inputs and outputs, Value Analysis

Source: own

From the SIPOC map can be inputs and outputs of each step and the value of each step is added. In the Japanese subsidiary, the sale of packaging is made differently than in other locations. Each produced piece is written off separately and put into the KLT box with a Kanban card. To optimise this process, workers should produce a whole pallet of KLT's not just one box. This would shorten the time needed to write off individual products, but these products can be written off at once. Produced pieces do not need to be produced Just-in-Time, because after the machining process, they are stored in the warehouse, where they wait for further production processes. Currently, the writing off of individual parts takes 360 s (6 min) per pallet. Writing one box takes 30 seconds. On each pallet, there are 36 boxes of Machined Electronic Steering Pumps. By changing writing off to the Batch takes 40 s because the operator needs to write into the system the number of produced pieces. Using Batch instead of writing off each piece can save up to 320 seconds per box.

Saving calculation:

Direct wage – 32 ¥/min

Frequency of writing off – 5 times/shift

Duration before optimisation – 30 min/shift

Duration after optimisation – 3,3 min/shift

Time saving – 26,7 min/shift

Saving per shift -> 32*26,7 = 854 ¥ (5,3€)

Saving per week (15 shifts) -> 880*15 = 12,810 ¥ (80€)

Saving per year (50 weeks) -> 12 810*50 = 640,500 ¥ (4 003€)

Total saving per year –> **640,500** ¥ **(4003€)**

Currently, each produced piece is written off individually and placed in a KLT box, leading to inefficiencies. Optimising this process by switching to batch writing instead of individual entries could significantly reduce processing time. The change would cut the writing-off time from 360s to 40s per pallet, saving approximately 26.7 minutes per shift, translating to an annual savings of 640,500 ¥ (4,003€).

5.4 Digitisation of the process of the sale of packaging

This part of the diploma thesis aims to find the optimal solution for the digitisation of the sale of packaging. This could potentially help Knorr-Bremse even more to reduce the time that can be used for production.

The process of the sale of packaging is associated with the SAP system and it's closely connected to the logistic processes. Therefore, Figure 22 and Figure 23 can be seen a process map of the sale of packaging and its impacts and triggers on individual systems in Knorr-Bremse Liberec. This production plant has been chosen as a pilot location before rollout to other production plants around the globe.

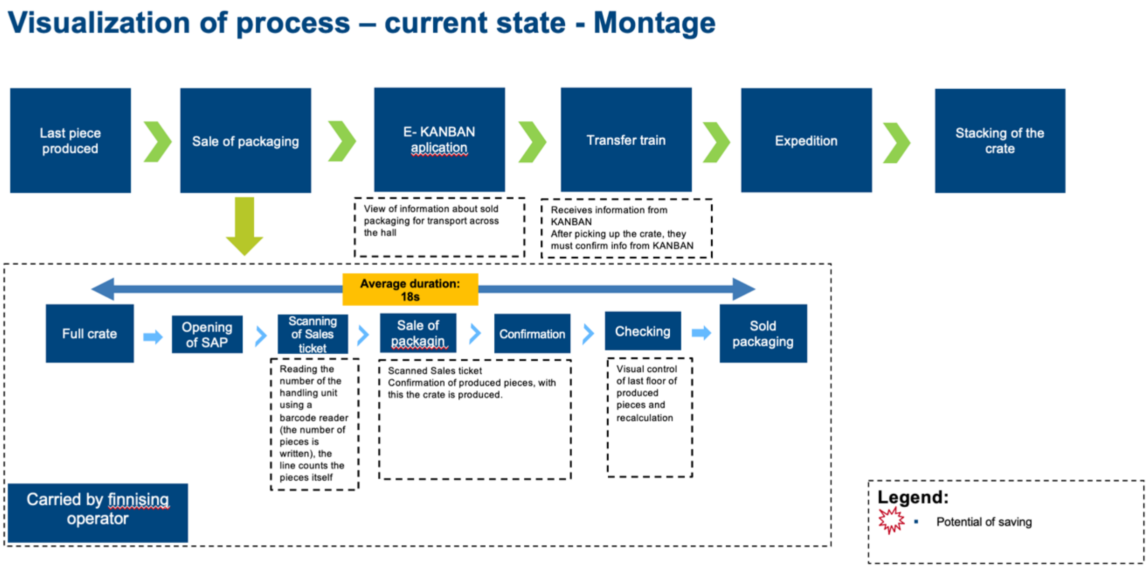


Figure 22: Process map of current state - Montage in KB Liberec

Source: Own

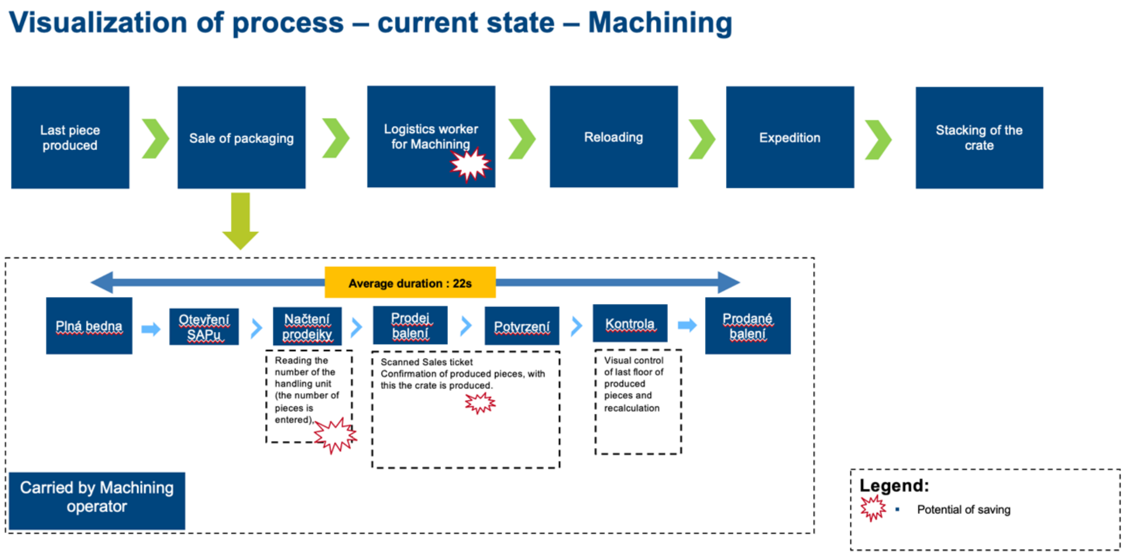


Figure 23: Process map of current state - Machining in KB Liberec

Source: Own

These two process maps reveal slight differences between the machining area and montage. Montages are more integrated into advanced systems such as E-Kanban, but in the machining area, the information about the full packaging is identified by a logistics worker, who walks through the machining area at a periodic interval. First of all, these systems need to be implemented even in the machine shop. Then, further digitisation and standardisation of the process can start.

To improve and modernise the sale of packaging and other SAP transactions where a computer with a scanner is needed Smart scanner can be used. This scanner can replace a computer at the final station of the production line. The next benefit can be a more intuitive interface.

These Smart scanners run on Android operating system, this is not only easy tu use by operators since they are used to using their mobile phones running on Android system, but also making aplications for this OS is not that hard. Using Smart scanner is also faster and more user friendly, because the SAP system interface is complicated for someone who is not used to it.

Each application can have its own pre-programmed SAP transaction, making it more user-friendly for operators. Instead of using SAP transaction codes, which can be complex and difficult to remember, Android applications can display clear, descriptive names for each transaction. This allows operators to easily open the relevant transaction for the sale of packaging and enter the number of produced pieces manually using the on-screen keyboard or by scanning with the integrated scanner. This streamlined approach not only simplifies the process but also speeds it up compared to manual data entry on a computer.

Another benefit is improved mobility. On most of the Lines in KB Liberec, at the final stations, there are computers with wired barcode scanners. This makes this process static, and the operator can easily swap produced boxes when producing smaller batches. In comparison, using Smart barcode scanners is mobile, and operators can use these scanners anywhere they want.

The next benefit can be space-saving on the lines. Nowadays, on each line at the end of the production process, there is a table with a computer and a scanner. This can take up space that can be used more effectively. Smart scanners don't take much space, operators can have them in their pocket, and the only thing these scanners need are charging cables. On following Figure 24 can be seen which scanners can fit the Knorr-Bremses needs.

Figure 24: Smart scanner fitting the needs of KB

Source: (zebra.com, 2025)

The next calculations for the first pilot line are calculated. As a pilot line for testing and potential future rollout on other lines and locations, line NG4 in Liberec has been chosen. On this line is currently running the project for optimising cycle time (C/T), and the sale of packaging is even after the implementation of changes that optimise the bottleneck. Therefore first Smart scanner should be purchased on this line. The estimated time saving is 5 seconds per one sale of packaging.

Calculation of savings for Smart scanners on the sale of packaging (NG4 line):

Direct wage – 8,9 CZK/min

Duration of downtime before optimisation – 2,4 min/shift

Duration of downtime after optimisation – 1,73 min/shift

Time saving – 0,66 min/shift

Saving per shift -> 8,9*0,66 = 5,8 CZK (0,25€)

Saving per week (15 shifts) -> 5,8*15 = 87 CZK (3,67€)

Saving per year (50 weeks) -> 87*50 = 4 350 CZK (183,54€)

Total saving per year –> **4 350 CZK (183,54€)**

Purchase price -> 39 037 CZK (1 647,1)

Return on investment (in years) 39037/4350 = 8,97 years

Return on this investment is pretty high, 8,97 years. But this investment is going to help KB Liberec reduce the duration of each sale of packaging. Another benefit is going to be the replacement of the current computer at the last station of the production line. With this company can save valuable space. The next benefit is the option of using Smart scanners for several SAP transactions that are currently operated by a computer and a barcode scanner. Therefore, investment in Smart scanners should be recommended for implementation in KB Liberec on all lines and all machines in the Machining area, and further to all locations of Knorr-Bremse.

For the implementation of Smart scanners to other locations, in-depth analysis needs to be done to achieve the desired time saving to speed up the production process and modernise production processes.

6 Conclusion

To conclude the practical part of this Diploma thesis problem of the sale of packaging appears between several locations. The first pilot location for the project of streamlining the process of the sale of packaging has been chosen as Knorr-Bremse’s subsidiary in Liberec, Czech Republic. In this location, three lines and two focus areas have been in focus. Improvements in terms of standardisation, layout change, and work redistribution brought the Liberec subsidiary of KB Liberec a potential saving of 76,785,5 CZK, which equals 7,181.73 EUR. This improvement also brought the potential of higher production, where KB Liberec can make up to 14,240,480 CZK, which equals 827,75 EUR in potential revenue. This revenue for higher production is only potential due to full utilisation of lines without any downtimes. An overview of all savings made by the project of optimisation of the sale of packaging can be seen in Figure 24. Another benefit brought by optimisation of the sale of packaging in the Machining area of KB Liberec was saving for Work reporting a the end of shift, which equals 44,291 CZK, that is approximately 1869 EUR per year.

Potential time saving for all Production Units

Subsidiary of Knorr-Bremse	PUT	Line	Time before optimation per shift (min/shift)	Time after optimation per shift (min/shift)	Time saving per shift (min/shift)	Financial saving in local currency	Financial saving (EUR/year)
Liberec, CZ	BCH	NG 4	20,3	12,1	8,2 (59%)	52 732,50	2 225,00
Liberec, CZ	BCH	OBC3	19,5	14,8	4,7 (24%)	31 372,00	1 323,73
Liberec, CZ	BCH	OBC4	8,5	6,9	1,6 (11,6%)	10 680,00	450,30
Liberec, CZ	MACH	-	24,12	16,2	7,92 (33%)	75 438	3 183
Lisieux, FR	BCH	LAA2	19,1	9,5	9,6 (49%)	-	2 880
Namegawa, JPN	MACH	-	30	2,5	26,7 (89%)	640 500	4 003
	Total						14 065,03

Potential of higher production for all Production Units with full utilization

PUT	Linka	Time before optimatimalization per shift (min/shift)	Time after optimalization per shift (min/shift)	Protentional of higher production (Pcs/year)	Protentional revenue (CZK/Year)	Protentional revenue (EUR/year)
BCH (CZ)	NG 4	20,3	12,1	4770	6 525	253 841,77
BCH (CZ)	OBC3	19,5	14,8	1115	545,5	23 015,10
BCH (CZ)	OBC4	8,5	6,9	2400	2 400	39 129,11
MACH/ADB (CZ)	Machining	33,6	21,03	n/a	n/a	n/a
BCH (FR)	LAA2	19,1	9,5	4770	n/a	292 841
Total						609 826,98

Figure 25: Overview of total savings made by the optimisation of the sale of packaging

Source: Own

For the location of Lisieux in France, the savings reach up to 2880 EUR, by streamlining the process of the sale of packaging, thanks to work redistribution and layout change. The French subsidiary is also able to make an additional 292,841 EUR in revenue with higher production.

For the Japanese subsidiary of Knorr-Bremse in Namegewa savings given by a more streamlined process of the sale of packaging make 640,500 ¥, which equals 4003 EUR.

The process of sale of packaging can be even more streamlined by using Smart scanners. These Smart scanners can help improve the process, but KB should find more use for them to be implemented. Implementing these scanners only for the sale of packaging is not efficient with the return on investment of 8,97 years (Example of line NG4 in KB Liberec).

Also success of desired goals should be evaluated. For the brakechamber area in Liberec goal was set to reduce the duration of downtime of the sale of packaging by 40 %. This goal hasn't been fulfilled because saving brought only 31,5 % of time reduction in the brakechamber area. For machining, two goals have been set, one for the sale of packaging, that is, a reduction by 33 %, and the second goal for Work reporting at the end of each shift, which was set to a 49 % time reduction. After the improvements reduction in time on the sale of packaging in the machining area of KB Liberec is 33 %, which means that the goal was fulfilled. For the work reporting, the time reduction made a 50 % improvement, which means the goal was also fulfilled.

The second subsidiary where optimization of the sale of packaging happened was the French subsidiary of Knorr-Bremse in Lisieux. For this subsidiary goal has been set to 30 % time reduction. After the implementation of corrective measures of change in layout, work redistribution, and standardisation of process, time reduction equals 49 % from the state before optimisation. That means that the goal has also been met.

The third subsidiary of Knorr-Bremse that has been analysed for improvements in the process of the sale of packaging is the Japanese subsidiary in Namegeawa. For this location, the goal has been set to a 30 % reduction in time. In Namegawa, this thesis made an 89 % improvement in time used for the sale of packaging by changing the packaging procedure and standardisation of work.

After the successful implementation of changes across KB locations and Standardisation of processes, the company should roll out these process changes to other locations around the globe. This would help all locations to save time by Sale of packaging and allow these locations to produce more pieces. Additionally, implementing Smart scanners into the Sale of packaging process can help reach higher time reduction and further lower the downtime.

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