Application of Lean Manufacturing and Theory of Constraints to the service sector

Author: Tom Davin Röhling
University of Twente
P.O. Box 217, 7500AE Enschede
The Netherlands

ABSTRACT

This research paper transfers the originally in the manufacturing sector applied theories of Lean Manufacturing and Theory of Constraints to the service sector to validate if the application leads to process optimization and improved resource utilization. This transfer is executed by the application of Lean Manufacturing theories and Theory of Constraints to a case company operating in the logistics sector, a subsector of the service sector.

The Lean Manufacturing theories of 5S and Automation, the method of Time Value Mapping, as well as Theory of Constraints in combination with Bottleneck theory are applied to the service sector.

The study reveals the transferability of the beforementioned theories from the manufacturing to the service sector, by the achievement of process optimization and improved resource utilization in the case company, which is measured by the criteria of time savings and cost reductions.

A One-piece flow automation, with a time savings and cost reductions potential of 42 percent was identified as the most suitable process improvement solution for the service sector case company.

Graduation Committee members:
First Supervisor: DR. IR. P. Hoffmann
Second Supervisor: DR. F.G.S Vos

Keywords
Lean Manufacturing, Theory of Constraints, Service Sector, Logistics in the Service Sector, Time Value Mapping, Automation

---

This is an open access article under the terms of the Creative Commons Attribution License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited.

CC-BY-NC

1. INTRODUCTION

This research aims to establish empirical evidence for the application utility of Lean Manufacturing and Theory of Constraints in the service sector. Current research about Lean Manufacturing and Theory of Constraints examines the application utility in the manufacturing sector which focuses on the production of goods ("Manufacturing Sector," 2020).

The service sector focuses on the production of intangible goods (Chappelow, 2020) which comprise industries such as "warehousing and transportation services, information services, securities, and other investment services, professional services, waste management, etc. (Chappelow, 2020)."

Company X, a company operating in the logistics sector, a sub-sector of the service sector, functions as the case company for theory application. For privacy reasons the company name cannot be disclosed. Throughout the research paper the company will be referred to as "Company X" or "Case Company". The processes of two departments of the case company, namely the Shipping and the Commercial department will be examined in the subsequent chapters.

The results found by the application of Lean Manufacturing and Theory of Constraints in the logistics sub-sector will be transferred to the other sub-sectors of the service sector by illustrating how the processes executed in the case company resemble processes of other service sector companies.

This research expands the academic knowledge base of Lean Manufacturing and Theory of Constraints by applying theories proven in the manufacturing sector to the service sector, to verify theory transferability and enable the expansion of application benefits to service sector companies.

The objective of the research is the achievement of process optimization and improved resource utilization in the service sector case company.

Process optimization can be defined as the alteration of a process to most effectively make use of the resources used for value creation. The goal of process optimization is the increase of efficiency which results in cost minimization (Kudryavtsev, 2018). Process optimization "increase[s] efficiency and guarantee[s] successful execution of critical business processes (Meyer, 2006, p. 1)."

The resources whose utilization should be improved can be classified as physical and human resources (Belyh, 2015).

Physical resources that can potentially be used more efficiently in the sample shipping and commercial department are vehicles, machines, and systems (Belyh, 2015).

Human resources whose efficiency can potentially be improved is the workforce that is performing manual work (Belyh, 2015).

According to initial discussions with the management of Company X, a possible solution is in the area of automation. Automation in the shipping and commercial department of Company X could be integrated by an implementation of a scanner-based procedure into the picking process of the shipping department. This implementation could facilitate the process in the shipping department and automate processes in the commercial department. Instead of manual registrations of products and package data on the delivery note and in SAP and transferring documents manually from the shipping to the commercial department, the scanner implementation would automate these manual tasks.

The research paper analyzes if automation as the selected Lean Manufacturing Theory leads to time savings and cost reductions in the observed processes and if there exist other automation possibilities, that would lead to superior results than the proposed scanner-based automation. If the to be analyzed implementation of Lean Automation solutions do not lead to profitable results in terms of the set success criteria, there is a need to choose and analyze different methods that could lead to more profitable results. If automation as a lean theory proves to provide positive results for the case company, which operates in the logistics sector, this provides evidence for the applicability of Lean Theories in the service sector.

To be able to assess the most suitable process optimization solution, the following criteria will be used for evaluating differing solutions.

1. Time savings – Redundancy created by more effective and efficient use of physical and/ or human resources lead to time-saving possibilities in operations (Belyh, 2015).
2. Cost reductions – More effective and efficient use of physical as well as human resources lead to cost reductions in operations (Belyh, 2015).

Time savings and cost reductions will be calculated on a ten-year basis because the case company assesses investment profitability on a ten-year horizon. A detailed description of the calculations can be found in the Improvement possibilities chapter.

How can Lean Theories and Theory of Constraints be applied in the service sector to achieve process optimization and improve resource utilization?

To facilitate the answering of the research question three sub-questions have been developed.

1. Which Lean Manufacturing and Theory of Constraints optimization theories could be applied to the service sector?
2. Which Lean Manufacturing and Theory of Constraints optimization theories that could be applied to the service sector have the most potential in achieving the defined criteria of time savings and cost reductions in the case company?
3. How can the Lean Manufacturing and Theory of Constraints optimization theories with the most potential for the case company be applied to the two departments to achieve time savings and cost reductions?

The research has practical relevance because it develops a clear plan that managers can use to improve the most critical process, the Bottleneck, of the sample shipping as well as the commercial department of Company X. The research aims to find a resource optimization potential in the before mentioned departments which will practically lead to time savings and cost reductions in operations if implemented by managers.

This academic paper functions as a practical example for other companies working on internal process improvements and automation in the service sector.

To answer the Research Question and the three Sub-questions, literature about Lean Manufacturing, Theory of Constraints, and Bottlenecks will be assessed and combined into a framework.

The Theoretical Framework discusses the case company and analyzes in which way the logistics sector integrates into the broader service sector and functions as a basis for analyzing Lean Manufacturing and Theory of Constraints in a different setting than the manufacturing sector.

Chapter 2.3 introduces the combination of Lean Manufacturing and the Theory of Constraints in this research.

Chapter 2.4 combines the Theory of Constraints and Bottleneck which both aim at the elimination of inefficiency in processes

The subsequent chapter analyzes Lean Manufacturing and its different concepts in more detail.
A motivated choice is made about the selection of applicable theories of Lean Manufacturing that enable the finding of an answer to the research questions and which relate to the Problem statement. The Lean theories 5S and Automation are discussed in more detail in the following chapters.

2. THEORETICAL FRAMEWORK

2.1 Case Company

[Confidential Appendix]
The shipping and commercial department are closely interlinked because their activities are complementing each other in the process of shipping products to customers. The shipping department is responsible for the manual work which includes the picking and shipping of orders and the commercial department has the function to execute back-office tasks. The commercial department digitally ships the from the shipping department processed orders in SAP and performs system-relevant activities. The specific processes performed in the two departments will be analyzed in more detail in the upcoming "Current Situation" Chapter.

The processes of the shipping department and the corresponding commercial department of Company X have been designed to operate as efficiently as possible according to industry standards. Ongoing digitalization and automation development in the business environment enables companies to further improve their processes and to achieve cost savings by improving the quality and speed of operations (McKinsey&Company, 2017).
Due to digitalization and automation which enable process improvements, the initially efficiently designed processes in the shipping and commercial department of Company X have become outdated and operations have become too costly when being compared to industry benchmarks. Processes that could be automated are executed manually in these departments. For instance, the employees of the shipping department manually write down the measurement and weight of the packed parcels on the processed delivery note and manually bring this delivery note to the commercial department for further processing. The commercial department has to enter data manually into SAP which could be facilitated by process automation.
The two departments do not have specific visible problems that need to be solved, but the management of Company X decided to optimize their practices to profit from the existing cost savings potentials.

2.2 Logistics in the Service Sector

Company X is not a standard manufacturing facility and therefore has different characteristics than the organizations discussed in current articles about Lean Theories and Theory of Constraints that are specialized in the manufacturing of products. Company X operates in the logistics industry which is part of the service sector. The logistics industry includes the picking and shipping of products in the most efficient way. The application of Lean Manufacturing and Theory of Constraints in this context extends the scope of existing research by providing evidence if the methods, proven in the manufacturing sector, can also be used to improve processes in service sector industries.

Literature classifies the service sector as the tertiary sector of the three economic sectors (Zeder, 2017).
"The tertiary sector describes all industries that provide services to other businesses or final customers (Zeder, 2017)." Next to the logistics industry, which is analyzed in this paper, retail, health care and financial services are additional examples of tertiary sector industries (Zeder, 2017).
When analyzing the contribution of different industries to the GDP, it is noticeable that the logistics industry takes up a large portion of the total GDP. In the United States, logistics costs accounted for 8 percent of total GDP in 2018 (SelectUSA, 2018). The GDP contribution of the entire service sector has been 68 percent in 2018 in the United States (Deloitte, 2018). In comparison, the manufacturing sector only contributed to 11 percent of total GDP contribution in the United States in 2018 (Deloitte, 2018). This shows that the logistics industry accounts for a significant portion of total GDP and contributes to a large extent to the tertiary sector. The logistics industry will, therefore, be taken as the basis for generalizing the applicability of Lean Theories in the other service sector industries.

2.3 Combination of Theory of Constraints and Lean Manufacturing

Both, Theory of Constraints and Lean Manufacturing aim at an increase in profit by the reduction of costs (Rattner, 2006). The increase in profit by cost reductions corresponds to the cost reductions criteria of this research and thereby justifies the application of Theory of Constraints as well as Lean Manufacturing.
Theory of Constraints application leads to cost reductions because "addressing the constraints provides the fastest and lowest cost means for increasing the throughput of any organization (Mathu, 2014, p. 35)." An increase in throughput by eliminating the constraints leads to lower cost and more efficient operations (Sinclair, 2016). Lean Manufacturing reduces costs by the creation of flow which is achieved by the elimination of waste (Moore, 1998).

2.4 Theory of Constraints and Bottleneck

Theory of Constraints functions as one of the two process improvement theories in this research.
The overall objective of the Theory of Constraints is the achievement of profit maximization which is accomplished by increasing the throughput of processes and operations in a system. Profit maximization by increasing throughput can be achieved by more efficient resource management of the company (Saleh, Immawan, Hassan, & Zakka, 2019). It is, therefore, necessary to place a focus on the constraint because its elimination offers the highest return to resource management and utilization (Slack, 2016). The constraint can be defined as the "weakest link (Slack, 2016, p. 522)" in the process. The constraint in the Theory of Constraints is synonymous with the Bottleneck of a process, which will be discussed subsequently.
Improvements can be implemented by using a five-step process. The first step is to identify the system constraint. Step two of the five-step process analyzes how the constraint can be exploited. In this step, constraint elimination is attempted by reducing or eliminating wasted time at the bottleneck process. During this step, process improvements are tried to be achieved without the need for expensive changes.
The third step involves the subordination of everything to the constraint (Slack, 2016). This means that the "non-constraint elements of the process are adjusted to a level where the constraint can operate at maximum effectiveness (Slack, 2016, p. 522)." In practical terms, this would mean the readjustment of processes and material flow through the shipping and commercial department of Company X. After non-constraint adjustments, the overall system is re-evaluated to assess whether the constraint has shifted or disappeared. If the constraint was successfully eliminated, step four can be ignored, and step five directly follows thereafter.

If cost-effective activities to eliminate the constraint were not successfully implemented in steps two and three, step four focuses on elevating the constraint. Elevating does in this context mean the elimination of the bottleneck. In step four, major system changes are conducted to eliminate the constraint.

After the elimination of the constraint, step five implies repeating steps one to four (Slack, 2016). This repetition and continuous elimination of constraints, also called bottlenecks, will be described in a later chapter and can be classified as the Kaizen approach in Lean manufacturing.

The Theory of Constraints is closely related to the method of Time Value Mapping which will be analyzed in the methods section of this paper. Theory of Constraints has the aim to eliminate the constraint (Slack, 2016) and the creation of a Time Value Map facilitates the achievement of this aim by visualizing non-value adding activities (Toolkit, 2018). The elimination of non-value-adding activities is comparable to the constraint elimination discussed in this chapter. The theory of Bottlenecks is to a large extent interlinked with the Theory of Constraints.

"Bottleneck detection in manufacturing is the key to improving production efficiency and stability in order to improve capacity (Roser, Lorentzen, & Deuse, 2015, p. 1)." The citation emphasizes the fact, that the goal of Bottleneck detection is the elimination of "waste with the ultimate aim to enhance overall productivity (Pandey, Agrawal, & Uma Maheswari, 2018, p. 786)."

A bottleneck can be defined as "a function that limits output (Roser et al., 2015, p. 2)." It slows down the interconnected system and incurs increased processing costs. This limitation of output and increased processing cost occurs because the bottleneck is a resource whose production and or processing capacity is lower than the production capacity required by the flow of goods through the process (Roser et al., 2015). An indication of a bottleneck in a system is a large "work-in-process inventory in the preceding buffer (Roser et al., 2015, p. 2)."

Bottlenecks can be divided into downstream and upstream bottlenecks. Downstream bottlenecks can be identified by blocked manual processes and overloaded inventories of manufactured goods (Roser et al., 2015).

A downstream bottleneck is located in the process of preparation for further processing which follows the process of manufacturing of goods.

Contrary to this, upstream bottlenecks can be recognized by idle manual processes and empty inventories of manufactured goods (Roser et al., 2015).

An upstream bottleneck is located in the process of manufacturing of goods which precedes the process of preparation for further processing.

The visual mapping of the interconnectedness of processes by the drawing of a process map facilitates the process of finding the downstream or upstream bottleneck.

Before removing a bottleneck, practices of bottleneck detection have to be performed. One studied practice by Roser, Lorentzen, and Deuse is the walking process, which is a tool to discover constraints. The walking process is facilitated by the creation of a process map in advance because the prior mapping of the processes which have to be observed fasten the walking process. During the walking process, the observer systematically analyzes all processes along the flow line of inventories and "monitors the data of different processes and inventories (Roser et al., 2015, p. 5)" for pinpointing the bottleneck in the system.

Pandey, Agrawal, Maheswari, and Uma Maheswari emphasize, that removing a bottleneck can improve performance in terms of cost reductions which is one of the key criteria of this research executed at Company X.

There are two options for accomplishing bottleneck removal. The first option is the allocation of additional resources to speed up the process and the second option is the elimination of waste by the usage of lean principles (Pandey et al., 2018). In this paper lean principles, including waste elimination, form the basis for bottleneck removal.

2.5 Lean Manufacturing

Lean Manufacturing can be classified as the second of the two overarching theories of this research.

Lean Manufacturing enables the production of products with less effort, compared to other manufacturing types, like mass production (Womack, 2007). This advantage of less effortful production through lean manufacturing methods leads to a minimization of costs (Plakhin, Al-Ogaili, Semenet, Kochergina, & Mihajlovskij, 2019). Cost minimization is achieved by the application of lean methods to improve processes by waste identification and elimination (Siregar, Arif Nasution, Prasetio, & Fadillah, 2017). There exist seven different types of waste in processes (R. Bowen, MCDonough, M., 2013). Waste is identified "along the value stream to find non value added activities (Siregar et al., 2017, p. 1)."

The seven types of waste are "Overproduction, Waiting, Transport, Inventory, Over-processing, Motion, and Defects (R. Bowen, MCDonough, M., 2013)." More precisely "overproduction occurs when a product is made without a buyer (R. Bowen, MCDonough, M., 2013)." "Waiting occurs when a product sits in waiting for processing (R. Bowen, MCDonough, M., 2013)." "Transport occurs when a product is moved to many different places (R. Bowen, MCDonough, M., 2013)." The waste of "Inventory occurs when a product is stored and it costs money (R. Bowen, MCDonough, M., 2013)." "Over-processing occurs when a step in the process is unnecessary or redundant (R. Bowen, MCDonough, M., 2013)." The sixth step, Motion, "occurs when people move excessively (R. Bowen, MCDonough, M., 2013)." Last but not least, the seventh type of waste is the occurrence of defects. This happens "when an error in the process occurs (R. Bowen, MCDonough, M., 2013)."

Lean Manufacturing has the objective of achieving a single flow (Siregar et al., 2017), which can also be labeled a one-piece flow (Tang, Ng, Chong, & Chen, 2016). In a one-piece flow, the production of products and execution of processes is sequenced to avoid the occurrence of queue times or batch production (Tang et al., 2016). The terminology "one-piece flow means that parts are moved through operations from step to step with no work-in-process in between either one piece at a time or a small batch at a time (Dolcemascolo, 2020)." The objective of a Lean one-piece flow is the prevention of non-value adding activities and movements which results in time savings in process execution (Tang et al., 2016).

"Lean" in Lean Manufacturing is characterized by the usage of fewer resources than needed in mass-producing systems with comparable outputs (Chahala & Narwal, 2017). The main advantage of "Lean" is the connection between cost minimization and productivity and quality improvement (Melović, Mitrović, Zhuravlev, & Braila, 2016). It can be summarized that "Lean manufacturing tools are simple techniques that allow you to see opportunities for improvements, significantly reduce losses, constantly improve the range of business processes, increase the transparency and manageability of an organization, use the potential of each employee of the company, increase competitiveness, and achieve significant economic benefits without large financial costs (Plakhin et al., 2019, p. 4)."

Table 1 gives a complete overview of the different Lean Manufacturing methods appearing in theory (Chahala & Narwal, 2017).

Table 1. Lean Manufacturing methods

Lean Manufacturing methods
5S
Automation
Continuous Flow
Continuous Improvement
Kan-Ban
Kaizen
Single Minute Exchange to Die (SMED)
Cellular Manufacturing
Six Sigma
Team Development/Training
Total Productive Maintenance
Total Quality Management (TQM)
Value Stream Mapping (VSM)
Visual Management
Work Standardization
Flexible manufacturing System (FMS)
Production leveling
Inventory Management
Zero Defect Concepts
WIP (Work in Process)
Lean Thinking

The complete list will be discussed in the Appendix (21 Methods of Lean Manufacturing) of this research paper.

To achieve process improvements by the elimination of the bottleneck in the shipping and commercial department of the case company, the Lean Manufacturing concepts of Automation and 5S will be discussed in more detail. The concepts are chosen because they enable waste elimination (Lawson, 2017) and standardization (Karthik & Silksonjohn, 2019). Waste elimination, by the application of Automation, is essential for the achievement of the defined criteria of time savings and cost reductions in the case company because of the existence of unnecessary movements and storage of goods in the processes. Additionally, standardization, which is part of 5S, can be applied to the, in the Current Situation chapter discussed, repetitive manual processes.
After the introduction and explanation of the selected theories, a motivated choice will be made in the Tool Selection and Application chapter about which method is the most suitable for the following process improvement implementation at the case company. This choice will then be taken as the basis for further analysis.
The selection and application of 1 out of 21 Lean Manufacturing concepts to the case company is representative for the theoretical goal of proving the applicability of Lean Manufacturing concepts to the service sector because all these concepts have the same objective of waste removal, as well as efficiency and productivity improvement by the creation of flow (Gupta, 2015). These objectives are reached by differing methods of the Lean Manufacturing concepts but with the aim for the same outcome.

2.6 Applicable theories of Lean Manufacturing – Automation, 5S

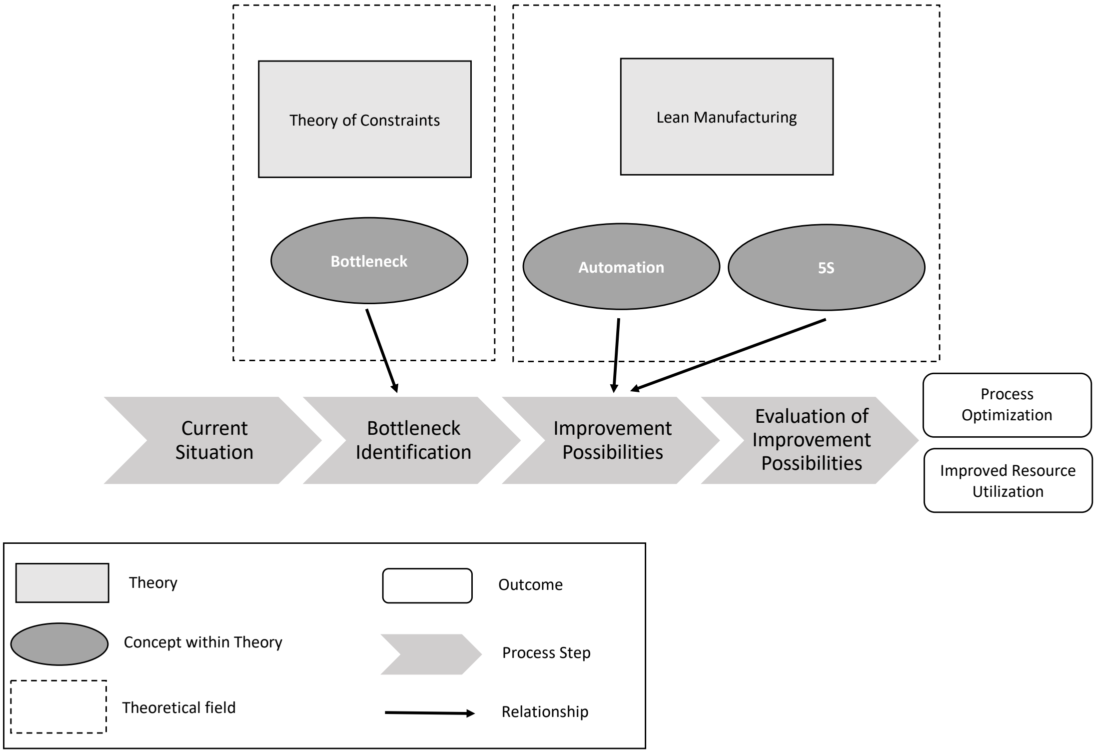
2.6.1 Automation

Due to the reason that initial discussions with the management of Company X had the result that an implementation of scanner-based product- and materials tracking could be a fitting optimization solution, automation, as a lean manufacturing method, will be considered in the following analysis as one of multiple automation possibilities. The implementation of scanners automates performed processes by the elimination of manual processes. The information technology which accompanies the scanners will be incorporated in the SAP workflows.
The incorporation of automation into manufacturing processes can be defined as "Cellular Manufacturing (Seifermann, Böllhoff, Metternich, & Bellaghnach, 2014, p. 588)." Seifermann et al. state that the implementation of automated solutions reduces manual workload. Automation, however, can have the disadvantage of being too complex and expensive, if the aim is the implementation of complete automation of processes (Seifermann et al., 2014).
Automation in cellular manufacturing is initiated by the identification of manual tasks that could potentially be automated by low-cost automation methods. In the following step, the benefits of the identified automation possibilities will be quantified, and a choice will be made, concerning the automation of the previously analyzed tasks (Seifermann et al., 2014).
Next to the previously described scanner-based automation, other automation possibilities will be analyzed in the improvement possibilities chapter of this paper.

2.6.2 5S

5S can be implemented to achieve bottleneck elimination and process improvements. It has to be highlighted, however, that bottleneck elimination and the achievement of process improvements are not a part of the concept of 5S. 5S is a "basic technique that exposes hidden problems in the form of waste which can be minimized and other lean tools can successfully be implemented (Karthik & Silksonjohn, 2019, p. 1469)." After the implementation of 5S, Automation, as a complementary Lean tool, can be implemented to achieve process optimization. 5S implies the specific observation of processes and aims at achieving process improvements through simplification (Karthik & Silksonjohn, 2019).
The theory is Japanese, and each S has a different meaning. "5S stands for Seiri (Sort), Seiton (Set in order), Seiso (Shine), Seiketsu (Standardize), and Shitsuke (Sustain) (Karthik & Silksonjohn, 2019, p. 1469)." The 5S will be analyzed in more detail in the Appendix (5S).
The fourth "S", "Standardize" has the most important function in testing the by the case company proposed implementation of the scanner-based automation because incorporating this method would mean a standardization of all previously manual executed and differing processes. Standardization of processes leads to a reduction in errors and therefore contributes to the achievement of cost reductions (Nissinboim & Naveh, 2018).
Next to the proposed solution by the case company, other solutions will be identified in the Improvement Possibilities chapter, that focus on the automation of processes. The implementation of process automation is facilitated by standardizing processes in advance to the implementation (Davenport, 2018).
Therefore, the subsequent section will focus on the theory of standardization.

Standardization can be defined as "the sum of inter-conditional actions and measures that lead to a rational unification of recurring solutions (Mĺkva, Prajová, Yakimovich, Korshunov, & Tyurin, 2016, p. 329)." Recurring solutions means carrying out actions without the occurrence of mistakes and waste (Mĺkva et al., 2016).
The implementation of standardization will lead to a reduction in time needed and/or costs of processes. Standardization has the advantage of reduced variability in operations, due to the reason



that all employees follow the same working procedures (MÍkva et al., 2016). As well, it is easier to train a new workforce when processes are performed in a standardized way. Another benefit is, that by improving processes with the means of standardization, a new baseline is created for measuring the efficiency of processes. This baseline can be taken as the starting point for further improvements (MÍkva et al., 2016).

Empirical findings of the application of Lean Theories in the manufacturing sector confirm that Lean Manufacturing and its corresponding concepts achieve a reduction in operating cost and an increase in an organizations' success (Melović et al., 2016) by the creation of flow (Kettering, 2018). Research proves that the application of Lean concepts in the manufacturing sector reduces waste and increases efficiency (Salonitis & Tsinopoulos, 2016).

2.7 Conclusion

It can be concluded that the in Figure 3 visualized and in the previous sections described Theoretical Framework functions as an interconnection of complementing Lean Theories and Theory of Constraints.

The Theoretical Framework visualizes the process steps of identifying a process improvement plan whose implementation leads to process optimization and improved resource utilization. The process steps will be discussed in subsequent chapters.

The first process step analyses the Current Situation of executed processes in the shipping and commercial department. Subsequently, the second process step focuses on the identification of the Bottleneck in the processes. This chapter discusses the application of the concept of Bottlenecks in the two departments of the case company and belongs to the overarching Theory of Constraints (Rattner, 2006). The third process step is the identification of Improvement Possibilities. These can be identified by the application of Lean Manufacturing concepts (Chahala & Narwal, 2017). Different Lean Manufacturing concepts have been discussed in the previous chapters, whereby Automation and 5S have been taken into closer consideration for the improvement application for Company X.

The Tool Selection and Application chapter will make a motivated choice about which of the two concepts will be utilized for the process improvement analysis in the case company.

After the identification of Improvement Possibilities, the last process step deals with the Evaluation of identified Improvement Possibilities. The goal of the corresponding chapter is the selection of the most suitable improvement to achieve Process Optimization and Improved Resource Utilization in the analyzed departments of Company X.

As illustrated in the Theoretical Framework, Lean Manufacturing and Theory of Constraints can be classified as the overarching theories of this research paper. The combined application of Lean Manufacturing and Theory of Constraints identifies if the discussed theories can be transferred and applied from the manufacturing to the service sector.

Figure 3. Theoretical Framework

2.8 Tool Selection and Application

Initial discussions with the management of the case company exposed that automation in the form of a scanner-based product-picking is considered as the most promising optimization solution for achieving time savings and cost reductions.

Automation has a cost-reducing effect because of its waste elimination potential (Lawson, 2017). Automation is chosen in this study because the largest expense in the case companies operations is the workforce. The integration of automation solutions that aim at the automation of manual tasks increases efficiency and reduces costs by making the workforce partially redundant (Lawson, 2017).

Automation as a Lean Theory will be used to eliminate non-value added activities, the bottleneck processes, which are currently being performed manually by the employees of the shipping and commercial department of the case company.

By automating processes of the shipping and commercial department time savings as well as cost reductions will be the result for Company X. A study published by Roland Berger has shown that companies can achieve annual savings of up to 40 percent and a 40-70 percent reduction of process time by the automation of repetitive manual tasks (Dr. Fabian Engels, 2018).

The concept of 5S will not be taken into consideration in the remaining parts of this paper because automation was identified as the most suitable concept for the achievement of time savings and cost reductions by the means of partial workforce elimination.

Regarding the analysis of the Theory of Constraints and the described five-step process, finding an answer to step one to four of the five-step process is the main focus of the following analysis. This analysis aims to achieve time savings and cost reductions in the shipping and commercial department of Company X, which will be achieved by the elimination of the constraint. Step one of the five-step process, identify the system constraint, is comparable with the Bottleneck identification. Step two to four of the five-step process will be applied in the Improvement Possibilities chapter.

It can be summarized that the Theory of Constraints focuses on the whole process of Bottleneck detection and elimination. If the application of Theory of Constraints throughout the analysis results in a positive outcome in terms of time savings and cost reductions for the analyzed improvement possibilities, this provides evidence for the applicability of the Theory of Constraints in the service sector.

The visualization method of Time Value Mapping will be applied to identify constraint elimination possibilities for the case company.

To be able to construct the Time Value Map all current activities and their corresponding execution times have to be identified and a differentiation has to be made between value added, non-value added and essential non-value added activities (Toolkit, 2018).

The activity execution times are gathered by the execution of approximate time interviews with four employees of the shipping and three employees of the commercial department.

The Time Value Map will also function as a tool to check if the implemented solution works, by identifying if the value-adding activities performed manually have increased and the manual non-value adding activities have decreased.

Two Time Value Maps will be constructed in the upcoming chapters of this research paper. The first will identify improvement potentials in the analyzed departments of Company X. The first Time Value Map will be accompanied by an analysis that focuses on the identification of the seven types of waste.

The second Time Value Map will be constructed after the improvement implementation to visually analyze the profitableness of the implemented changes and to determine if Lean Manufacturing and Theory of Constraints can successfully be applied in the service sector. Time Value Mapping in this analysis focuses only on the time needed for the execution of manual tasks. Tasks being performed in the background by automation of systems will not be included in the Time Value Map because they do not incur manual labor costs.

3. METHODOLOGY

This research is constructed as design research. Design research aims at a practical application of academic knowledge (Henseler, 2017). For answering the research questions academic knowledge about Lean Manufacturing, Bottlenecks, and Theory of Constraints is applied to the specific processes of the shipping and commercial department of Company X. It can be constructed as design research because the research will apply existing knowledge to real-world business practice to expand the scope of existing theories.

3.1 Research Design

The research aims to identify a process optimization potential that leads to improvement in resource utilization. The resources whose utilization should be improved can be classified as physical and human resources as discussed previously ("Key Resources in the Business,"). The target of improving resource utilization is the achievement of time savings and cost reductions.

The researcher makes use of multiple qualitative and quantitative data sources to obtain a complete overview of the performed processes in the analyzed departments of Company X. Data Triangulation is used to incorporate multiple data sources in the study to enhance the credibility of the analysis (Salkind, 2010).

Qualitative research aims at the understanding of human behavior (Aliaga, 2006) “It’s methods generate words, rather than numbers, as data for analysis (Bricki, 2007, p. 2).”

Quantitative research, on the contrary, is used to analyze a topic based on collected numerical data (Aliaga, 2006).

The data collection can be divided into two complementary sources, namely Primary data collection and Secondary data collection.

“Primary data is an original and unique data, which is directly collected by the researcher from a source such as observations, surveys, questionnaires, case studies and interviews according to his requirements (Ajayi, 2017, p. 1).”

Secondary data, on the contrary, is easily accessible and contains sources such as “government publications, websites, books, journal articles, internal records (Ajayi, 2017, p. 1).” Secondary data has been collected by someone else in advance of the research (Ajayi, 2017).

As a secondary data source, the internal documents of Company X will be analyzed. The analysis of secondary documents has the advantage that employees remain unaffected by the analysis (Siebenbrock, 2018). Document analysis functions as a mean to get an overview of all processes and helps to prepare further data collection techniques which are necessary to validate the information collected from internal documents (Siebenbrock, 2018).

The data gathered from Internal document will be used for the construction of a Process Map and will be complemented by data gathered from unstructured interviews. The Process Map will be analyzed in the Current Situation chapter.

Unstructured interviews are a form of primary data collection (Zhang). They are performed orally and during the interviews, open-ended questions are asked to the interviewee (Siebenbrock, 2018). Asking open-ended questions facilitates a discussion between interviewer and interviewee and the interviewer can ask follow-up questions to get more insights into the topic (Siebenbrock, 2018). An advantage of the execution of unstructured interviews is the non-limitation of respondents' answers which could be a problem in structured interviews with closed questions (Siebenbrock, 2018). By the execution of unstructured interviews, the interviewer can receive complete information about the exact execution of processes in the shipping and commercial department of the case company.

The execution of three unstructured interviews with the team leader of the shipping department, the team leader of the commercial department, and one general manager will provide the necessary data for finalizing the Process Map which is needed for further analysis. The researcher will ask the interviewees to precisely explain the processes executed in the respective department. After the explanation of processes by the interviewees, the interviewer will ask the interviewees about potential improvement suggestions for achieving time savings and cost reductions. The gathered information about improvement suggestions will be used as an additional data source to construct a plan for the achievement of process improvements in the shipping and commercial department of Company X. The answers to the different interviews are cross-examined to guarantee the validity of the results.

In addition to unstructured interviews, structured interviews will be conducted to gather approximate processing times of the shipping and commercial department. The approximate time interviews will be conducted with three employees of the commercial and four employees of the shipping department. The outcomes of the structured interviews will be used to construct a Time Value Map, which graphically classifies if time spend for a process is value-adding or non-value adding. The aim of this visualization and classification of process times is the elimination of waste and streamlining of the analyzed process and belongs to the Theory of Lean Manufacturing (Toolkit, 2018). Figure 4 in the Appendix shows an example of a Time Value Map (Toolkit, 2018).
Structured time interviews can be classified as a quantitative data collection method because the interviewer asks the interviewees to indicate process times, in minutes, of the current working day, which is recorded as a numerical value (Blackstone, 2012).
An advantage of approximate time interviews is the fact that the researcher can collect quantitative data without the occurrence of the Hawthorne effect which would bias the collected data (Kenton, 2019). The Hawthorne effect states that people that are aware of an ongoing observation “modify their behavior simply because they are being observed (Kenton, 2019).” The Hawthorne effect does not occur during the execution of approximate time interviews because employees are not observed by the researcher and can execute their activities without interference.

SAP data, as a quantitative secondary data source will be used to generalize the in the approximate time interviews collected data of processes approximated in a limited time-period to the general processes of the shipping and commercial department. “Generalizability can be defined as the extension of research findings and conclusions from a study conducted on a sample population to the population at large ("Generalizability and Transferability,").”
In this analysis, the data collected from the limited approximation period is classified as the sample population. All processes performed during a year in the shipping and commercial department can be classified as the population at large and can be retraced by the utilization of SAP data.
The following section discusses how the three sub-questions of this research will be answered.

Sub-question one, “Which Lean Manufacturing and Theory of Constraints optimization theories could be applied to the service sector?” was answered in the Theoretical Framework.
Sub-question two, “Which Lean Manufacturing and Theory of Constraints optimization theories that could be applied to the service sector have the most potential in achieving the defined criteria of time savings and cost reductions in the case company?” will be answered by the Improvement evaluation chapter. This chapter evaluates the most profitable improvement possibilities regarding the defined criteria of time savings and cost reductions.
Sub-question three, “How can the Lean Manufacturing and Theory of Constraints optimization theories with the most potential for the case company be applied to the two departments to achieve time savings and cost reductions?” will be answered in the Bottleneck Identification and the Improvement Possibilities chapter.
The Bottleneck Identification chapter will analyze the constraints in the processes of the case company and the Improvement Possibilities chapter discusses practical applications of the previously reviewed theory to improve the processes of the case company with a focus on time savings and cost reductions.
The Current Situation chapter, which introduces the case analysis, is not used for answering one of the research questions but functions as a basis for conducting the subsequent analysis.
By finding an answer to the three sub-questions the research question, “How can Lean Theories and Theory of Constraints be applied in the service sector to achieve process optimization and improve resource utilization?” can be answered in the Conclusion of this paper.

3.2 Data analysis

The collected qualitative and quantitative data will be analyzed according to the criteria of time savings and cost reductions. The theories presented in the theoretical framework will be applied to the gathered data about the processes of the shipping and commercial department of Company X. The findings of this theory application will be used to construct an improvement plan for the analyzed departments.
If the application of Lean Manufacturing and Theory of Constraints results in process optimization and improved resource utilization by the criteria of time savings and cost reductions in the two departments of Company X, the applicability of the theories can be generalized to other service sector companies with the same process characteristics.

3.3 Limitations

Under normal circumstances, observations of employees would have been the primary choice for constructing a Process Map. “Observational research findings are considered strong in validity because the researcher is able to collect a depth of information (Brown)” about the particular research topic. Due to the reason that companies must suspend contacts for the period of COVID-19, observation in the shipping and commercial department is not possible, and the research has to be conducted with alternative methods, document analysis, and unstructured interviews, which can lead to less reliability of data because these methods have the risk of depicting the activities of employees in an idealized way (Cacciattolo, 2015).
A limitation of document analysis, as a qualitative research method is, that the analyzed documents could contain insufficient detail, necessary for the research because they have been created without a research agenda (G. Bowen, 2009). This limitation is prevented by the complementary execution of unstructured interviews.
A disadvantage of unstructured interviews is the possible inaccuracy of the information provided by respondents ("Strength and Weaknesses of Qualitative Interviews," 2015).
The disadvantage is abrogated by the accompanying document analysis and the execution of multiple independently performed unstructured interviews.

Another limitation is a regulation from the workers' council of the case company, that prohibits the recording of process times of employees. If the regulation would not be in place, observation of employees and the recording of process times would be the first option to gather accurate time data instead of conducting approximate time interviews.

Observation, as a primary data collection method is performed by actively observing and recording the processes performed by specific employees (Siebenbrock, 2018). Observation as a data collection method can be classified as obtrusive because the observed employees are aware of the observer (Siebenbrock, 2018). The main advantage of observation as a data collection method is its superior accuracy compared to approximate time interviews because the observer does not have to rely on the accuracy of information provided by the interviewee (Choudhury).

A disadvantage of obtrusive observation is the problem that employees that know that they are being observed perform differently than normally (Siebenbrock, 2018). This disadvantage would, however, not play a significant role in this research because of the Hawthorne effect (Bennett, 2019). "The Hawthorne effect says that increased observation equals increased productivity (Bennett, 2019)." The Hawthorne effect in this research would show that the results of the research would be even more profitable than indicated by the results. Employees perform less productive under normal working conditions without the presence of an observing third party (Bennett, 2019).

A disadvantage of the execution of approximate time interviews is the risk of inaccurate data provisioning by respondents, as already discussed for unstructured interviews ("Strength and Weaknesses of Qualitative Interviews," 2015). Employees who are not observed during process execution and have to evaluate their performance during an interview tend to "give themselves an overly inflated positive self-evaluation (Miller, 2013)". This biased self-evaluation has to be taken into account when interpreting the interview data.

The disadvantage is extenuated by the execution of multiple independently performed approximate time interviews. The answers to the different time interviews are cross-examined to guarantee the validity of the results.

The from the approximate time interviews collected data with employees of the shipping and commercial department can be classified as representative because the departments process approximately 60 orders per day. The process steps are repetitive and therefore, 60 repetitions can be assessed as representative for the generalization over a time period of one month, one year, and the 10-year Investment Horizon.

4. CURRENT SITUATION

To assess the current situation of the shipping and commercial department a process map is created to visualize the executed processes and its connections. The process map can be found in the Appendix in Figure 5. Process maps give an understanding of the as-if situations before the improvement implementation (Slack, 2016).

The following passage describes the visualized processes of the process map in more detail.

The shipping process starts with an in SAP incoming order which was created by the Service Center. The Service Center is a different business unit that focuses on transport initiation.

The Production Planning checks if the requested products are available in the warehouse of the shipping department. If the products are available, the Production Planning can directly create a delivery note in SAP. Once the delivery note has been created, it is forwarded to the shipping department where it is printed out for further processing.

If an item on the delivery note is not available in the warehouse of the shipping department the Production Planning does not pass on the delivery note to the shipping department, because the department could not process the delivery note. The Production Planning first has to initiate the supply of the required product and wait until it is stored in the warehouse of the shipping department.

The tasks of the Production Planning can be observed in Figure 6 in the Appendix.

As soon as the goods are available again, the delivery note can be prepared, and the shipping department can begin to pick the order.

Employees of the shipping department print out the received delivery notes three times a day. The department has 9:00 to 17:00 workdays.

After the printing, picking the delivery note is started. The employees in the shipping department look at the individual items on the printed delivery note which contains the material number, the required product, and the requested quantity. The employees then take the required products from the warehouse racks and process them according to the picking-request.

During packing, the employees of the shipping department pack the required products into a suitable package/packages, which they select themselves, weigh this package/packages after packing, and note the weight of the package and the corresponding dimensions by hand on the delivery note. The employees determine the weight of the package with the help of an analog scale, which is located at the workplace. Before closing the package, accompanying documents must be printed and included.

After packing the products, the packed package(s) is/ are placed on a shelf where it/ they remain(s) until the next steps necessary for subsequent shipping have been prepared.

The employees who have packed the order place the processed delivery notes in a predefined storage tray. The picking process can be seen in Figure 7 in the Appendix.

The commercial department subsequently picks up the stored delivery notes from the tray, packs them digitally in SAP, and prepares the shipping bags for the subsequent shipping of the orders. For digital packing, the commercial department needs the weight and dimensions of the packed packages, previously written on the delivery notes by the employees of the shipping department. These values have to be entered manually in the system by the commercial department.

The next step is to select the packaging materials used by the employees of the shipping department in the system. This is necessary for the shipping provider to calculate the exact shipping costs depending on dimensions and weight of the packages.

Possible packaging materials are already registered in SAP and must be selected according to the details indicated on the processed delivery notes.

After the employees have packed everything in the system, the forwarding agent who will deliver the orders must be specified.

After the commercial department has filled in all the data, a delivery note is printed for the customer. Within the EU, this delivery note is sufficient, as the package does not go through customs.

Outside the EU, the delivery note, an invoice, and an export accompanying document are required for customs. Before employees can print the required documents for non-EU shipment they have to wait for customs to approve the shipping requests. The waiting times are used to start processing the next delivery notes and does not result in idle time.

After the digital packaging, employees of the commercial department assemble the corresponding shipping bags and deliver multiple shipping bags to a collection point in the shipping department. Employees in the commercial department have to deliver the bags manually to the shipping department.

This task is not done at prescribed times or intervals, but flexibly according to the processing speed of the commercial department. The processes performed in the commercial department are depicted in Figure 8 in the Appendix.

Employees from the shipping department subsequently assign the shipping bags to the correct packages and attach the bags to the assigned packages. An example of a shipping bag can be seen in Figure 9 in the Confidential Appendix and an example of a package can be seen in Figure 10 in the Confidential Appendix. Once the shipping bags have been attached, the packages are placed in another storage rack until they are picked up by the shipping agent.
The shipping process is illustrated in Figure 11 in the Appendix.

The physical movements in the shipping and commercial department are depicted in Figure 12 in the Confidential Appendix. The blue arrows visualize the physical movement during a process in the shipping department and the orange arrow visualizes the physical movement during a process in the commercial department.

The accuracy of the processes visualized in the process map have been confirmed during interviews with managers and employees of the two departments.
The first step for checking accuracy were two independent interviews with managers and employees of the two departments to check for discrepancies between the perceived execution of processes. During these interviews, the managers and employees were asked to depict their processes as detailed as possible. No discrepancies were found between the information gathered from the independent interviews.
The next step in assessing the validity of the process map were follow up interviews with six employees of the two departments to assess approximate times needed for the execution of activities. The interviewed employees reassured the accuracy of the constructed Process Map during these interviews. The approximate times gathered during the interviews confirm the accuracy of the process map because they do not deviate significantly. Would the times deviate significantly this could be an indicator for an additional activity that is missing in the process map.
Managers as well as employees of the two departments assured that processes are conducted as described in this chapter and that no workarounds exist. The departments follow a fixed procedure that is not changed by eventualities.
The approximate time interviews and its outcomes will be discussed in the upcoming Bottleneck chapter.

The beforementioned finding that the processes are executed without workarounds is an advantage of the current processes in the two departments. The standardization of processes shows an implementation of Lean Manufacturing concepts in the departments (Karthik & Silksonjohn, 2019). Standardization leads to the elimination of waste by the repetition of processes which has a mistake-reducing effect (Karthik & Silksonjohn, 2019).
Another advantage of current processes is the fact that idle time of employees does not occur during process execution. The management has designed the processes in such a way that even though waiting times occur, employees can perform different activities during the unavoidable waiting times. An example is the occurrence of waiting times due to customs approval and simultaneous digital processing of delivery notes.
When analyzing the function of different employees it can be noticed that the production planners are very useful because they contribute to waste elimination which is the main goal of Lean Manufacturing (Karthik & Silksonjohn, 2019). Only orders that can immediately be processed are handed over to the shipping department. If the shipping or commercial department would have to check the availability of stored products before the processing of a delivery note, reorder products, as well as solve unforeseen problems, the processes of the departments could not be classified as standardized. Therefore, the benefits of standardization can only be reaped by the execution of variable activities by the production planners.

The following chapters will analyze potential improvement possibilities, that have the goal of further improving the already well-structured processes of the analyzed departments. The goal is to find an improvement possibility that retains the current advantages of process execution and additionally enables time savings and cost reductions in the analyzed processes.

5. BOTTLENECK IDENTIFICATION

The Bottleneck Identification chapter provides an answer to sub-question three of this research. In this chapter, the Bottleneck of the previously illustrated processes will be identified. The previously constructed process map, which can be seen in Figure 5, serves as the baseline for bottleneck identification because it visualizes the interconnectedness of processes (Roser et al., 2015).
Two interviews with the team leaders of the shipping and commercial department were conducted to point out the difficulties in the day-to-day activities of employees. The interviews were conducted with the focus on the processes that are visualized in the process map, which is shown in Figure 5.
Under normal circumstances, a walking process and the observation of employees during process execution would have been the primary option for the identification of the Bottleneck. However, due to Covid19 restrictions, unstructured interviews about process execution difficulties were conducted in this research to pinpoint the bottleneck.
The team leader of the shipping department indicated that there are no present difficulties in the day-to-day activities of his employees.
The team of the commercial department stated that his department never has idle time. There are always delivery notes to be processed and regularly to be processed orders increase to the point where the order load is too high, and the department is not able to complete all incoming orders in time. This limits output of the two departments. Too high workload occurs mostly when one or more employees of the department are absent and other employees have to carry out excess work during their regular working hours.
When the workload gets too high overtime is necessary or additional work has to be done during the weekend. This overtime incurs additional costs for Company X.
This problem of too high workload in the commercial department was confirmed by a general manager of the company.
The permanent presence of too many open delivery notes that have to be processed to initiate the shipping of packed products shows, that the bottleneck can be identified in the digital packing and shipping process of the commercial department. Another indication for the presence of the bottleneck is the regular necessity of commercial department employees to work overtime, while employees of the shipping department constantly operate with an unchanged workload, without the necessity of overtime.
The presence of the bottleneck results in a delay of shipping of orders to the client.
The bottleneck can be classified as a downstream bottleneck because it leads to blocked manual processes and overloaded inventories in the commercial department (Roser et al., 2015).

The digital packing and shipping in the logistics sector is comparable with the process of preparing finished goods for further processing, in the manufacturing sector and the manual packing of products with the manufacturing of goods in the manufacturing sector (Roser et al., 2015).

After the previous identification of the bottleneck in the digital packing and shipping process of the commercial department by the means of unstructured interviews with multiple interviewees, quantitative analysis of processes of the shipping and commercial department makes the qualitative findings measurable and enables the execution of a detailed analysis of time savings and cost reductions potentials in the upcoming chapters.

For the execution of quantitative analysis, approximate time interviews were conducted in the shipping and commercial department. The four interviewees of the shipping department approximated their process times for one workday, which can be seen in Table 2,3,4 and 5 in the Confidential Appendix.

The daily values have to be divided by the daily order quantity, to calculate an average approximate time for the executed processes. After calculating the average approximate process times of the four interviews, the values from the interviews will be combined and averaged to excel at general average approximate process times that will be used throughout the following analysis. The daily order quantity is determined by dividing the number of delivery notes processed in one year, see Figure 13 in the Confidential Appendix, by the number of yearly working days. The daily order quantity equals thereby approximately 60 orders per day.
A comparison between the general average approximate process times per employee are depicted in Table 6 in the appendix. Table 7 illustrates the average time per activity as well as the spread of the answers of the four interviewed employees. The average activity times will be used for the construction of a Time Value Map in Chapter 5.1.

Table 7. Average activity time in min & spread of data – Shipping Department

Activity	Average activity time	Shortest activity time	Longest activity time
The shipping department prints the delivery note	1.5	1	2
Shipping employee goes to the warehouse, gathers the products listed on the delivery note from the warehouse racks and returns to the workplace	1.33	1	1.5
Packs the products in suitable packages and adds accompanying documents in the packages and closes the packages	3.33	2	4
Weights the packed packages and makes a handwritten notation on the delivery note that includes weight of the packages and corresponding dimensions	0.5	0.5	0.5
Places packed products on a waiting shelf and the processed delivery note in a storage tray	0.5	0.5	0.5
Employee of the shipping department attaches shipping bags to the corresponding packages and places the packages in a storage rack	0.83	0.5	1.5

Table 7 highlights the low spread of approximate activity times which confirms the validity of the average activity times utilized in the following time savings and cost reductions calculations.

In addition to interviews with employees of the shipping department, three interviews were conducted with employees of the commercial department. The interviewees were asked to approximately indicate execution times of the digital packing process of delivery notes with differing number of products per order, as well as the physical creation and transportation of shipping bags. The three approximate time interviews can be seen in Tables 8, 9, and 10 in the Confidential Appendix.

To be able to generalize the findings of the approximate time interview interviews, additional data is needed to make a forecast for future resource utilization.
Figure 14, which can be found in the Confidential Appendix, displays the orders sent in the EU. This data is important because other shipping specifications occur for EU-shipments, then for Non-EU-shipments.
[Confidential Appendix]

Figure 16 has the same purpose as Figure 14, with the difference that it focuses on Non-EU orders, which have to be processed differently than EU-orders. Figure 16 is listed in the Confidential Appendix.

Figure 17 calculates the proportion of in Tables 8, 9, and 10 measured processing times of Non-EU orders to their total occurrence over the one-year data collection period and can be found in the Confidential Appendix. The data of Figure 17 will be used for further analysis to generalize the collected data.

Figure 13, which is located in the Confidential Appendix, calculates the total proportion of EU orders and Non-EU orders to total orders for non-dangerous goods.
[Confidential Appendix]

The results of the previous figures will be used in the following two calculations that assess the average process times in the shipping and commercial department. This data will be used for the construction of a Time Value Map in the following chapter.

Figure 18 calculates the approximate processing times of the commercial department for the digital shipment of EU- and Non-EU orders and the approximate processing times for shipping bag creation and transportation from the commercial to the shipping department. During the three interviews with the employees of the commercial department, zero spread between approximate time estimations was discovered. That is why Figure 18 only visualizes the approximate process times and not the shortest- and longest activity time as shown in the average approximate time analysis of the shipping department.

EU Shipping

Average picking-request processing time per product in min	Number of products
3	1
3	2
4	3
14	25

Non-EU Shipping

Average picking-request and invoice creation processing time per product in min	Number of products
6	1
7	2

EU- and Non-EU Shipping

Time needed for the delivery of shipping bags to the shipping department in min	Avrage amount of shipping bags
1	4

Average processing time EU-Shipping in min	3.1
Average processing time Non-EU-Shipping in min	6.2

Average general processing time	4.2

EU Shipping

Printing of documents and packing of shipping bag
1

Figure 18. Average Approximate Time Calculation Commercial department

The delivery time of shipping bags from the commercial to the shipping department is calculated by taking the average of the process times gathered from the approximate time interviews. The average delivery time is one minute. This value has to be divided by two because the process map shows that employees of the commercial department deliver shipping bags to the shipping department and simultaneously collect the processed delivery notes for further processing in the commercial department.

The same procedure is undertaken for the calculation of average printing and packing time of shipping bags. The average time needed for printing and packing is one minute.

For the calculation of average processing time for EU-shipping, the calculated percentages of figure 13 are used to balance the different processing times according to their likelihood of appearance. After the balancing of processing times, the average processing time for EU-Shipping is calculated. The average processing time is 3.1 minutes.

The same calculation is executed for the average processing time for Non-EU shipping. The average processing time totals 6.2 minutes.

For calculating the average general processing time, the average EU and Non-EU processing times have to be balanced according to its probability of occurrence. The probability of occurrence is illustrated in Figure 14. The average general processing time equals 4.2 minutes and will be used as the main value for the following calculations.

Figure 19 in the Appendix illustrates the process map of the shipping and commercial department with the integration of process times for each process step in minutes.

5.1 Time Value Map Construction

The following section deals with the construction of a Time Value Map of the analyzed processes of the case company and identifies the appearance of wastes in the processes.

The method of Time Value Mapping differentiates between activities that are value adding, non-value adding, or essential non-value adding (R. Bowen, MCDonough, M., 2013).

Value-added time is plotted above and non-value-added time below the centerline. The centerline displays the duration of the entire process (R. Bowen, MCDonough, M., 2013).

Value-added activities can be classified as activities that "increase the value of the product or service from the customer's perspective (Toolkit, 2018)." Non-value-added activities, on the contrary, do not increase the value of the product or service (Toolkit, 2018). Non-value added activates can be discovered by checking if one or more of the seven types of waste, as analyzed in the Lean Manufacturing Chapter in the Theoretical Framework, are present in the analyzed activity (R. Bowen, MCDonough, M., 2013).

Next to Value Added Activities and Non-Value Added Activities there also exist "Essential Non-Value Added Activities (Toolkit, 2018)." These activities are necessary for the business, but customers would not be willing to additionally pay for them (Toolkit, 2018).

Non-value-added activities can be classified as avoidable waste and essential non-value added activities, on the contrary, can be described as unavoidable waste (Toolkit, 2018).

Ten different identified activities are visualized in Figure 20.

Activity number	Activity Description	Time in sec	Category
1	The shipping department prints the delivery note	90	Essential non-value added time
2	Shipping employee goes to the warehouse, gathers the products listed on the delivery note from the warehouse racks and returns to the workplace	80	Essential non-value added time
3	Packs the products in suitable packages and adds accompanying documents in the packages and closes the packages	200	Essential non-value added time
4	Weights the packed packages and makes a handwritten notation on the delivery note that includes weight of the packages and corresponding dimensions	30	Essential non-value added time
5	Places packed products on a waiting shelf and the processed delivery note in a storage tray	30	Non-value added time
6	Employee of the commercial department picks up stored delivery notes	30	Non-value added time
7	Digital packing and shipping of order in SAP	252	Essential non-value added time
8	Prints documents and packs shipping bag	60	Essential non-value added time
9	Stores multiple shipping bags at workplace and delivers shipping bags to a collection point in the shipping department	30	Non-value added time
10	Employee of the shipping department attaches shipping bags to the corresponding packages and places the packages in a storage rack	50	Essential non-value added time

Figure 20. Time Tracking Time Value Map

The printing of delivery notes (no. 1) can be classified as Essential non-value added time, as it is necessary for the employees to execute the picking process, but customers would not be willing to additionally pay for this activity (Toolkit, 2018).
The gathering of products from the warehouse and returning to the workplace (no. 2) where the packing of packages will be performed can be classified as Essential non-value added time, as it is a necessary activity that has to be performed so that the customer will receive the order. It is however not value adding because the activity only involves the internal movement of a product and does not provide additional value for the customer, assuming that no failure occurs during the packing process. A mispacked package would, however, decrease the value for the end customer.
The packing of products in suitable packages and adding of accompanying documents in the packages and closing of the packages (no. 3) can also be classified as Essential non-value added time, as it is necessary for the shipment to the client but does not add additional value.
The weighting of packages and notation of weight and dimensions (no. 4) can be classified as Essential non-value added time, as it is necessary for the subsequent shipping to the client. The assessment of weight and package dimensions does, however, not directly add value for the customer.

The placing of packed products in a waiting shelf and the processed delivery note in a storage tray (no. 5) can be classified as Non-value added time. When analyzing the seven types of waste, activity number four can be classified as the waste of "Waiting (Toolkit, 2018)."
The picking up of stored delivery notes by an employee of the commercial department (no. 6) can be classified as Non-value added time, as it is unnecessary transport which is one of the seven types of waste (Toolkit, 2018). The delivery notes do not have to be physically transported from one department to the other, as it is currently done. The physical transport can be undertaken in digital form or be eliminated completely.
The digital packing and shipping of orders in SAP (no. 7), can be classified as Essential non-value added time, as it is a back-office activity that is necessary for the shipment of the packages to the client but does not add direct value for the client.
The printing of documents and packing of the delivery bag (no. 8) can also be classified as Essential non-value added time, as for the shipment of products, specific documents are needed which have to be attached to the packages. They however do not add value for the customer.
The storing of multiple shipping bags at the workplace and the delivery of shipping bags to a collection point in the shipping department (no. 9) can be classified as Non-value added time, as it involves the transportation and storing of shipping bags which are two avoidable wastes. Both of these wastes can be avoided by a restructuring of processes.
Last but not least, the attaching of shipping bags to the corresponding packages and placing of the packages in a storage rack (no. 10) can be classified as Essential non-value added time, as it is necessary for the subsequent shipping of the products but does not add direct value for the customer.

The Time Value Map, Figure 21, is constructed by plotting the previously analyzed activities above or below the centerline of the map, according to categories of Value added time, Non-value added time, and Essential non-value added time (Toolkit, 2018). One column in this Time Value Map visualizes one minute of activity execution.
It can be observed that all activities are placed beneath the centerline which indicates that there do not exist value adding activities in the sample shipping and commercial department according to the Time Value Mapping definitions utilized in the manufacturing sector.

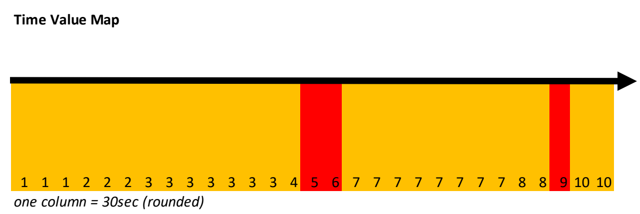


Figure 21. Time Value Map of Current Situation

6. IMPROVEMENT POSSIBILITIES

This chapter examines two improvement possibilities that can result in time savings and cost reductions in processes of the case company operating in the service sector. The findings of this chapter provide an answer to sub-question three, which is discussed in the Methodology chapter.

The two improvement possibilities apply the Lean Manufacturing concept of Automation to the shipping and commercial department of Company X. Automation solutions are chosen because of the previously analyzed benefits of cost

minimization through the elimination of the largest expense, the manual workforce (Lawson, 2017).
The first improvement possibility can be classified as a one-piece flow and the second, as a complete automation through the implementation of service robots.
The improvement possibilities are chosen because they improve the analyzed processes by the means of two different approaches. The one-piece flow improvement possibility improves processes by software implementation and system automation, that makes repetitive manual processes redundant and alters the operations of the workforce.
The complete automation through the implementation of service robots' improvement possibility improves processes by hardware and software implementation, which leads to system automation as well as the replacement of the complete human workforce by robots.

The first improvement possibility is the achievement of a one-piece flow, as discussed in the Theoretical Framework.
In a one-piece flow "parts are moved through operations from step to step with no work-in-process in between either one piece at a time or a small batch at a time (Dolcemascolo, 2020)."
The Time Value Map highlights, that waiting and unnecessary transport of products are the main cause of waste occurrence in the current processes. By the elimination of these wastes, work-in-process is avoided, and the processes can be executed by one department instead of two. The one-piece flow automates the digital shipping of orders in SAP, which is the main task executed in the commercial department. By the automation of the digital shipping process, delivery bag packing can be relocated to the shipping department to eliminate the previously discussed wastes and thereby reduce processing times of delivery notes.
A one-piece flow can be achieved by the previously addressed scanner-based automation in combination with business process automation. Business process automation can be defined as "the use of technology to complete business processes with minimal human intervention (M. Rouse, 2020)." The workforce is the largest expense in logistics business processes (Lawson, 2017), therefore, reducing human intervention through automation facilitates the highest time savings and cost reductions.

The usage of scanners in the shipping department facilitates the picking process by automatically transferring data into SAP that is currently added manually.
The one-piece flow process improvement can be implemented as follows.
All delivery notes have to display a barcode that links to the order details in SAP. The first step of the picking process is the scanning of the barcode printed on the delivery note. A mask will open in SAP that guides the employee through the automated digital shipping process. To enable the automated process a document has to be created that displays different barcodes that correspond to different packages. These barcodes need to store information about the package dimensions and have to be placed at the workplaces of the employees of the shipping department. Instead of manually noting the dimensions of the package on the delivery note and later transferring it into SAP, the employee executing the process scans the corresponding barcode on the document and the dimensions are automatically added in the SAP.

Scanner-based automation enables the implementation of business process automation throughout the analyzed departments. In current processes, processed delivery notes are transported from the shipping to the commercial department for digital shipment. The commercial department performs the back-office tasks for digital shipment, compiles the delivery bags, and delivers the bags to the shipping department. In the shipping department, the bags are then attached to the corresponding packages. This process can be automated by scanner-integration, SAP mask integration, as suggested during an interview with an employee of the shipping department, and system automation. In addition to scanning a barcode that signals the system that the employee has to be guided through the automated process and a second barcode that stores the package dimensions, the creation of an SAP mask, that requests the input of weight of the packed package, makes the manual notation of package weights on the delivery note redundant. By the implementation of the changes, all information that is manually noted on the delivery note in current processes is automatically added to SAP. Therefore, the delivery of the processed delivery notes from the shipping to the commercial department is unnecessary. By implementing system automation, the commercial department can be made redundant because back-office activities can be automated in SAP. After the automated integration of data in SAP, through scanner and mask utilization, the digital shipment can automatically be executed in SAP without the active participation of the employee. The system needs to determine the shipping agent and decide if additional documents have to be added to the delivery. This process can be executed by a programmed decision-making software that is implemented in SAP. For non-EU orders, an invoice has to be added to the shipment. Shipments sent within the EU do not need an invoice. Specific products need accompanying certificates. After the automated program has completed the digital shipping, the accompanying documents will be printed automatically at the workplace in the shipping department. The employee who packed the packages can then create and attach the shipping bag to the packages and place them in a storage rack for subsequent collection by the shipping agent. Figure 22 in the Appendix displays the One-piece flow process map with corresponding process execution times.

In contrast to the achievement of a one-piece flow, a more radical improvement approach is the changing of processes by complete automation through the implementation of service robots. "Service robots AGVs are primarily used for the realization of internal transport processes. Service logistics robots in the manufacturing processes have a very large estimate of the significance of factors when it comes to physical labour reduction (Karabegović, Karabegović, Mahmić, & Husak, 2015, p. 1)." Achieving automation through the employment of internal transport service robots would eliminate the waste of transport by employees, as discussed in the Theoretical Framework. The service robots could be programmed to gather products from the warehouse, deliver them to the workplace and after processing, deliver the packed products to the storage rack where the packages are picked up by the shipping agent. An investment in internal transport service robots would automate the processes to the extent where employees have the sole task of packing and preparing the shipment in the system.
In addition to internal transport service robots, there exist autonomous handling, packaging, and sorting robots that can operate in the logistics sector (Karabegović et al., 2015).
The integration of service robots that automate the packaging process, in combination with in the previous section described system automation would make the human workforce in the analyzed processes of the case company redundant.

7. EVALUATION OF IMPROVEMENT POSSIBILITIES

This chapter evaluates the improvement possibilities outlined in the previous chapter, by the execution of a profitability analysis and an ease of implementation and impact analysis, and thereby provides an answer to sub-question two.

A profitability analysis can be undertaken by assessing the time needed for current operations manually performed by employees and comparing the outcome to the expected time needed after the implementation of the improvement solution. The data gathered from the approximate time interviews will be taken as a basis for current process times and the theoretical calculated time savings potential will be subtracted from the approximate time interviews data. This calculation reflects the time needed for the processing of one order after the implementation of the process improvement.

The theoretical time needed for the processing of one delivery note has to be multiplied by the number of delivery notes processed during the last 12 months. The outcome of this multiplication is the time needed for one-year delivery note processing with improved processes.

To calculate the total time savings, the time needed for the processing of one delivery note before the improvement implementation also has to be multiplied by the number of delivery notes processed during the last 12 months. The one-year processing time after the improvement implementation has to be subtracted from the one-year processing time before the improvement implementation to calculate the total one-year time savings.

By multiplying the outcome of the one-year time savings calculation by 10-years, the time savings of the case company's investment horizon can be identified.

Cost reductions will be calculated by taking the outcome of the "Time savings" criteria, to calculate how much this saves Company X in terms of employee cost on the initially discussed 10-year investment horizon. To arrive at a final value for "cost reductions", necessary investments for the implementation of the process improvement solution will be subtracted from the previously calculated 10-year employee-cost-savings. The outcome of this subtraction displays the final value for the "cost reductions" criteria.

[Confidential Appendix]

In the following sections, time savings and cost reduction potentials will be calculated for two improvement possibilities, namely the One-piece flow and Complete automation through the implementation of service robots.

One-piece flow:

When implementing the previously described One-piece flow multiple redundant processes can be saved. These processes are highlighted in red in Figure 23 which can be found in the Appendix. Figure 23 displays the processes of the commercial and shipping department and depicts the corresponding process times.

The overall process time of the shipping and commercial department combined is 14.2 minutes per order.

The implementation of the One-piece flow improvement would make the delivery of shipping bags to the commercial department redundant because shipping bags would be composed in the shipping department during the picking process. This redundancy would save one minute in process time. This saves seven percent of the total process.

The digital processing of delivery notes would be automated by SAP automation and would make manual digital processing activities redundant. This automation saves 4.2 minutes per order which equals approximately 30 percent of the total process.

The third process which would be made redundant by the implementation is placing of packed products on a waiting shelf and the processed delivery note in a storage tray. The automation prohibits the waste of unnecessary transport which saves 0,5 minutes per delivery note. This saving equals 3.5 percent of the total process time.

Last but not least, the One-piece flow implementation shortens the process of attaching shipping bags in the shipping department to the corresponding packages and the placing of packages in a storage tray. The employees do not have to spend time sorting the different shipping bags and packages but can directly attach the shipping bag to the packed packages. This process simplification approximately saves 0.33 minutes per order which equals 2 percent of the total process.

In total, the implementation of the One-piece flow saves 42 percent of the total process, without the emergence of alternative activities.

Figures 24 and 25 in the Confidential Appendix depict the savings potential over a month, a year, and a 10-year Investment Horizon. The total hours which the One-piece flow implementation would save per month are 114 hours, per year 1365 hours, and in the 10-year Investment Horizon 13650 hours.

Figure 26 illustrates the Cost Savings Potential of the analyzed automation and can also be found in the Confidential Appendix. The hourly employee cost for the case company is composed of the yearly employee cost and the corresponding yearly working hours.

By the implementation of the One-piece flow automation the case company has a savings potential of 4337 euros monthly, 52039 euros yearly, and 520389 euros on the 10-year Investment Horizon.

The Time Value Map of the One-piece flow, which can be seen in Figures 27 and 28, shows that all non-value added activities, initially being shown in the Time Value Map of the Current Situation will be made redundant by the automation.

These activities are, first, the placing of packed products on a waiting shelf and the processed delivery note in a storage tray, second, the gathering of the stored delivery notes by the commercial department, and third, the storing of multiple shipping bags at the workplace in the commercial department and the delivery of shipping bags to a collection point in the shipping department.

The automation of one essential non-value added activity, namely the digital packing and shipping of order in SAP, enables the avoidance of the non-value added activities in the processes of the commercial and shipping department of the case company.

Additionally, figure 28 visualizes the total time savings potential of 42 percent of the automation.

Activity number	Activity Description	Time in sec	Category
1	The shipping department prints the delivery note	90	Essential non-value added time
2	Shipping employee goes to the warehouse, gathers the products listed on the delivery note from the warehouse racks and returns to the workplace	80	Essential non-value added time
3	Scans the barcode on the delivery note, packs the products in suitable packages and adds accompanying documents in the packages and closes the packages	200	Essential non-value added time
4	Scans the to the package corresponding barcode from the packaging document and manually weights the package and enters the weight in SAP	30	Essential non-value added time
5	Prints documents and packs shipping bag	60	Essential non-value added time
6	Employee of the shipping department attaches shipping bags to the corresponding packages and places the packages in a storage rack	30	Essential non-value added time

Figure 27. Time Tracking Time Value Map – One-piece flow

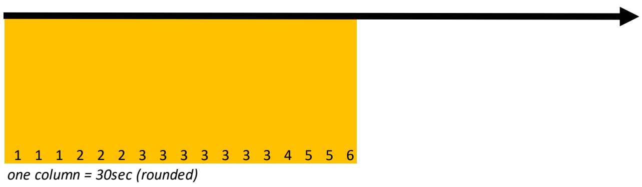


Figure 28. Time Value Map One-piece flow

Complete automation through the implementation of service robots:

The second automation possibility, discussed in the previous chapter is complete automation through the implementation of service robots.
This automation makes all manually performed processes of the shipping and commercial department redundant with the aim of cost reductions.
By the integration of service robots, 14,2 minutes, which equals 100 percent of the manual process time will be automated, as can be seen in Figure 29 in the Appendix.

Figure 30 in the Appendix depicts the monthly time savings potential that would be achieved by the integration of complete automation through the implementation of service robots. Approximately 290 hours would be saved per month by complete automation.
Figure 31 in the Appendix visualizes the time savings potential per year when implementing the complete automation by service robots. 3477 hours of manual labor would be saved by the automation solution per year.
On a 10-year Investment Horizon, the case company would save 34774 manual labor hours as can be seen in Figure 32 in the Appendix.

Figure 33 in the Appendix analyzes the cost reductions potential of complete process automation by the integration of service robots. Instead of calculating with a one-time investment cost for robots' purchase and incorporation in the case company's structure, the cost calculation is performed by an hourly cost of 20 euros per robot. A study by Roland Berger has shown that the total hourly cost of a robot is 18 to 20 euros in the logistics sector (Berger, 2016).
This research will take 20 euros as a value for total hourly service robot costs to calculate conservatively.
This hourly cost is more precise than a one-time purchasing and incorporation cost because depreciation of the service robots will involve regular maintenance, replacements, and upgrades to ensure continuing efficiency (Owen-Hill, 2017).
By the implementation of complete automation through service robots the case company has a savings potential of 5796 euros monthly, 69549 euros yearly, and 695489 euros on the 10-year Investment Horizon.

The construction of a Time Value Map is not necessary for complete automation through the implementation of service robots because all current manual processes would be automated by the improvement. The service robots receive the necessary information for activity execution by instructions of the preceding activities of the customer service center which is responsible for order preparation and the coordination of activities.

Next to the analysis of time savings and cost reductions potentials, the ease of implementation and the corresponding impact is another factor that has to be taken into account when selecting the most suitable improvement solution.
Figure 34 displays a matrix that visualizes the ease of implementation on the x-axis and the impact on the y-axis, of both analyzed improvement possibilities.

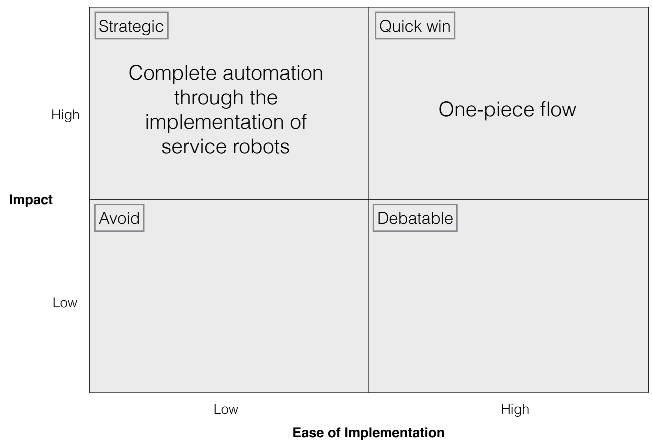


Figure 34. Ease of Implementation/Impact matrix

Both improvement possibilities have a high impact which becomes evident by the positive outcomes in time savings and cost reductions that can be achieved by the implementation of either of the two improvement solutions.
The difference in suitability for the case company can be identified by comparing the Ease of Implementation.

In the complete automation by the implementation of service robots improvement option, a high upfront investment would be needed to profit from the benefits. Additionally, the automation could not be implemented immediately, because robots would have to be purchased and programmed first, to execute the individual processes currently being performed by human labor. Therefore, the Ease of Implementation can be classified as low.

The managers aim is to implement a solution that significantly improves the criteria of time savings and cost reductions and to implement the improvement as quickly as possible and with minimal upfront investment costs.

It can be concluded that the One-piece flow, scanner-based automation, is the ideal solution because it’s high Ease of Implementation results in an immediate process improvement for the case company.

The integration of the one-piece flow does not involve an investment and can be implemented in a short time period. The programming effort which is needed to implement the scanner-based automation is already in use by other departments of Company X and just has to be transferred and applied internally to the shipping and commercial department of Company X.

The scanner-based One-piece flow automation saves 13650 hours and achieves 520389 euros in cost reduction on the 10-year Investment Horizon of the case company.

8. DISCUSSION AND RECOMMENDATIONS

8.1 Discussion of the Case

After the implementation of the, as the most suitable improvement possibility identified one-piece flow, another Time Value Map needs to be constructed to check if the implemented solution reflects the theoretical improvement calculations conducted in this research and visualized in the constructed Time Value Map.

Subsequently to the implementation, managers of Company X can use the information of the One-piece flow optimization to learn from the results and improve other processes of the case company. The learning from past actions for the execution of future improvement implementations belongs to Kaizen in Lean Manufacturing, which is a continuous improvement approach (M. Rouse, 2018).

The application of Kaizen was not the scope of this research because the goal of this paper was the improvement of resource utilization in the form of time savings and cost reduction in the shipping and commercial department of Company X. The approach can, however, be used by Company X to further improve their processes in the future through continuous improvement (Womack, 2007).

8.2 Discussion of the Research

The calculated improvements in time savings and cost reductions that can be achieved by an application of Lean Manufacturing and Theory of Constraints confirm, that the theories can be applied in the logistics sector. The logistics sector does not focus on the manufacturing of products but on transportation and handling, which can be classified as the flow of goods (SelectUSA, 2018). Lean Manufacturing and Theory of Constraints were initially designed to improve processes in the manufacturing sector (Dettmer, 2002). Theory of Constraints, Bottleneck identification, and the method of Time Value Mapping were successfully applied in this research to identify improvement possibilities in the case company operating in the logistics sector. Automation as a Lean Manufacturing concept was applied after the detection of improvement possibilities to achieve process optimization and improved resource utilization.

The applicability of Lean Manufacturing concepts and Theory of Constraints in the logistics sector can be transferred to the service sector because service sector industries offer intangible services instead of tangible goods (Chappelow, 2020). Increasing standardization of services across industries in the service sector makes a comparison between services with different characteristics possible ("Service Standardization,"). This enables the transfer of the research outcomes of the logistics case company to other organizations operating in the logistics sector and to organizations operating in other service sector industries.

The conducted research proves the applicability of Lean Manufacturing and Theory of Constraints in the service sector. Due to the reason that the applied theories were developed for the manufacturing sector, this study provides the opportunity to adapt existing research to the characteristics of the logistics sector. By altering existing theory an academic relevant contribution can be made.

After the application of different Lean Manufacturing theories and Theory of Constraints, it is noticeable that the application of the method of Time Value Mapping has to be altered to the activities of the logistics sector.

In the manufacturing sector, there is a clear distinction between value added and non-value added activities. In the manufacturing sector, all activities that increase the value of the product from the customers' perspective are classified as value added activities (Toolkit, 2018). “Value Added Activities are those that transform the product from raw material into finished goods that the customer is willing to pay for (Beels, 2019).”

In logistics, the only value adding activity is the delivery of goods to the client. In addition to the delivery of goods, no value adding transformation is undertaken according to the definition of value added activities. The research has shown that none of the processes of the case company could be classified as value adding. However, in logistics, the internal movement and handling of products are necessary for delivering the product from the producing company to the end customer. In the logistics sector, the internal movement and handling of products can, therefore, be classified as value adding activities. The internal movement and handling of products includes the gathering of products from the warehouse, the packaging of packages, and the adding of accompanying documents in the packages.

The initially developed definitions for non-value adding and essential non-value adding activities can be retained after the redefining the scope of value added activities in the logistics sector.

The subsequent section applies the altered Time Value Map definition to the Current Situation of the case company and the integration of the One-piece flow.

Figures 35 and 36 visualizes the processes currently executed in the shipping and commercial department of Company X. When comparing Figure 35 with Figure 20, it is noticeable that three activities previously classified as essential non-value added have been re-classified to value-added activities.

These activities are, first, “Shipping employee goes to the warehouse, gathers the products listed on the delivery note from the warehouse racks and returns to the workplace”, second, “Packs the products in suitable packages and adds accompanying documents in the packages and closes the packages”, and third, “Employee of the shipping department attaches shipping bags to the corresponding packages and places the packages in a storage rack.”

All activities that have been re-classified are involved in the transportation and or handling of products.

Activity number	Activity Description	Time in sec	Category
1	The shipping department prints the delivery note	90	Essential non-value added time
2	Shipping employee goes to the warehouse, gathers the products listed on the delivery note from the warehouse racks and returns to the workplace	80	Value added time
3	Packs the products in suitable packages and adds accompanying documents in the packages and closes the packages	200	Value added time
4	Weights the packed packages and makes a handwritten notation on the delivery note that includes weight of the packages and corresponding dimensions	30	Essential non-value added time
5	Places packed products on a waiting shelf and the processed delivery note in a storage tray	30	Non-value added time
6	Employee of the commercial department picks up stored delivery notes	30	Non-value added time
7	Digital packing and shipping of order in SAP	252	Essential non-value added time
8	Prints documents and packs shipping bag	60	Essential non-value added time
9	Stores multiple shipping bags at workplace and delivers shipping bags to a collection point in the shipping department	30	Non-value added time
10	Employee of the shipping department attaches shipping bags to the corresponding packages and places the packages in a storage rack	50	Value added time

Figure 35. Time Tracking Time Value Map Current Situation – Addition to research

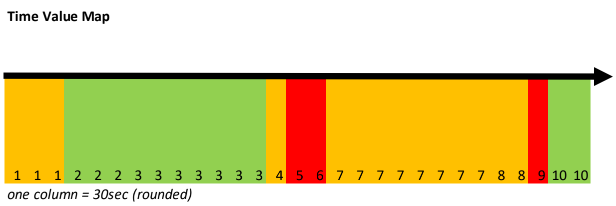


Figure 36. Time Value Map Current Situation – Addition to research

After the Implementation of the One-piece flow only value added and essential non-value added activities remain in the processes of the case company according to the newly developed definition, as can be seen in Figure 37. Figure 38 highlights that after the automation implementation, predominantly value added activities will keep being performed manually by employees of the case company, and 42 percent of essential non-value added and non-value added activities will be automated.

Activity number	Activity Description	Time in sec	Category
1	The shipping department prints the delivery note	90	Essential non-value added time
2	Shipping employee goes to the warehouse, gathers the products listed on the delivery note from the warehouse racks and returns to the workplace	80	Value added time
3	Scans the barcode on the delivery note, packs the products in suitable packages and adds accompanying documents in the packages and closes the packages	200	Value added time
4	Scans the to the package corresponding barcode from the packaging document and manually weights the package and enters the weight in SAP	30	Essential non-value added time
5	Prints documents and packs shipping bag	60	Essential non-value added time
6	Employee of the shipping department attaches shipping bags to the corresponding packages and places the packages in a storage rack	30	Value added time

Figure 37. Time Tracking Time Value Map One-piece flow – Addition to research

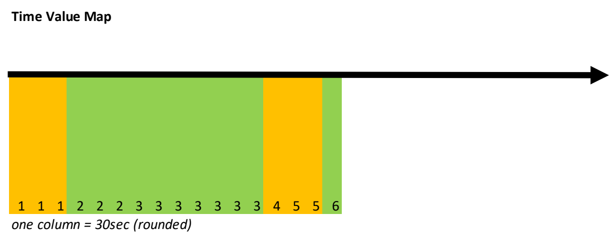


Figure 38. Time Value Map One-piece flow – Addition to research

9. LIMITATIONS AND SUGGESTIONS FOR FURTHER RESEARCH

Referring back to the limitations discussed in the methodology of this paper, the inability to gather data by employee observation due to COVID-19 restrictions, and process time recording due to workers council regulations, does not have a negative impact on the study results.

The alternative data collection methods of document analysis and unstructured interviews in place of employee observation, and approximate time interviews in place of process time recording have led to reliable study results. The complementary application of the alternative methods compensated for method-specific disadvantages.

Further research has to be conducted that does not only focus on the Theoretical application of the discussed theories in the service sector but also examines the practical implementation of an optimization project. In this way, reliable conclusions can be made about the application of Lean Manufacturing and Theory of Constraints.

This research analyzed one case company operating in the service sector. A potential limitation is the risk that the analyzed company is not representative of other service sector companies. Additional research of multiple service sector companies is advisable to reliably generalize the findings to the complete service sector.
The conducted research was carried out in a company operating in the logistics sector. The literature highlighted that due to standardized processes in the service sector, the results can be transferred to other service sector industries, but it is advisable to conduct further research that applies Lean Manufacturing and Theory of Constraints in different service sector industries to increase the reliability of results.
Last but not least, in this research, automation was identified as the most suitable Lean Manufacturing method for process improvements in the service sector. Additional studies that apply different Lean Manufacturing methods are necessary to make a reliable generalization for the applicability of all Lean Manufacturing methods in the service sector.

10. CONCLUSION

This study provides evidence for the applicability of Lean Manufacturing and Theory of Constraints in the service sector.
The combination of Theory of Constraints and Bottleneck theory in combination with the method of Time Value Mapping facilitated a precise identification of improvement possibilities in the processes of the case company.

Suitable Lean Manufacturing theories were analyzed for the achievement of an improved resource utilization of the case company. Automation, as the most suitable Lean Manufacturing theory, was applied to the identified process improvement potentials of the case company and two improvement options were developed by the creation of improvement plans.
The improvement plans were assessed according to the criteria of time savings and cost reductions. In addition, the specific preferences of the case company, which were identified by interviews with key decision-makers, were taken into account for the selection of the most suitable automation improvement plan. The improvement possibilities were evaluated according to the defined criteria and a motivated choice was made for the most suitable automation implementation, the One-piece flow automation. The analysis serves as a blueprint for the case company to implement the suggested solution in their processes to achieve process optimization and improve resource utilization by the criteria of time savings and cost reductions.
The application of Lean Manufacturing and Theory of Constraints led to the development of an addition to research, by adapting the method of Time Value Mapping to the characteristics of the logistics sector.
It can be concluded that the application of Lean Manufacturing and Theory of Constraints can be transferred from the manufacturing sector to the service sector to achieve process optimization and improve resource utilization with the criteria of time savings and cost reductions.

11. ACKNOWLEDGEMENTS

The composing of this bachelor thesis was made possible thanks to multiple instances.
First and foremost, I have to thank my first supervisor DR. IR. P. Hoffmann for assisting me throughout the writing process of my thesis. Without her support during regular feedback sessions, I would not have been able to achieve the results presented in this paper.
I would like to thank DR. F.G.S Vos, my second supervisor for the useful advice he provided me during feedback sessions.
Most importantly, I would like to thank Company X for the possibility to write my thesis, even though of the difficult times in the Corona crisis. It is not self-evident that a company employs interns in economically difficult situations.
Special thanks to my colleagues at Company X who supported me throughout the writing process of my thesis.
Finally, I would like to thank my family and friends for the support during the stressful times of writing my thesis. Your mental support and love means a lot to me.

12. APPENDIX

12.1 Sections

21 Methods of Lean Manufacturing

The outcomes of each of the 21 methods will shortly be described in the following paragraph.

Implementing 5S can lead to a reduction in wasted time and motion (Chahala & Narwal, 2017). Automation leads to a reduced human effort by providing an accurate automatic system (Chahala & Narwal, 2017). Continuous flow ensures that there exists a continuous flow throughout the value stream (Chahala & Narwal, 2017). Continuous improvement makes sure that there is constant improvement and overall efficiency is improved (Chahala & Narwal, 2017). The Kan-Ban method minimizes work-in-process by integrating a scheduled production (Chahala & Narwal, 2017). Kaizen has the target of implementing continuous change (Chahala & Narwal, 2017). Single Minute Exchange to Die (SMED) frees up capacity and enables the production of small batches by minimizing setup time and cost (Chahala & Narwal, 2017). Cellular manufacturing aims at optimizing processes by improving cell design (Chahala & Narwal, 2017). Six Sigma improves quality, operational performance, practices, and systems (Chahala & Narwal, 2017). Team Development/ Training leads to enhanced motivation of employees and increased knowledge of the workforce (Chahala & Narwal, 2017). Total Productive Maintenance improves the capability and consistency of processes and ensures uptime (Chahala & Narwal, 2017). Total Quality Management (TQM) prevents the occurrence of defects by improving quality (Chahala & Narwal, 2017). Value Stream Mapping (VSM) ensures conformance to Lean Manufacturing principles by visualization of processes (Chahala & Narwal, 2017). Visual Management has the target of helping employees to make correct decisions and manage their working activities by the provision of visual information (Chahala & Narwal, 2017). Work Standardization reduces variation from differing working methods by making sure that all employees execute their tasks in the same way (Chahala & Narwal, 2017). Flexible Manufacturing System (FMS) provides a flexible change in the manufacturing environment which contains layout, methods, and machines (Chahala & Narwal, 2017). Production leveling reduces waste and unevenness (Chahala & Narwal, 2017). Inventory Management ensures the correct sequencing of supplies in the production (Chahala & Narwal, 2017). The Zero Defect Concept has the goal of eliminating everything responsible for waste creation (Chahala & Narwal, 2017). Work in Process (WIP) summarizes all types of costs which occur during the execution of processes (Chahala & Narwal, 2017). Last but not least, Lean Thinking eliminates waste and provides benefits to an organization by the discovery of new ideas (Chahala & Narwal, 2017).

5S

The 5S will be analyzed in more detail in the following paragraph.

Seiri (Sort) describes the elimination of items from the workplace which are not needed for the execution of processes. Elimination of unnecessary items facilitates the execution of processes (Karthik & Silksonjohn, 2019).

Seiton (Set in order) focuses on improving the arrangement and labeling of items in storage to make them easily available and easy to find by employees performing processes (Karthik & Silksonjohn, 2019).

Seiso (Shine), as the English translation implies has the purpose of keeping the workplace clean to prevent the deterioration of equipment and machinery necessary for process execution (Karthik & Silksonjohn, 2019).

Seiketsu (Standardize) aims at “preventing the accumulation of unneeded items, preventing procedures from breaking down, and preventing equipment and materials from getting dirty (Karthik & Silksonjohn, 2019, p. 1471).” The standardization of processes by technical means also helps to prevent manual procedures from breaking down and therefore has to be added to this definition.

Last but not least, Shitsuke (Sustain) stands for the implementation of control mechanisms to make sure that lean methods are continued daily (Karthik & Silksonjohn, 2019).

12.2 Figures

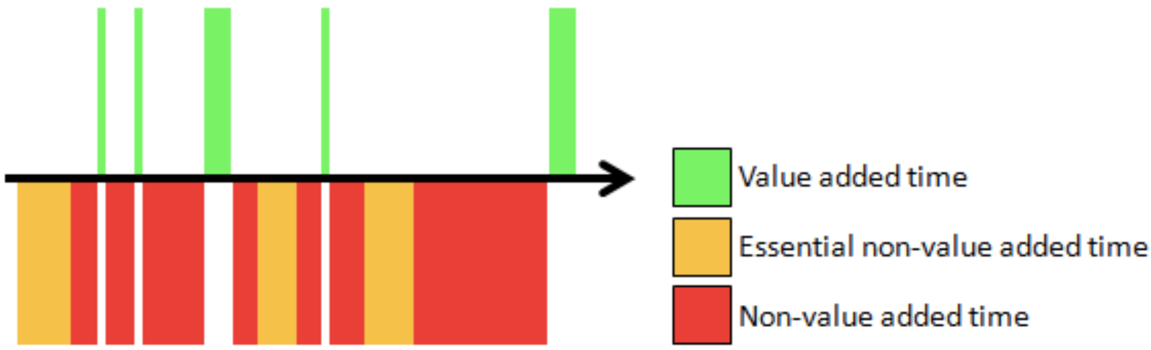


Figure 4. Example of a Time Value Map

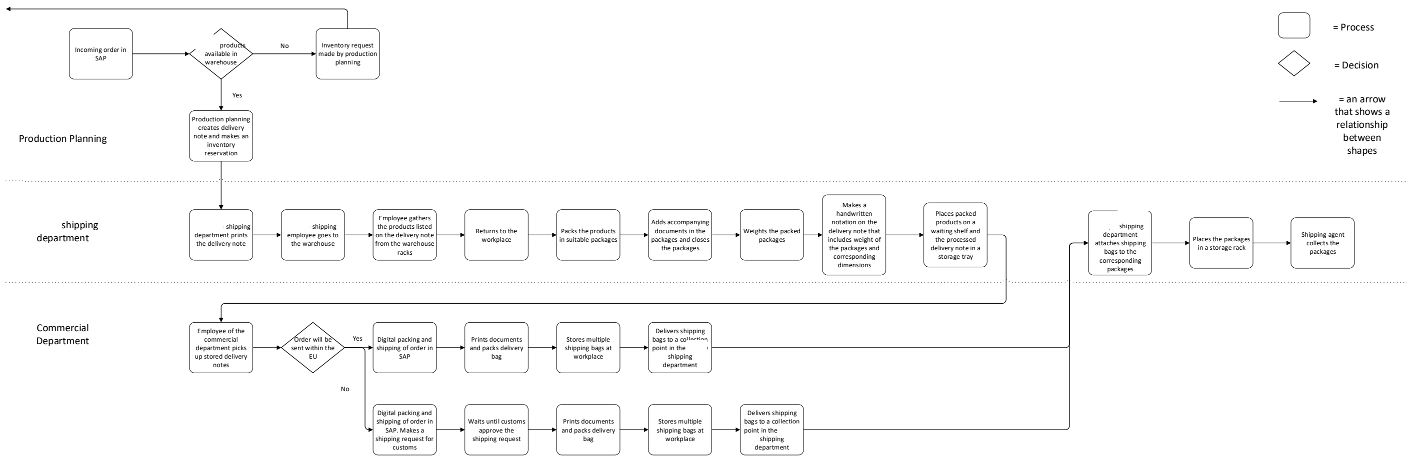


Figure 5. Process Map

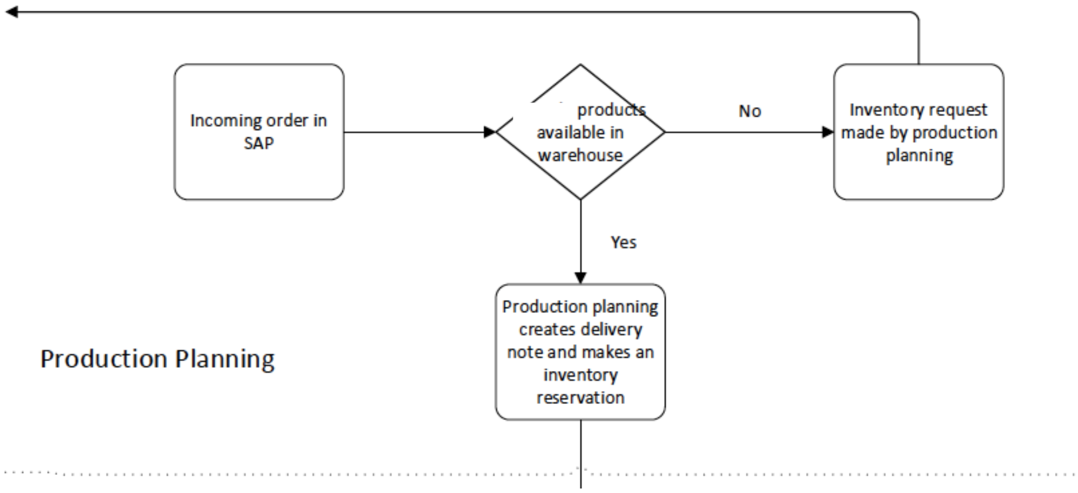


Figure 6. Process Map Production Planning

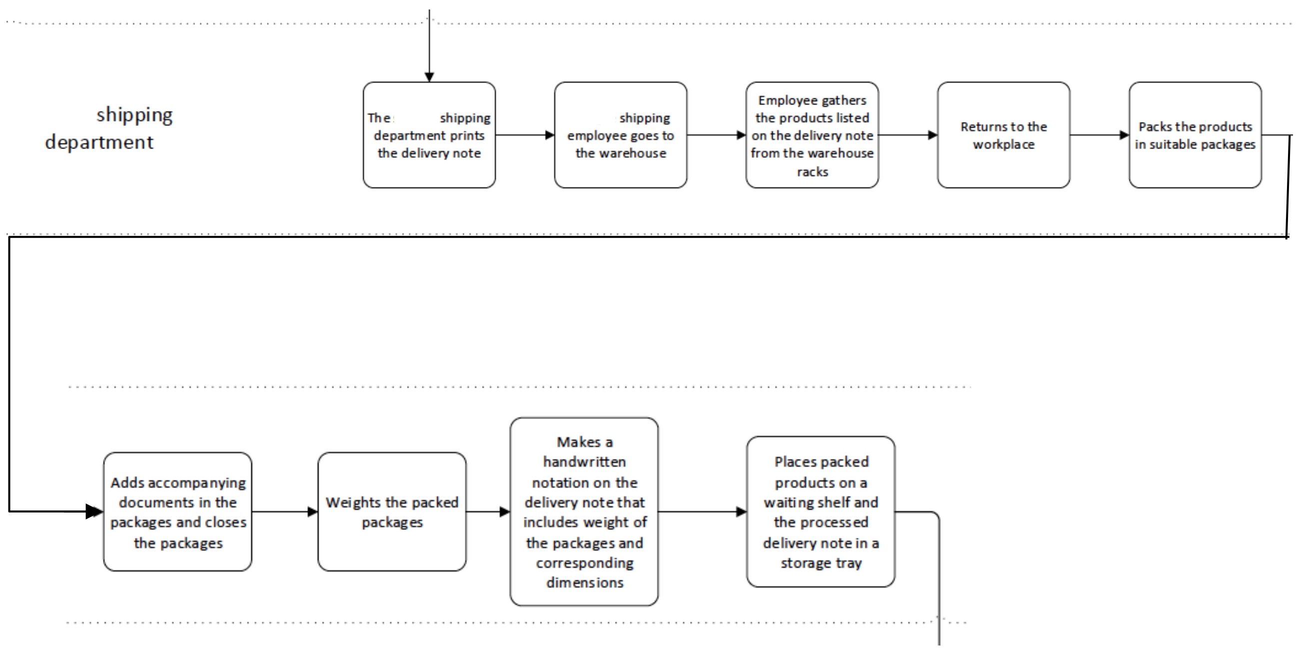


Figure 7. Process Map Picking process Shipping Department

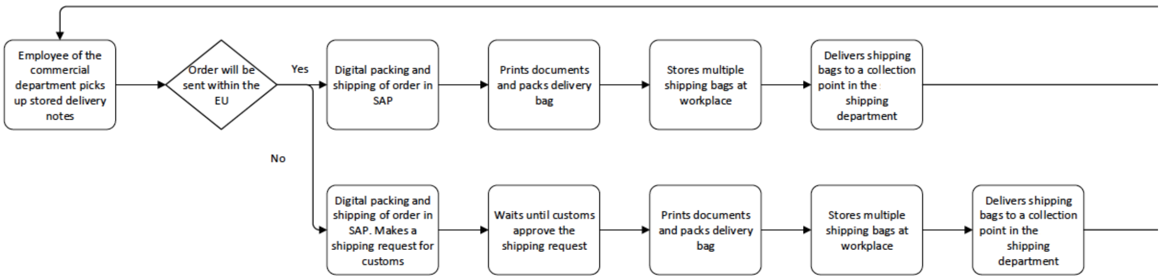


Figure 8. Process Map Commercial Department

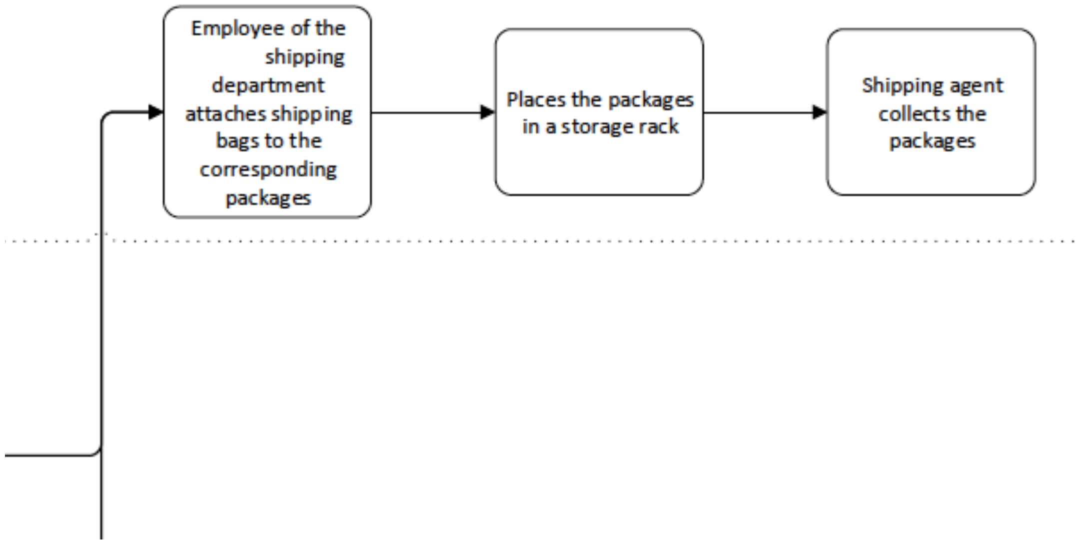


Figure 11. Process Map Shipping

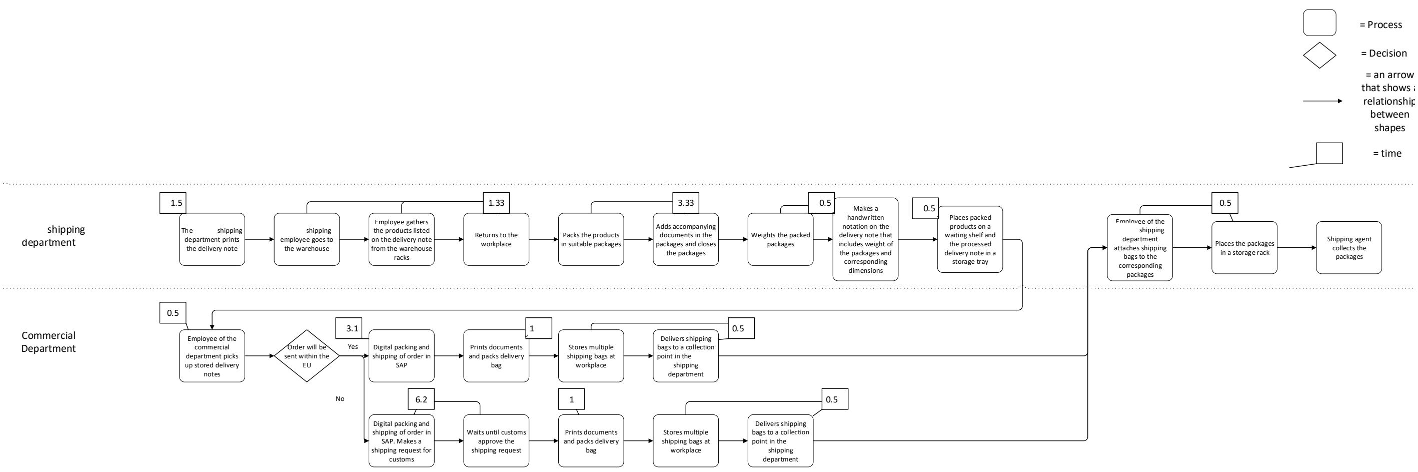


Figure 19. Process Map with activity times

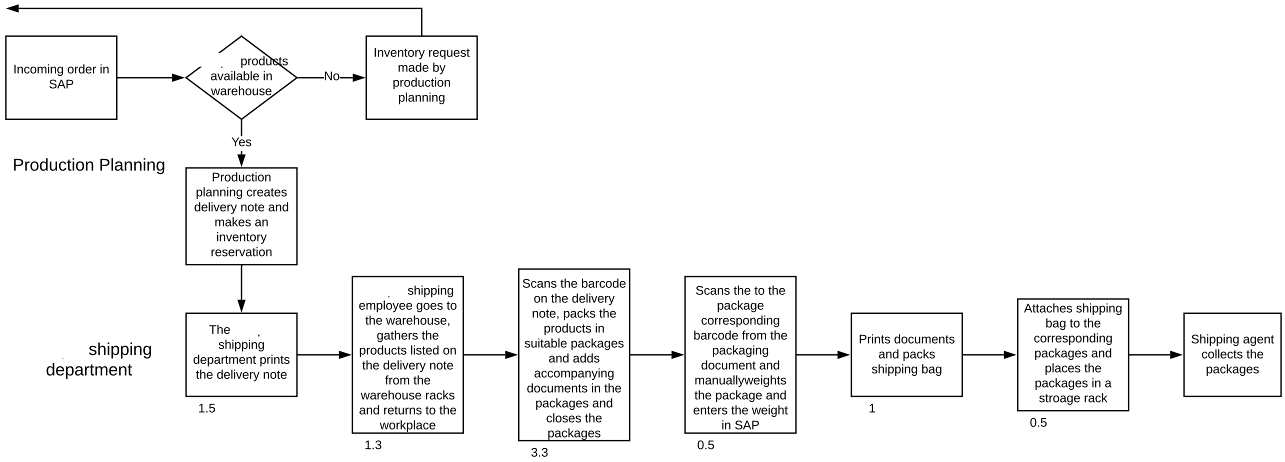


Figure 22. Process Map with activity times

Redundant processes highlighted in red

Commercial Department

Time needed for the delivery of shipping bags to the shipping department in min	Average amount of shipping bags
1.00	4.00
Average processing time EU Delivery Notes in min	3.10
Average processing time Non-EU Delivery Notes in min	6.20
Average general processing time	4.20
Printing of documents and packing of shipping bag	1.00

Shipping Department

Activity	General average approximate process times	Shorter Process
The shipping department prints the delivery note	1.50	
Shipping employee goes to the warehouse, gathers the products listed on the delivery note from the warehouse racks and returns	1.33	
Packs the products in suitable packages and adds accompanying documents in the packages and closes the packages	3.33	
Scans the to the package corresponding barcode from the packaging document and manually weights the package and enters the weight in SAP	0.50	
Places packed products on a waiting shelf and the processed delivery note in a storage tray	0.50	
Employee of the shipping department attaches shipping bags to the corresponding packages and places the packages in a storage rack	0.83	0.50

Figure 23. Time Savings Potentials One-piece flow - Process

Redundant processes highlighted in red

Commercial Department

Time needed for the delivery of shipping bags to the shipping department in min	Average amount of shipping bags
1.00	4.00
Average processing time EU Delivery Notes in min	3.10
Average processing time Non-EU Delivery Notes in min	6.20
Average general processing time	4.20
Printing of documenrs and packing of shipping bag	1.00

Shipping Department

Activity	General average approximate process times
The shipping department prints the delivery note	1.50
Shipping employee goes to the warehouse, gathers the products listed on the delivery note from the warehouse racks and returns to the workplace	1.33
Packs the products in suitable packages and adds accompanying documents in the packages and closes the packages	3.33
Scans the to the package corresponding barcode from the packaging document and manually weights the package and enters the weight in SAP	0.50
Places packed products on a waiting shelf and the processed delivery note in a storage tray	0.50
Employee of the shipping department attaches shipping bags to the corresponding packages and places the packages in a storage rack	0.83

Figure 29. Time Savings Potentials Complete Automation – Process

Time Savings Potential - Month	
Average processing time EU Delivery Notes in min	2598.58
Average processing time Non-EU Delivery Notes in min	2828.23
Printing of documents and packing of shipping bag	1294.42
Time needed for the delivery of shipping bags to the shipping department in min	323.60
The shipping department prints the delivery note	1941.63
Shipping employee goes to the warehouse, gathers the products listed on the delivery note from the	1721.57
Packs the products in suitable packages and adds accompanying documents in the packages and closes the packages	4310.41
Scans the to the package corresponding barcode from the packaging document and manually weights the package and enters the weight in SAP	647.21
Places packed products on a waiting shelf and the processed delivery note in a storage tray	647.21
Employee of the shipping department attaches shipping bags to the corresponding packages and places the packages in a storage rack	1074.37
Total in min	**17387.22**
Total in h	**289.79**

Figure 30. Time Savings Potentials Complete Automation - Month

Time Savings Potential - Year	
Average processing time EU Delivery Notes in min	31182.90
Average processing time Non-EU Delivery Notes in min	33938.80
Printing of documents and packing of shipping bag	15533.00
Time needed for the delivery of shipping bags to the shipping department in min	3883.25
The shipping department prints the delivery note	23299.50
Shipping employee goes to the warehouse, gathers the products listed on the delivery note from the warehouse racks and returns to the workplace	20658.89
Packs the products in suitable packages and adds accompanying documents in the packages and closes the packages	51724.89
Scans the to the package corresponding barcode from the packaging document and manually weights the package and enters the weight in SAP	7766.50
Places packed products on a waiting shelf and the processed delivery note in a storage tray	7766.50
Employee of the shipping department attaches shipping bags to the corresponding packages and places the packages in a storage rack	12892.39
Total in min	**208646.62**
Total in h	**3477.44**

Figure 31. Time Savings Potentials Complete Automation - Year

Time Savings Potential - 10-year Investment Horizon	
Average processing time EU Delivery Notes in min	311829.00
Average processing time Non-EU Delivery Notes in min	339388.00
Printing of documents and packing of shipping bag	155330.00
Time needed for the delivery of shipping bags to the shipping department in min	38832.50
The shipping department prints the delivery note	232995.00
Shipping employee goes to the warehouse, gathers the products listed on the delivery note from the warehouse racks and returns to the workplace	206588.90
Packs the products in suitable packages and adds accompanying documents in the packages and closes the packages	517248.90
Scans the to the package corresponding barcode from the packaging document and manually weights the package and enters the weight in SAP	77665.00
Places packed products on a waiting shelf and the processed delivery note in a storage tray	77665.00
Employee of the shipping department attaches shipping bags to the corresponding packages and places the packages in a storage rack	128923.90
Total in min	**2086466.20**
Total in h	**34774.44**

Figure 32. Time Savings Potentials Complete Automation – 10-year Investment Horizon

Investment Cost	included in hourly cost	
Robot cost/Hour	**€**	**20.00**

Cost Savings Potential		
Cost Savings Potential - Month	**€**	**5,795.74**
Cost Savings Potential - Year	**€**	**69,548.87**
Cost Savings Potential - 10-year Investment Horizon	**€**	**695,488.73**

Figure 33. Cost Savings Potential Complete Automation

12.3 Tables

Table 6. Comparison of General Average Approximate Process Times - Shipping Department

Activity	Employee 1 - Approximate Tiime in min/ work day	Employee 1 - Approximate Time in min/ delivery note	Employee 2 - Approximate Tiime in h/ work day	Employee 2 - Approximate Time in min/ delivery note	Employee 3 - Approximate Tiime in h/ work day	Employee 3 - Approximate Time in min/ delivery note	Employee 4 - Approximate Tiime in h/ work day	Employee 4 - Approximate Time in min/ delivery note	General average approximate process times
The shipping department prints the delivery note	60	1	120	2	120	2	90	1.5	1.50
Shipping employee goes to the warehouse, gathers the products listed on the delivery note from the warehouse racks and returns to the workplace	90	1.5	60	1	90	1.5	90	1.5	1.33
Packs the products in suitable packages and adds accompanying documents in the packages and closes the packages	240	4	180	3	120	2	180	3	3.33
Weights the packed packages and makes a handwritten notation on the delivery note that includes weight of the packages and corresponding dimensions	30	0.5	30	0.5	30	0.5	30	0.5	0.50
Places packed products on a waiting shelf and the processed delivery note in a storage tray	30	0.5	30	0.5	30	0.5	30	0.5	0.50
Employee of the shipping department attaches shipping bags to the corresponding packages and places the packages in a storage rack	30	0.5	60	1	90	1.5	60	1	0.83

13. REFERENCES

Ajayi, V. (2017). Primary Sources of Data and Secondary Sources of Data.

Aliaga, M., Gunderson, M. (2006). *Interactive Statistics, 3rd Edition*: Pearson.

Beels, M. (2019). What is Value Added vs. Non-Value Added Work? Retrieved from https://www.the-center.org/Blog/February-2019/What-is-Value-Added-vs-Non-Value-Added-Work#:~:text=On%20the%20shop%20floor%2C%20Value,piercing%20or%20welding%20a%20part.

Belyh, A. (2015). Key Resources Building Block in Business Model Canvas. Retrieved from https://www.cleverism.com/key-resources-building-block-in-business-model-canvas/

Bennett, T. (2019). The Hawthorne effect: How the process of being watched affects our performance. Retrieved from https://thriveworks.com/blog/the-hawthorne-effect-how-the-process-of-being-watched-affects-our-performance/

Berger, R. (2016). Of Robots and Men - in logistics.

Blackstone, A. (2012). *Sociological Inquiry Principles: Qualitative and Quantitative Methods*. University of Maine: Saylor Foundation.

Bowen, G. (2009). Document Analysis as a Qualitative Research Method. *Qualitative Research Journal*.

Bowen, R., MCDonough, M. (2013). Constructing a time value map. Retrieved from https://www.brighthubpm.com/six-sigma/52896-constructing-a-time-value-map/

Bricki, N., Green, J. (2007). A Guide to Using Qualitative Research Methodology.

Brown, L. Observational Field Research. Retrieved from http://faculty.washington.edu/wpratt/MEBI598/Methods/Collecting%20Data%20Through%20Observation.htm

Cacciattolo, K. (2015). A Comparison of Depth Interviews and Observations as Methods of Data Collection.

Chahala, V., & Narwal, M. S. (2017). An empirical review of lean manufacturing and their strategies. *Management Science Letters, 7*(7), 321-336. doi:10.5267/j.msl.2017.4.004

Chappelow, J. (2020). Service Sector. Retrieved from https://www.investopedia.com/terms/s/service-sector.asp

Choudhury, A. Advantages and Limitations 'Observation' Method for Data Collection. Retrieved from https://www.yourarticlelibrary.com/social-research/data-collection/advantages-and-limitations-observation-method-for-data-collection/64507

Davenport, T. H., Brain, D. (2018). Before Automating Your Company's Processes, Find Ways to Improve Them. *Harvard Business Review*. Retrieved from https://hbr.org/2018/06/before-automating-your-companys-processes-find-ways-to-improve-them

Deloitte. (2018). *Changing the lens: GDP from the industry viewpoint*. Retrieved from https://www2.deloitte.com/us/en/insights/economy/spotlight/economics-insights-analysis-07-2019.html

Dettmer, H. W. (2002). Beyond Lean Manufacturing : Combining Lean and the Theory of Constraints for Higher Performance. Retrieved from http://goalsys.com/books/documents/TOCandLeanPaper-rev.1.pdf

Dolcemascolo, D. (2020). Achieving one-piece flow. Retrieved from https://www.reliableplant.com/Read/14703/one-piece-flow

Dr. Fabian Engels, W. H., Dr. Johannes Distler, Christoph Kiefer. (2018). RPA - Tomorrow's must-have technology How robotic process automation can speed up your business.

Generalizability and Transferability. Retrieved from https://writing.colostate.edu/guides/guide.cfm?guideid=65

Gupta, V. (2015). Lean manufacturing: A Review. *International Journal of Science Technology & Management*.

Henseler, J. (2017). Bridging Design and Behavioral Research With Variance-Based Structural Equation Modeling. *Journal of Advertising, 46*(1), 178-192. doi:10.1080/00913367.2017.1281780

Karabegović, I., Karabegović, E., Mahmić, M., & Husak, E. (2015). The application of service robots for logistics in manufacturing processes. *Advances in Production Engineering and Management, 10*(4), 185-194. doi:10.14743/apem2015.4.201

Karthik, S., & Silksonjohn, J. (2019). A case study of 5s implementation in inspection process. *International Journal of Mechanical and Production Engineering Research and Development, 9*(3), 1469-1476. doi:10.24247/ijmperdjun2019154

Kenton, W. (2019). Hawthorne Effect. Retrieved from https://www.investopedia.com/terms/h/hawthorne-effect.asp

Kettering. (2018). Understanding the Principle of Flow in Lean Manufacturing. Retrieved from https://online.kettering.edu/news/2016/07/07/understanding-principle-flow-lean-manufacturing

Key Resources in the Business. Retrieved from http://www.ecommerce-digest.com/key-resources.html

Kudryavtsev, E. (2018). *Automation of optimization of discrete technological processes.* Paper presented at the MATEC Web of Conferences.

Lawson, E. (2017). Six benefits of automation in lean manufacturing. Retrieved from https://www.automationmag.com/7692-six-benefits-of-automation-in-lean-manufacturing/

Manufacturing Sector. (2020). Retrieved from http://www.businessdictionary.com/definition/manufacturing-sector.html

Mathu, K. (2014). Applying the Theory of Constraints in the south african coal supply Chain. *Mediterranean Journal of Social Sciences, 5*(9), 131-141. doi:10.5901/mjss.2014.v5n9p131

McKinsey&Company. (2017). A future that works: Automation, Employment and Productivity. *MCKINSEY GLOBAL INSTITUTE*.

Melović, B., Mitrović, S., Zhuravlev, A., & Braila, N. (2016). *The role of the concept of LEAN management in modern business.* Paper presented at the MATEC Web of Conferences.

Meyer, L. (2006). Business process optimization: combining project management and six sigma best practices to better understand and optimize critical business processes.

Miller, M. E. (2013). Effects of Accurate and Inflated Employee Performance Self-Evaluations on Memory Accuracy. Retrieved from https://www.semanticscholar.org/paper/Effects-of-Accurate-and-Inflated-Employee-on-Memory-Miller/a7d8072d1c2ff4476eb281aed9b5868327db6ed4

MÍkva, M., Prajová, V., Yakimovich, B., Korshunov, A., & Tyurin, I. (2016). *Standardization-one of the tools of continuous improvement.* Paper presented at the Procedia Engineering.

Moore, R., Scheinkopf, L. (1998). Theory of Constraints and Lean Manufacturing: Friends or Foes? Retrieved from http://www.tocca.com.au/uploaded/documents/lean%20and%20toc.pdf

Nissinboim, N., & Naveh, E. (2018). Process standardization and error reduction: A revisit from a choice approach. *Safety Science, 103*, 43-50. doi:https://doi.org/10.1016/j.ssci.2017.11.015
Owen-Hill, A. (2017). How to Plan a Robotics Budget for 2017. Retrieved from https://blog.robotiq.com/how-to-plan-a-robotics-budget-for-2017#:~:text=At%20a%20cost%20of%2035k,depreciation%20comes%20maintenance%20and%20upgrade.
Pandey, P., Agrawal, S., & Uma Maheswari, J. (2018). *Optimizing flow process through synchronisation of cycle time.* Paper presented at the IGLC 2018 - Proceedings of the 26th Annual Conference of the International Group for Lean Construction: Evolving Lean Construction Towards Mature Production Management Across Cultures and Frontiers.
Plakhin, A. E., Al-Ogaili, S. M. M., Semenet, I. I., Kochergina, T. V., & Mihajlovskij, P. V. (2019). *Development of the production system through lean management tools.* Paper presented at the IOP Conference Series: Materials Science and Engineering.
Rattner, S. (2006). What is the Theory of Constraints, and How Does it Compare to Lean Thinking? Retrieved from https://www.lean.org/common/display/?o=223#:~:text=Lean%20focuses%20its%20efforts%20on,no%20major%20problems%20between%20them.&text=TOC%20uses%20the%20bottleneck%20process,while%20lean%20focuses%20on%20pull
Roser, C., Lorentzen, K., & Deuse, J. (2015). Reliable shop floor bottleneck detection for flow lines through process and inventory observations: the bottleneck walk. *Logistics Research, 8*(1). doi:10.1007/s12159-015-0127-2
Rouse, M. (2018). What is Kaizen (continuous improvement)? Retrieved from https://searcherp.techtarget.com/definition/kaizen-or-continuous-improvement
Rouse, M. (2020). business process automation (BPA). Retrieved from https://searchcio.techtarget.com/definition/business-process-automation#:~:text=Business%20process%20automation%20(BPA)%20is,bringing%20on%20a%20new%20employee.
Saleh, C., Immawan, T., Hassan, A. B., & Zakka, M. N. (2019). *Profit Optimization Through the Application of Theory of Constraints (TOC): A Case Study in Printing Company.* Paper presented at the IOP Conference Series: Materials Science and Engineering.
Salkind, N. (2010). Triangulation.
Salonitis, K., & Tsinopoulos, C. (2016). Drivers and Barriers of Lean Implementation in the Greek Manufacturing Sector. *Procedia CIRP, 57*, 189-194. doi:https://doi.org/10.1016/j.procir.2016.11.033
Seifermann, S., Böllhoff, J., Metternich, J., & Bellaghnach, A. (2014). *Evaluation of work measurement concepts for a cellular manufacturing reference line to enable low cost automation for lean machining.* Paper presented at the Procedia CIRP.
SelectUSA. (2018). Logistics and Transportation Spotlight. Retrieved from https://www.selectusa.gov/logistics-and-transportation-industry-united-states
Service Standardization. Retrieved from http://clicresearch.org/wp-content/uploads/2011/11/12_en_service_standardization.pdf
Siebenbrock, H. (2018). *Grundlagen der Organisationsgestaltung und -entwicklung.* Altenberge: niederle media.
Sinclair, K. A., Sadler, B.A. (2016). *Driving Cost Reduction and Carbon Plant Productivity Improvement through Theory of Constraints and Planned Maintenance Capability*: Springer, Cham.
Siregar, I., Arif Nasution, A., Prasetio, A., & Fadillah, K. (2017). *Analysis of production flow process with lean manufacturing approach.* Paper presented at the IOP Conference Series: Materials Science and Engineering.
Slack, N., andBrandon-Jones, A., & Johnston, R. (2016). *Operations management.* . Harlow, England: Pearson.
Strength and Weaknesses of Qualitative Interviews. (2015). Retrieved from http://www.opentextbooks.org.hk/ditatopic/29793
Tang, S., Ng, T., Chong, W., & Chen, K. (2016). *Case Study on Lean Manufacturing System Implementation in Batch Printing Industry Malaysia.* Paper presented at the MATEC Web of Conferences.
Toolkit, C. I. (2018). Time Value Map. Retrieved from https://citoolkit.com/articles/time-value-map/
Womack, J. P., Jones, D. T., & Roos, D. . (2007). *The machine that changed the world. New York: Free Press.*
Zeder, R. (2017). The Three Economic Sectors. Retrieved from https://quickonomics.com/the-three-economic-sectors/
Zhang, Y., Wildemuth, B. Unstructured Interviews.