STRUCTURING THE VALUATION PROCESS FOR GREATER EFFICIENCY AND ACCURACY AT A MULTINATIONAL MACHINE MANUFACTURER

Bachelor thesis Industrial Engineering and Management
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COLOPHON

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PREFACE

Dear reader,

This thesis marks the end of my academic journey in the bachelor's program of Industrial Engineering and Management at the University of Twente. For my final project, I focused on improving the accuracy and reducing the cycle time of the valuation process of the company.

I would like to thank the company for providing the assignment and for all the available resources. It was a pleasure to be part of the team. I am especially grateful to all the employees who helped me and took the time to assist me. Special thanks go to my company supervisor for his continuous guidance, support, and feedback.

I also want to express my appreciation to Caj Donkervoort for his constant feedback and motivation.

Finally, I want to thank my first supervisor, Lucas Meertens, and my second supervisor, Renata Guizzardi, for their support, feedback, and valuable insights throughout the project.

Daan Rolleman

Enschede, June 2025

MANAGEMENT SUMMARY

This thesis analyzes and restructures the valuation process at a high-end steel processing machinery manufacturer. The company exports machines all over the world, which requires an invoice with the value of the transport unit. This invoice is needed for insurance and customs purposes. This process is currently unstructured, time-inefficient, and inaccurate.

To solve this problem, the main research question addressed in this thesis is as follows:

"What is a clear and relevant implementation plan to structure the container valuation process such that the value accuracy is improved, and cycle time is reduced?"

To structure this process, the Business Process Management (BPM) lifecycle is used together with Lean Manufacturing (LM) and the Theory Of Constraints (TOC). The current process is modelled and analyzed, revealing that the largest issue in the process is that a finance employee executes the valuation. This employee has no machine knowledge, and his manual involvement leads to long cycle times (around 9 hours) with low cycle time efficiency (around 11%) and low accuracy (deviation of the real value could go up to 45%). This is the reality. The norm set by the company is that the accuracy reaches at least 95% and the cycle time reduces by at least 50%.

A new process is proposed, which uses a newly developed automated valuation tool. This tool uses existing data, such as the bill of materials and packing lists, to automatically calculate the container values. This eliminates the need for manual input, thereby reducing cycle time and improving accuracy. The new process is estimated to have a cycle time efficiency of nearly 92%, representing an improvement of approximately eighty percentage points, a relative increase of around 715% compared to the original efficiency. This results in a time saving of approximately 8,8 hours per valuation. Furthermore, the valuation accuracy is estimated to reach 100% since there is no more manual input. However, this only holds when all activities, such as loading the containers, are executed as prescribed. The annual cost savings are approximately €2,917, with a net first-year saving of around €885. This shows that the company's norm has been successfully met.

An implementation plan, including a transition tree and role-specific responsibilities, is provided to ensure a smooth transition from the current to the redesigned process. Although the valuation tool is still a prototype, initial tests validate the accuracy and efficiency of it. Future development and employee training are essential to ensure long-term success.

This project demonstrates how structured process redesign, and automation can improve accuracy and efficiency. The proposed solution not only enhances operational performance, but also reduces financial risks, offering substantial value to the company.

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AI Disclaimer

AI models, such as ChatGPT and CoPilot, have only been used for checking and correcting spelling errors in the text. All content is my own and I take full responsibility for the final result.

Anonymity statement

For anonymity reasons, the name of the company is not given in this report. There is referred to “The company” when talking about the organization.

1 INTRODUCTION

1.1 ABOUT THE COMPANY AND THE ASSIGNMENT

In this section, the company and the assignment are briefly introduced.

1.1.1 The company

The company where the research is executed, is a manufacturer of high-end steel processing machines. The company sells their machines all over the world and has a lot of international export activities. Next to selling the machines, the company also provides the software and service to work with those machines. Customers can configure the machine exactly how they want it. Company employees help the customer to configure the perfect machine which aligns the best with their work style and requirements. That is the power of this company. Customers get the perfect machine for their operations.

1.1.2 Brief introduction to the assignment

When a machine is sold, it is first assembled in the workshop. It is then checked and tested. Before transporting the machine, it is disassembled into multiple parts because the whole machine does not fit in one transport unit.
For the export, an invoice is needed with the value of these containers or trailers for insurance and customs reasons.

The process of valuing these containers and trailers is the process which is investigated in the thesis report. The current process is analyzed, and improvements are made. A transport unit can be a container or a trailer. In this report, when a container is mentioned, the same applies to a trailer. For simpler writing reasons, only one of the two is mentioned.

1.2 PROBLEM IDENTIFICATION

This section outlines the key issues affecting the valuation process. By mapping the interrelated problems and causes in a problem cluster, the core problem and action problem can be found.

1.2.1 Problem cluster

To make the whole problem landscape visible, a problem cluster is made. The problem cluster is shown in Figure 1. This problem cluster is used for identifying connections between problems and to find the core problem which is addressed in this project.

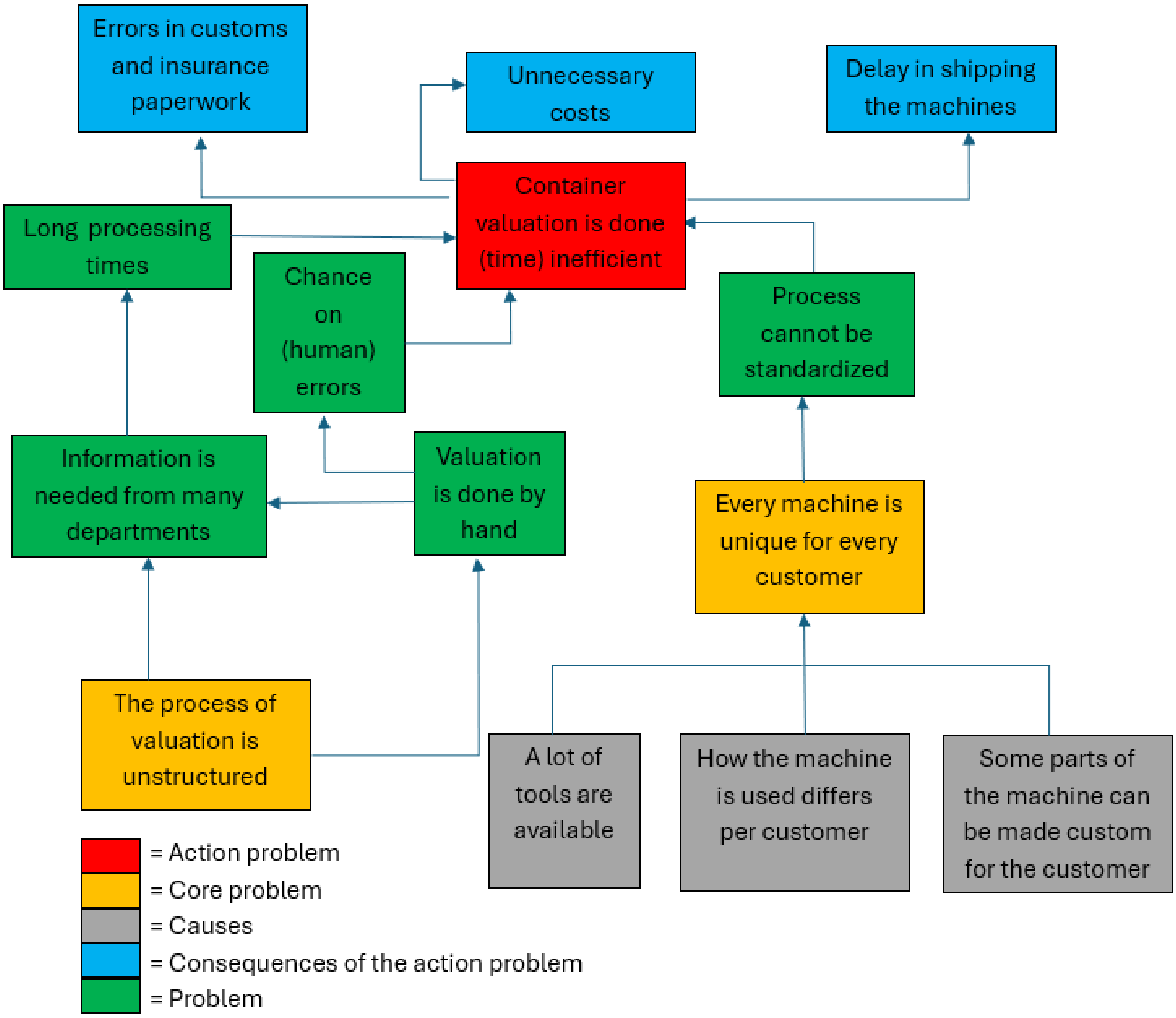

Figure 1: Problem cluster.

1.2.2 Explanation of problem cluster

This problem cluster is built with five colors representing the action problem, core problems, causes, problems, and consequences of the action problem.
The problem which is visible is the action problem, the valuation process is executed (time)inefficient. The direct consequence of this action problem is that there can be errors in your paperwork. Next to this, because it is time-inefficient, it can cause delay in shipping the machines. Lastly, it causes unnecessary costs since the process simply takes too many steps and time.

One of the core problems is the fact that every machine is unique for every customer. This is the case because there are a lot of different tools available to choose from. Next to this, every customer uses their machine in another way. No process in a factory looks the same and that is why they use it in their own way. Lastly, some parts of the machine can be made custom for the customer. If they have specific extra tools which they want, the company can do this for the customer. Those factors are not added as problems, but as a cause since they are not problems. They are positive rather than negative. All these factors contribute to the fact that every machine is unique for every customer. This is a core problem because the valuation process cannot be standardized. When every drill or saw for example was the same, it would also always be shipped in the same way and the valuation would therefore also be the same. The only difference would be that a discount could be given on one of the machines and not on the other machine, but that percentage of discount could easily be subtracted from the value of the container or trailer. However, this core problem cannot be solved because this is the power of the company. They have machines for everyone since they can add specific parts for customers.

What is noticed as well in the process is that information for the valuation is needed from a lot of different departments because everyone has a bit of information for the valuation. This is the cause for long processing times because there is waiting time between those departments. Next to this, the other problem contributing to inefficient valuation is the fact that there is a chance of (human) errors. This is a consequence of executing the valuation by hand. Almost everything which is done by hand is sensitive to errors. Working back, the core problem behind those problems is that the process of valuation is just unstructured. Everyone does a bit of the valuation and communication is just done when someone needs the information from the colleague. This problem is chosen to solve because this is the only solvable aspect of the action problem. When this problem is solved, the valuation process should be a lot more efficient. The employees involved should be able to follow a given path when doing the valuation and know when they must do the valuation and when they must execute which step.

1.2.3 Action problem definition

The action problem is defined as follows:

"The transport coordinator should reduce cycle time and have a more accurate container-value by having a structured valuation process."

Currently, the container valuation process is executed (time)inefficient and the core problem behind that is that the valuation process is unstructured. Therefore, the transport coordinator should reduce time and improve accuracy by structuring the valuation process.

According to Weske (2007), a process is considered structured when the business process model prescribes all the activities and their execution constraints in a complete and unambiguous manner.
According to Slack et al. (2016), the advantage of a structured process is that it gives a common currency for the evaluation and comparison of all types of work.

1.2.3.1 Norm and reality

There is a discrepancy between the current state of the process and the desired norm. In its current state, the activities and their execution in the valuation process are not standardized, activities are performed ad hoc and depend on informal communication. The goal of this project is to design a process with prescribed activities which follow a planned path. This should enable the process to be faster and more accurate.

The aim is to change the perceived discrepancy between norm and reality. This is measured by the cycle time and the accuracy of the valuation process. According to Dumas et al. (2018), structured processes are expected to reduce unnecessary delays and minimize errors, making improvements in these indicators reliable evidence of increased process structure. The reality is that deviations in accuracy reach up to 45% and that the cycle time is around 9 hours. The norm given by the company is that the accuracy goes up to at least 95% and that the cycle time reduces by at least 50%.

1.2.3.2 Problem owners

The problem owners in this process are the transport coordinators since they manage the valuation process and make sure that the finance department does it.

1.3 MAIN RESEARCH QUESTION

The core problem is that the valuation process is unstructured. The consequence of this is that the valuation process is executed time(inefficient) which causes long cycle times and low valuation accuracy. From this, the following research question is formed:

"What is a clear and relevant implementation plan to structure the container valuation process such that the value accuracy is improved, and cycle time is reduced?"

1.4 INTENDED DELIVERABLES

To reduce time and get a more accurate valuation by structuring the valuation process, the following deliverables are proposed:

1. Mapping of the current process – process model of the current valuation process
2. Time and accuracy analysis of the current valuation process
3. A process model of the new valuation process
4. An implementation plan for the new valuation process model

For the first and third deliverable, a process model must be developed to get insights into the current and new valuation process. The current process is analyzed, and the process is improved based on that analysis and on a literature search. Last, an implementation plan for the new valuation process is developed to explain how the new valuation process should be executed.

1.5 PROBLEM-SOLVING APPROACH

The problem-solving approach is done according to the BPM lifecycle, as showed in Figure 2, because it contains of a range of methods and tools to identify processes and to manage individual processes (Dumas et al., 2018). For this research, the process needs to be identified and managed to improve it. This is why the BPM lifecycle is used. The BPM lifecycle goes through multiple stages, which are process identification, process discovery, process analysis, process redesign, process implementation and process monitoring & controlling. The enlarged version of the BPM lifecycle is added to appendix 8.1.

Those stages and the usability of the stages are explained below while we detail the content of each of the remaining chapters in this thesis. The complete research design can be found in appendix 8.4.

The process identification stage refers to the processes which are relevant to the problem being identified. The outcome of this stage is the process architecture, which shows the whole organization. From this architecture, the choice is made which processes are managed in the lifecycle. For this project, the choice is already made that the valuation process is managed.

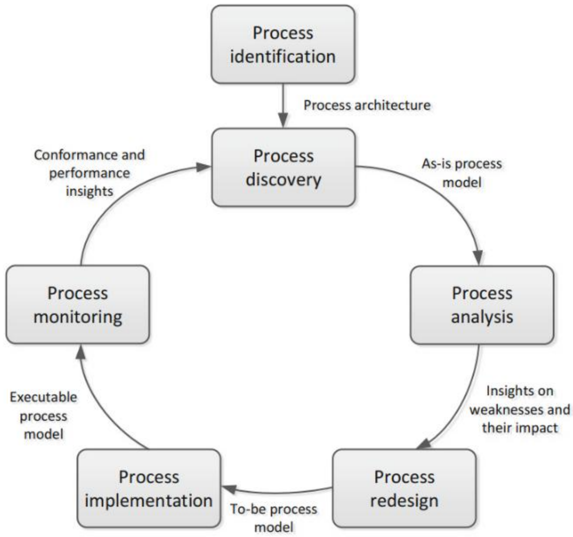

Figure 2: BPM lifecycle.

Chapter 2

In chapter 2, the theoretical background for this research is explained. Next to this, a systematic literature review is conducted to investigate which theory can be used best for process modelling. The following question is answered:

"Which BPM language can be used best for process modelling, based on literature?"

Chapter 3

In the process discovery stage, the current state of the chosen process is documented in the form of an as-is process model. The as-is process is a process model of the current process which gives insights into the current process. In this chapter, the following research question is discussed:

"What does the current valuation process model look like?"

Chapter 4

In the process analysis stage, issues with the as-is process model are identified and documented and if needed quantified. The output of this stage is a collection of issues and their impact. Next to this, an identification of the effort needed to solve the issues can be made. For this project, an analysis of the valuation process needs to be made to know how good it performs and to know where improvements should be made. The cycle time and the accuracy of the valuation process are analyzed. In this chapter, the following research questions are answered:

"What is the accuracy of the valuation?"
"How much time does the valuation take?"

Chapter 5

In the process redesign phase, changes to the processes which would solve the issues in the analysis phase are identified. Multiple options are analyzed and compared. These options are found from either theory or interviews and the database is investigated to check the options for redesigning the process. The best option is chosen and implemented in the redesign. The output of this stage is the to-be process model. For this project, this includes how the valuation process should be redesigned. In this chapter, the following research question is answered:

"What should the new valuation process model look like, based on literature?"

In the process implementation stage, the changes to move from the as-is model to the to-be model are prepared and performed. This is done in two ways. In the organizational change management, the set of activities needed to change the way of working for all participants in the process is covered. Process automation covers the development and deployment of IT systems to support the to-be process. The output of this stage is an executable process model. For this project, improvements are made such that there is a new valuation process. This also includes changes for the employees, which means that there needs to be a clear plan which is understandable and easy to implement. Next to that, the plan is validated within the company and with a business case. In this chapter, the following research question is answered:

"How should the new valuation process be executed?"

In the process monitoring phase, the new process model is executed, and relevant data is collected to analyze how well the process works. Bottlenecks, if they are there, are identified and the cycle starts over again to solve them. This gives insight into the need for changes. For this project, there is no time left to execute this stage. This stage will be executed by the company itself when this project is finished.

Chapter 6

In this chapter, the conclusion of the research is given. The sub-research questions and the main research question are answered. Next to this, some limitations will be discussed with suggestions for future research.

1.5.1 Scope of the research

This research project is limited to the valuation process for the containers or trailers which are sent to the customers of the company. The research is conducted for the company only and only their way of working is investigated.

1.6 ASSESSMENT OF VALIDITY AND RELIABILITY OF MEASUREMENT

In this section, the assessment of validity and reliability of measurement is discussed. Validity refers to the accuracy of the measurement. It tells if the findings are really about what they appear to be about. Reliability refers to the consistency of the measurement. If the measurement is done multiple times with the same result, it has high reliability. Together, high reliability and validity make the research more accurate and trustworthy (Saunders et al., 2019).

1.6.1 Interviews and Observations

The data gathering for some research questions is done via interviews and observations. It can be checked whether the right information is given during the interviews and observations by showing the deliverable, a process model of the current process, to the employees involved, to check whether it is correct or not. According to Saunders et al. (2019), this helps to improve the validity of data gathering. This is not only done with the process model but with all deliverables which are a result of the interviews and observations. Because the interviews are done with multiple employees, it can be checked whether they describe the process differently or equally, which ensures reliability.

1.6.2 Literature search

The literature search is reliable and valid since a systematic literature review is used (Snyder, 2019). Next to this, the sources are cited according to the APA 7th edition rules such that other people can review those sources as well. The preference is to use peer-reviewed articles, since these sources are reviewed subjectively and the risk of bias or methodological flaws reduces (Kelly, Sadeghieh, & Adeli, 2014). However, if there are no peer-reviewed articles, other types of sources may have to be used.

1.6.3 Company data

According to Saunders et al. (2019), the acquisition of data can be made reliable and valid by using the concept of triangulation, which says that the data should be acquired from multiple different independent sources. For this research, for most data, there are multiple sources from which data can be obtained such that validity and reliability is ensured.

2 THEORETICAL BACKGROUND

In this chapter, the theoretical background of this project is discussed. The main focus is to find methods for redesigning and improving processes. These methods are used to reduce cycle time and improve the accuracy of the valuation process. As such, it forms the foundation for the rest of this project. Next to that, a systematic literature review is conducted to find the best BPM language for process modelling.

2.1 BUSINESS PROCESS MANAGEMENT (BPM)

"Business Process Management (BPM) is the art and science of overseeing how work is performed in an organization to ensure consistent outcomes and to take advantage of improvement opportunities." (Dumas et al., 2018, p. 1). This is what is needed for this research project. The valuation process needs to be analyzed and improved to ensure consistent outcomes. Improvement can take different meanings. The most typical meanings are cost reduction, execution times reduction, reduction of error rates and innovation. In this case, the aim is to reduce time and reduce errors.

In every organization there are processes. According to Dumas et al. (2018), processes are entire chains of events, activities, and decisions that ultimately add value to the organization, and its customers. This means what companies do whenever they deliver a service or a product to customers. The design and execution of such processes have an impact on the quality of services and products, as well as on the efficiency with which these processes are carried out. Organizations can outperform other organizations by optimizing their processes. Doing this, the company can have a lot of advantages since it can save them time and money, but it can also increase the quality of the output. This is not only the case for customer-oriented processes but also for internal processes. What is important to highlight is that BPM is not improving single activities but manages entire processes. This is highly applicable for this research. The valuation must be investigated for redesigning to save time and get better accuracy.
"Business process management includes concepts, methods, interactions, and techniques to support the design, administration, configuration, enactment, and analysis of business processes." (Weske, 2007, p. 5). This explanation of BPM also shows that BPM is applicable for this research. The valuation process needs to be analyzed and redesigned. It tells that the BPM theory contains of several methods and concepts to investigate and improve business processes.

BPM is centered around the BPM lifecycle. This lifecycle offers a guide to steer the entire improvement process and provide a systemic perspective (Calçado et al., 2024). It goes through multiple stages including discovery and analysis of the current process, redesign and implementation of the new process and monitoring of the new process.

2.2 LEAN MANUFACTURING (LM)

Lean Manufacturing (LM) focuses on multiple waste types in business processes. The main elements of LM are reduction of process lead times, improvement of process and product quality to zero defects, minimization of cost and inventory reduction. The goal of LM is to maximize value and minimize waste. In lean, the seven most important types of waste are: overproduction, delay and wait time, transportation, processing, inventory, unutilized talent, and defects. LM uses multiple tools to maximize value and minimize waste, including (Taghizadegan, 2006):

- **5S**:
  A workplace organization method which wants to create a clean, organized, and efficient workplace. The 5S are the following:
  - **Seiri** (Sort): Only keep the essential things.
  - **Seiton** (Set in place): Organizing the remaining things in a logical and efficient way.
  - **Seiso** (Shine): Maintain the clean and organized workspace.
  - **Seiketsu** (Standardize): Capture the practices of the first 3S.
  - **Shitsuke** (Sustain): Set procedures to ensure that 5S will be used in the future.
- **Value Stream Mapping (VSM)**:
  A tool for analyzing and designing flows of materials and data. It shows all the activities which are involved in the process. Some activities add value, and some do not add value. With that, bottlenecks can be found, and improvements can be made.
- **Poka-Yoke**:
  Poka-Yoke is a Japanese term which means mistake-proofing. It is a method for error prevention and to ensure quality in a process.
- **Kaizen:**
  Kaizen is the Japanese term for continuous improvement. Any action which helps to improve the process is called Kaizen.

There are more lean tools, but those tools are the most important.
Taghizadegan (2006) emphasizes that these tools are effective when working on continuous improvement and optimizing efficiency. For this project, lean can be used to reduce the waiting time and to reduce inefficiencies in the valuation process.

2.3 Business Process Analysis (BPA)

Business Process Analysis (BPA) is a crucial part in the BPM lifecycle. It is aimed at identifying bottlenecks, inefficiencies, and opportunities for improving processes. According to Dumas et al. (2018), BPA is a valuable tool to gain insights into how a process works, enabling the identification of root causes behind problems such as delays, errors and cycle time.
In this thesis, BPA is applied to examine the valuation process with the focus on cycle time and accuracy.

The cycle time can be examined with a flow analysis. It includes the identification of time needed for each step, including processing and waiting times. With that, the average cycle time, which is the average duration from the start to the completion of the process, and the cycle time efficiency, which is the ratio of actual work time to the total cycle time, can be calculated. This gives a clear representation of the quality of the process, including the delays, long task cycle times and inefficiencies. With that, changes can be made where possible to have a more efficient process. While other techniques, such as Value Stream Mapping (Taghizadegan, 2006) and queuing analysis are also useful for analyzing cycle time, flow analysis is considered the most effective approach for this project (Dumas et al., 2018).

BPA can be used to analyze the accuracy of the valuation process by identifying errors and deviations between the real value and the as-is value. BPA can also be used to discover the causal factors behind deviations and errors.

By understanding the current state of the process, organizations can uncover inconsistencies, inefficiencies, and potential errors. These insights help to make improvements that enhance the overall speed, reliability, and accuracy of the process.

2.4 BPM AND LEAN MANUFACTURING

Traditionally, BPM and Lean Manufacturing are seen as two distinct methods.
BPM focuses most on information flowing and works with a top-down view; decisions are made at the highest level. LM addresses physical flows with a bottom-up view; the lower or less powerful levels are considered first.
However, they can be used jointly when improving and redesigning a process. BPM can focus on guiding the complete improvement process and provides systemic perspective while aligning it with other organizational goals, where LM can focus on tactical tools which maximize value and minimize waste (Calçado et al., 2024).

This shows that BPM and LM can effectively be used together when improving the valuation process investigated in this project. BPM addresses the systemic issues while LM addresses the operational inefficiencies. BPM is used to guide the redesign of the process and Kaizen is the tool used to improve the process. With Kaizen, continuous improvements are made to reduce cycle time and improve accuracy.

2.5 THEORY OF CONSTRAINTS (TOC)

The Theory Of Constraints (TOC) helps to improve processes by finding the biggest constraint. The biggest constraint is the biggest problem that blocks the achievements of a goal or delays the process the most. After finding the constraint, it is improved, and the rest of the process is adapted to it. This is done in five steps, which are called the Five Focusing steps (Gupta & Boyd, 2008):

1. **Identify the system's constraint:**
   In this step the part of the process which limits the performance of the process the most is identified.
2. **Decide how to exploit the system's constraint:**
   In this step, the output of the constraint is maximized without making any investment, using only the existing resources.
3. **Subordinate the rest of the system to the decisions made above:**
   In this step, other processes, activities, or resources are aligned to support the constraint.
4. **Elevate the constraint:**
   In this step, action is taken to eliminate the constraint. This may include making additional investments to increase the capacity of throughput of the constraint. However, before making such investments, it is important to assess whether it will deliver a sufficient return by elevating the constraint.
5. **Go back to step 1:**
   In this step, the entire process is done over again. The next biggest constraint is sought and the whole cycle is repeated.

The TOC contains of multiple tools, including (Kim et al., 2008):

- **Current reality tree (CRT)**:
  A method based on logic which is used to identify core problems and causes that cause undesirable effects.
- **Evaporating cloud (EC)**:
  A logical diagram to represent a problem which has no obvious satisfactory solution.
- **Future reality tree (FRT)**:
  The FRT is similar to the CRT, but it shows the future state. This can include proposed actions, policies, or behaviours.
- **Negative Branch Reservation (NBR)**
  The NBR is a tool which identifies and addresses undesirable, negative results of the proposed changes.
- **Prerequisite tree (PRT)**:
  A tool to outline the steps needed to achieve the future state and to map obstacles which could hinder you from achieving this state.
- **Transition tree (TT)**:
  A tool for creating an execution plan to move from current to future state. It shows how to make the change happen.

These tools help to identify constraints and resolve those (Gupta & Boyd, 2008).
The TOC can be used next to BPM and LM. BPM structures the overall improvement process, LM addresses waste and inefficiencies and the TOC ensures that the biggest constraint in the process is solved. TOC searches for the biggest constraint in the valuation process which causes long cycle times and low accuracy. Once this constraint is identified, efforts are made to solve it to improve the entire process. For this project, a transition tree can be used in order to show which actions should be taken to change from the current process to the desired process.

2.6 Business Process Model and Notation (BPMN)

The chosen theoretical perspective is BPM. During the research project, two process models are made to gain insight into the current valuation and to show how the new valuation process should look like. In BPM, there are several languages with which the process can be modelled. Some examples of languages are UML, BPMN, petri-nets. The question is which language can be used best for process modelling. For this, a systematic literature review is conducted. Following from that, the knowledge question for the systematic literature review is:

"Which BPM language can be used best for process modelling?"

The whole systematic literature review can be found in appendix 8.3. The search is conducted in Scopus. This is a multidisciplinary, academic database which has a lot of journal pages which are peer-reviewed.
This systematic literature review contains the choice for key concepts, inclusion & exclusion criteria, a search log which shows which search queries have been used for the literature review and how many hits followed from those queries. After that, the identified sources which will be used for answering the knowledge question are documented. The Prisma diagram from Page et al. (2021) is used to show how many sources were first found and how many sources have been excluded before finding the final set of identified sources. After this, a concept matrix is given which shows which sources contain the concepts.

Following from the systematic literature review, the following is concluded:

Farshidi et al. (2024) conclude that it makes more sense for academics to argue why they did not select BPMN rather than discussing why they did choose BPMN for process modelling. They did compare multiple BPM languages and found that BPMN covers the most BPM modelling features. Those features include communication, analysis, enaction, functionality and more. Campos & De Almeida (2014) compare the languages UML, EEML and BPMN. From the comparison, it could be concluded that UML and EEML are suitable languages, but that BPMN is classified as most suitable. Debnath et al. (2012) rank multiple processing languages based on LSP, which stands for Logic Scoring of Preferences. When ranking the alternatives, it came out that BPMN scored the best. Following that, the authors concluded that BPMN is the best language for modelling business processes at a competitive level. Wautelet and Poelmans (2017) compare RUP/ UML Business Use Case Models and BPMN. For multiple elements, they investigate the alignment between RUP/ UML and BPMN. Their conclusion is that BPMN can be used better than RUP/ UML at operational level. Zuhaira and Ahmad (2020) evaluate multiple languages. Based on the scores from the comparison, they conclude that BPMN should be retained as common process language to support the principle of joint understanding.

To conclude from these articles, BPMN should be chosen as the BPM language to model the processes. Some articles highlighted that BPMN is already the most standard language to choose, but they wanted to do research because it is not the case that standards are always the best choice. However, the articles show that there are good reasons for choosing BPMN as process modelling language.

With that being said, the answer to the knowledge question is that BPMN should be used as the BPM language for process modelling. BPMN will be used to model the current process and the improved valuation process for this project.

3 CURRENT PROCESS

In order to analyze the current valuation process, a BPMN model is developed. Not only is the valuation process itself modelled, but also some parts of the whole business process before the valuation takes place. This is done to better understand the valuation process itself.
Before presenting the process model itself, this section discusses the data collection and the steps for constructing the model. An explanation is given next to the model to clarify the elements.

3.1 DATA COLLECTION

To develop a correct and realistic process model of the current valuation process, interviews and observations are conducted with the employees involved. The aim is to gain insights into the entire process. This includes not only the flow of the process, but also the techniques used to value the containers.

Before the interviews and observations are conducted, informed consent is asked from the participants. In the informed consent form, the participants are informed about the purpose of the study, the use of their answers, the confidentiality of their answers and the voluntary basis of their participation. This includes that the employees can withdraw from the interview whenever they want.

The interviews are of a semi-structured nature. Some questions are prepared before the interview such that the most important topics are discussed. However, there is enough room for flexibility and to explore topics in greater depth during the interview since it is conducted like a conversation. By interviewing in this way, the researcher can ask more questions on certain topics when needed such that all aspects of the process are discussed.

Next to the semi-structured interviews, the researcher observes one of the employees while doing his job. During the observation, the employee explains what he is doing and why he does his work in that way. This gives the best insight into the valuation process and shows bottlenecks or possible bottlenecks.

The employees involved in the valuation process are the transport coordinators and a finance employee. The transport coordinators are interviewed, and the finance employee is observed. The transport coordinators arrange and request the valuation, while the finance employee does the actual valuation itself.

The findings from the interviews and observations are summarized into the process model of the current valuation process. This shows the flow of the process, but also the way of working of the employees involved. After the model is finished, the transport coordinators and finance employee are asked about the correctness of the model. This ensures the best representation of the real valuation process.

3.2 PROCESS MODEL OF CURRENT PROCESS

Figure 3 shows the process model of the current valuation process. The model is made with the BPMN language in Bizagi modeler. In appendix 8.2, the BPMN elements used in the model are explained.

Dumas et al. (2018) give five steps to discover a process.
First, the boundaries of the process are identified. The start boundary is the customer who configures and orders a machine. From there on, the entire process starts since the configuration and Bill Of Materials are needed for the valuation process.
The end boundary is the customer who receives the machine. As the process starts with the order of the machine, it ends with the delivery of the machine. For this project, the valuation steps are most important, but the ordering and delivery moments are also modelled to give context.

The second step is to identify the main activities and events. These are rough versions which can change when really modelling the process. The identification is done by observing and interviewing the employees involved. The main activities and events for every department/ employee are documented in Table 1.

Table 1: Main activities and events.

Person/ Department	Main events/ activities
Customer	Ordering machine(With configuration)
	Receiving machine
Workshop	Assembling machine
	Disassembling machine
	Put machine in containers
	Make load list
Transport coordinator	Make and send invoice
	Receive filled in invoice
	Send invoice to customs authorities
	Make other transport documents ready
	Send machine
Finance	Allocate parts in packages and containers
	Calculate percentage in container
	Calculate value
	Send filled in invoice

The third step is to identify resources and their handoffs. First, the pools are defined. Those pools are the same as the people/ departments in the table above. There also is a customs authorities pool since they receive the invoice. Then, the main events and activities are placed at the right spot in the pools and the points where work is handed over to another pool are modelled.

In the fourth step, the control flows are identified. In this step, links between events are formed. This is done to identify when and why a task is performed. It includes dependencies on other departments or people and conditions for a workflow to be executed. For example, the decision point in transport coordinator where there is a choice between export or not.

The fifth step is to identify additional elements. The main events and activities are already added to the model, but additional elements need to be added to really represent the valuation process. All steps which are executed in real life are added in the model. For example, the finance employee must first finish other tasks before he starts the valuation.

To ensure the best model, it is validated by the employees involved. They review the model and provide feedback. After processing the feedback, this step is done again until the employees agree on the final model. According to Saunders et al. (2019), this helps to improve the validity of the data and information gathering. An enlarged version of the process model is available in appendix 8.5.

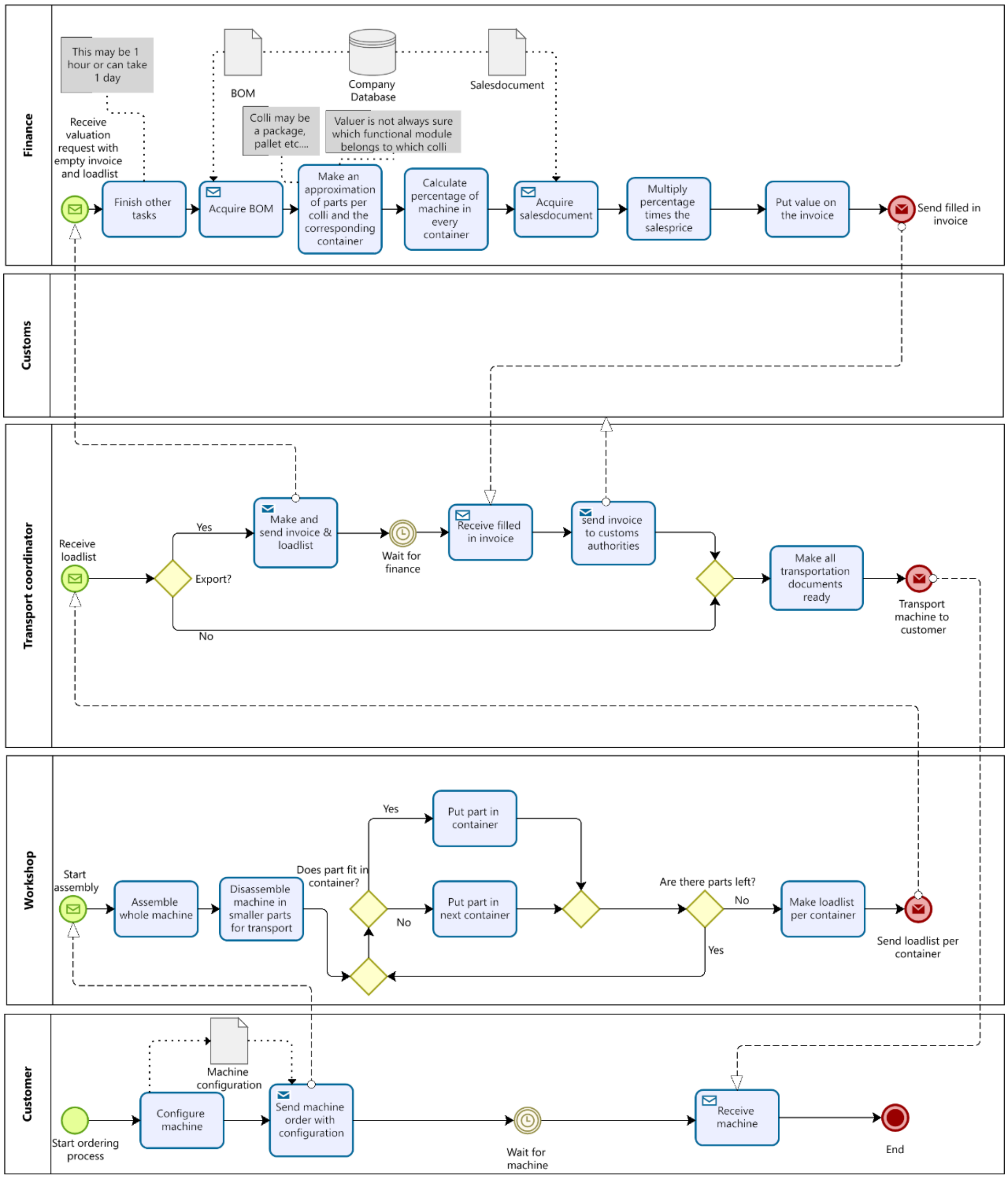

Figure 3: Process model valuation process.

3.3 EXPLANATION OF PROCESS MODEL

In this section, the process model of the current valuation process is explained.

The process model shows five pools. These five pools are two external parties, the customer and the customs authorities, and three intern departments, the workshop, the transport coordinator, and the finance department. The customer is included in the process model because they provide input for the valuation process. The customs authorities are included in the process model since the invoice is sent there. However, this pool is closed since the work of the customs authorities is not part of the valuation process of the company.

At the start of the ordering process, the customer configures, with help from the sales department, the machine they want, and which works the best for them. The result of this is a document with a machine configuration. This configuration is sent together with the order to the company.

At the workshop, the machine is assembled according to the machine configuration. After that, some checks with the machine are done and the machine is disassembled into smaller parts for transportation. For every part, it is checked whether they fit in the first container or trailer. When it does not fit, it will be stored into the next container or trailer. When this is done, a load list per container or trailer is made. This load list is sent to the transport coordinator.

When the transport coordinator receives the load list, there are two possibilities. The first possibility is that the transport is sent to an EU-country, and no invoice is needed. The other possibility is that the transport is sent to a non-EU country, and an invoice is needed. When that is the case, the transport coordinator makes an invoice without value on it and sends this together with the load list to the finance department. Then, they request the finance department to do the valuation and to put the value on the invoice. The transport coordinator will pick up some other tasks while waiting for the finance department.

A colleague at the finance department receives the valuation request at an unexpected time. Because of this, he first must finish other tasks he is still working on. This can take him 1 hour, but can also take a day, depending on how important the other tasks are. When he starts with the valuation, he first must acquire the Bill Of Materials (BOM) from the company database. When he acquired this, he tries to place the parts on the BOM into the right package. Those packages are then placed in the right container. Based on the cost price of the parts, the percentage of the machine which is in every container is calculated. After that, he acquires the sales document from the company database and multiplies the percentages with the sales price. The outcome of this is the value of the container or trailer and this value is put on the invoice. After that, he sends the invoice back to the transport coordinator.

When the transport coordinator receives the filled-in invoice, the invoice is sent to the customs authorities. After that, the other transportation documents are prepared, and the machine is shipped to the customer. Upon arrival, the machine is installed, and the customer gets to use it.

4 PROCESS ANALYSIS

In the previous section, it became clear how the current process is executed and who does which part of the valuation. In this section, the current process is analyzed. The cycle time of the process is analyzed by investigating how long each step in the process takes. Following that, the cycle time efficiency can be calculated. Next to that, the accuracy of the valuation is analyzed by comparing the value on the invoice with the real value of the container.

Some of the data used in this section is collected during interviews and observations as described in section 3.1. In addition, there is data extracted from the database of the company. This data includes historical shipment data per country and machine values to perform the accuracy analysis. The machine values are confidential and are therefore multiplied by a random number X. This ensures that sensitive data is protected, while keeping it useable for the accuracy analysis since the percentual differences between two values do not change.

4.1 EXPORT DISTRIBUTION

Before analyzing the cycle time and accuracy, the distribution of transport to EU or to non-EU countries is calculated. It is important to know this distribution as only for non-EU countries, an invoice and the corresponding valuation is needed. This distribution is used in the cycle time analysis later as well.

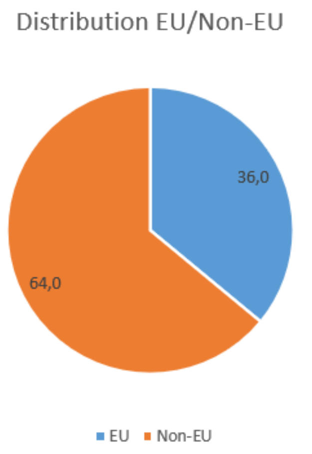

Figure 4: Distribution EU/ Non-EU.

Figure 4 shows the distribution of containers and trailers which go to EU or Non-EU countries. This distribution is based on the transport data of the company for the year 2024. Approximately 64% of the containers and trailers are sent to countries outside the EU and approximately 36% goes to countries in the EU.

4.2 TIME ANALYSIS

Following the process model, a time analysis of the valuation process can be made. This cycle time analysis is a flow analysis of the valuation process. Flow analysis are techniques to approximate the performance of a process or set of tasks (Dumas et al.,2018). To perform the cycle time analysis, the cycle times of each task must be known. From interviews and observations, the task cycle times documented in Table 2 have been obtained. Those cycle times are the average times between the start of the task and the completion of the task (Dumas et al., 2018).

Table 2: Task Cycle Times.

Task	Cycle time
Make and send invoice & load list	5 minutes (1/12 hour)
Receive filled in invoice and sending it to customs authorities	10 minutes (1/6 hour)
Acquire Bill Of Materials (BOM)	5 minutes (1/12 hour)
Approximate parts in container and calculate percentages	60 minutes (1 hour)
Acquire sales document	5 minutes (1/12 hour)
Multiply percentages with sales price and put value on invoice	10 minutes (1/6 hour)
Finish other tasks (Time between starting with valuation and request of valuation)	1 hour – 1 day → Average of this is taken which is 12½ hours
Send invoice to customs authorities	5 minutes (1/12 hour)

Those cycle times are visualized by documenting them in the process model. The result of this is shown in Figure 5. The cycle time “Waiting for finance”, is the sum of the cycle times of the finance department.

The formula for calculating the total cycle time is the following (Dumas et al., 2018):

$$CT = \sum_{i=1}^{n} p_i \ x \ T_i$$

The probability of having containers or trailers which are sent to a country outside the EU is based on the distribution of EU and Non-EU as shown in Figure 4. The probability of having an export container or trailer is 64%, where the probability of having a non-export container or trailer is 36%.

The total cycle time of the valuation process is the time between making and sending the invoice and sending the invoice to the customs authorities. The cycle time is zero when the machine is sent inside the EU, because no invoice is needed then. The cycle time when no invoice is needed is also considered in the total cycle time because it influences the total time which the transport coordinator takes to arrange the transport. For example, if all transport were sent outside the EU, no invoices would be needed, and the cycle time would be zero. Then, it would make no sense to improve the valuation process.
With the formula given above and the task cycle times in Table 2, we calculate the total cycle time as follows:

$$CT = \left(0{,}64 \ x \ \left(\frac{1}{12} + 13\frac{5}{6} + \frac{1}{6}\right)\right) + 0{,}36 \ x \ 0 = 9.0133 \ hours$$

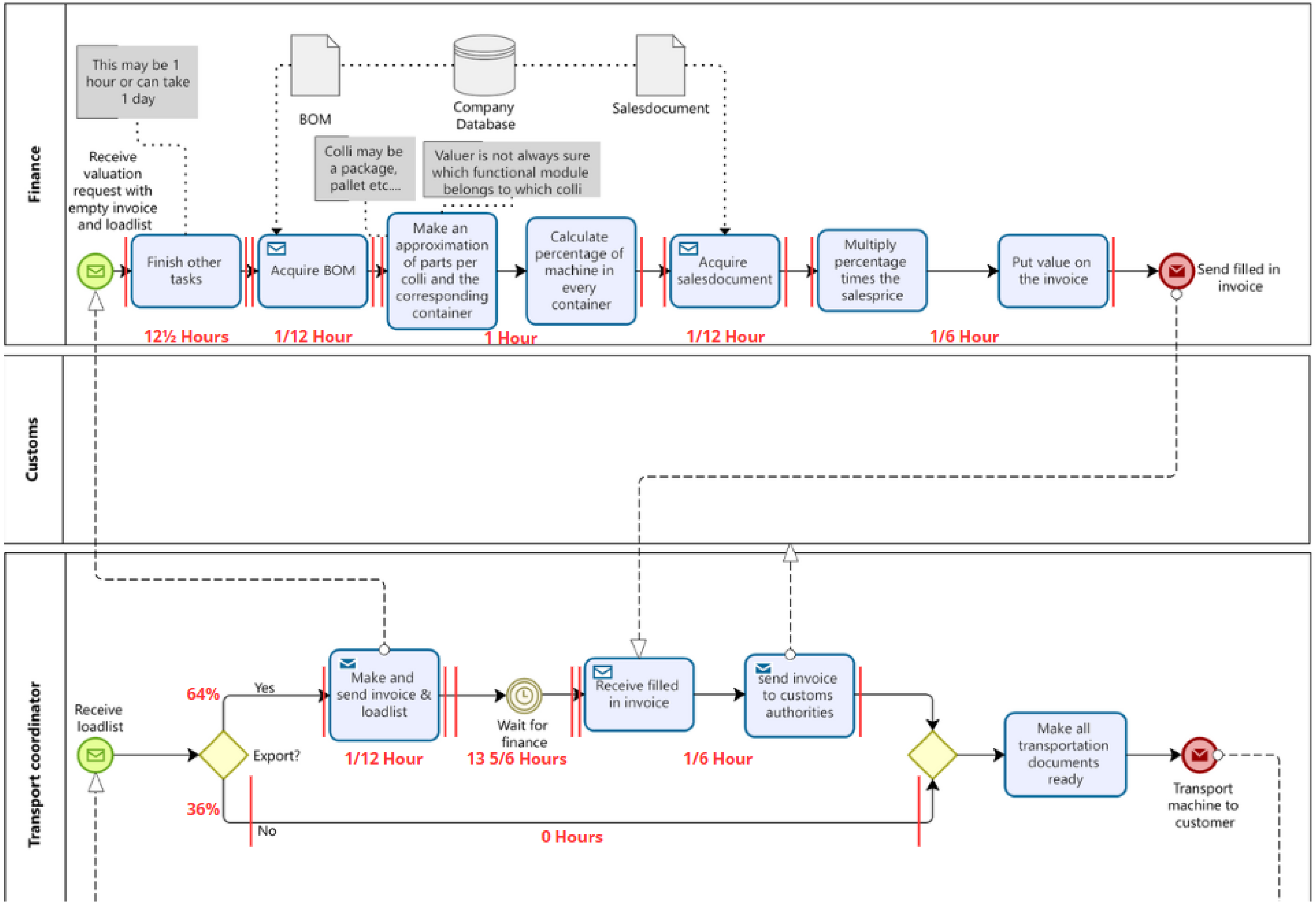

Figure 5: Cycle times valuation process.

The cycle times in Figure 5 include waiting time. Processing time is the cycle time of the process excluding the waiting times (Dumas et al., 2018). Therefore, the processing time is the portion of time where actual work is done. In Figure 6, the waiting times are deleted.

To know how time-efficient the valuation process is, a calculation is done to determine the cycle time efficiency. The cycle time efficiency is the ratio of total processing time to the total cycle time. When the ratio is close to 100%, there is little room for improvement except for making substantial changes. When the ratio is close to 0%, there is greater room for improvement by reducing the waiting times.

The formula for calculating the Cycle Time Efficiency (CTE) is the following (Dumas et al., 2018):

$$CTE = \frac{TCT}{CT}$$

In here, the cycle time is the cycle time as calculated above (9,0133 hours). The TCT is the Theoretical Cycle Time, which is the time a case would take if there was no waiting time at all (Dumas et al., 2018).

The Theoretical Cycle Time is first calculated. The processing times used in the equation can be found in Figure 6.

$$TCT = \left(0{,}64\ x\ \left(\frac{1}{12} + 1\frac{1}{3} + \frac{1}{6}\right)\right) + 0{,}36\ x\ 0 = 1.0133\ hours$$

With that, the Cycle Time Efficiency is calculated:

$$CTE = \frac{1.0133}{9.0133} = 11.24\%$$

It can be seen that the cycle time efficiency is 11.24%.
The waiting time of the finance employee is a key factor in the low cycle time efficiency of the valuation process. The waiting time for the finance employee is 12½ hours on average, which is a big part of the total cycle time ($13\frac{5}{6}$ hours) of the finance employee. The causal factors for the low cycle time efficiency are discussed in the section Causal factors.

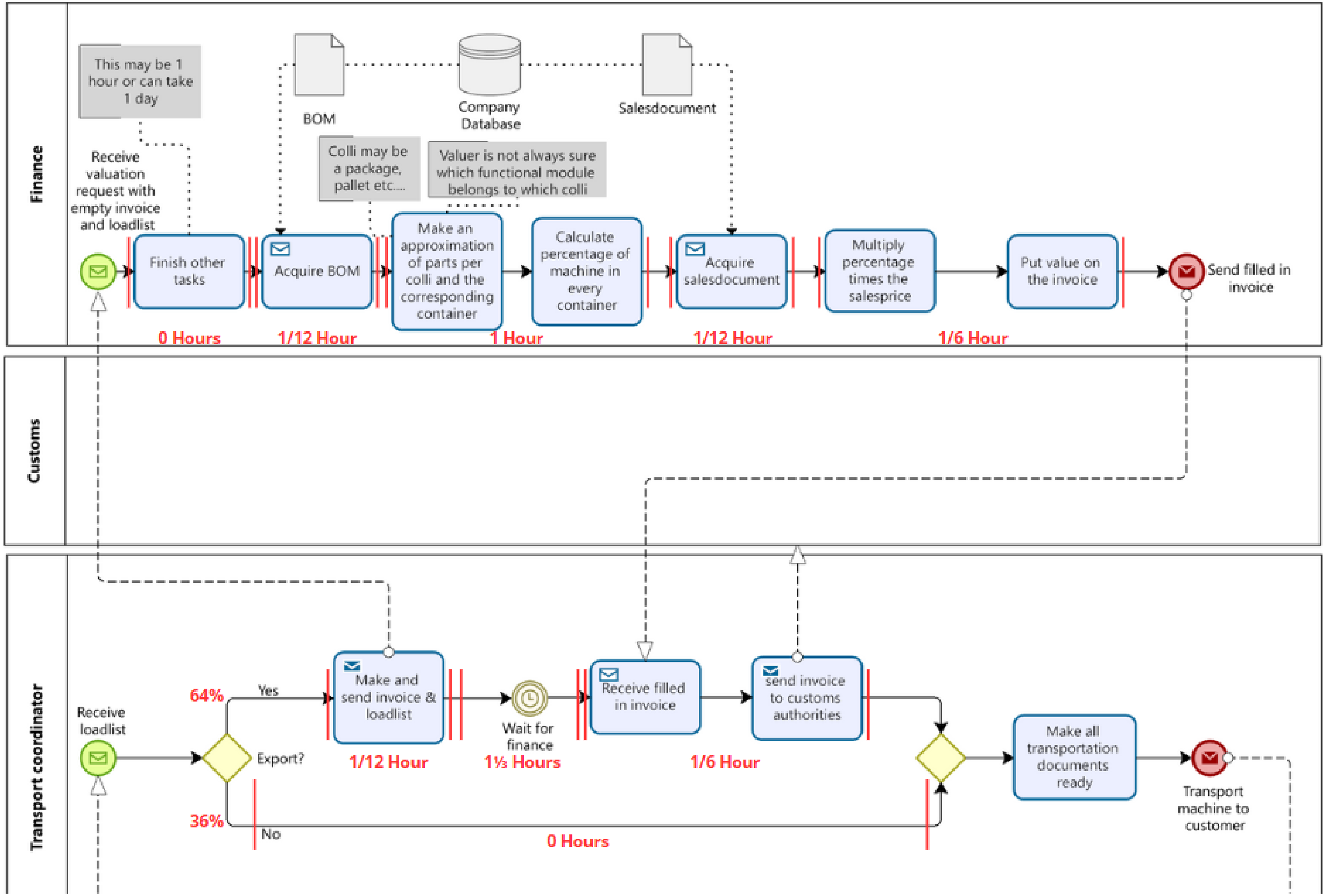

Figure 6: Processing times valuation process.

4.3 Accuracy analysis

Next to the cycle time, the accuracy of the valuation process is analyzed.

According to Williams et al. (2003), accuracy defines the quality of the instrument measurement. It is the difference between the reading of an instrument and the true value of what is actually being measured.
In the analysis of the process, the accuracy of the valuation is evaluated. It is evaluated whether the valuation on the invoice is the real value of the container
The accuracy analysis is done by comparing the invoice values with the real value of the container or trailer. This is done by asking employees where parts consist of and in which container they are placed.

For this analysis, three projects have been taken and investigated. All the materials which are on the Bill Of Materials (BOM) must be placed in the right package and the corresponding container or trailer. For this, there is a load list configurator. This configurator shows which packages are in which container. To place every part in the right package, employees are asked what the part exactly is and where it is placed. With that, the right value of the containers is found. This value is compared to the value which is on the invoice. The results of this comparison can be found in tables 3, 4 and 5 below. The values are multiplied by a random number X because those numbers are confidential and cannot be shared.

Table 3: Accuracy analysis results Project A.

Container #	Value on invoice	Real value	Percentual difference
1	€ 894.576,66	€ 884.443,12	-1.13%
2	€ 287.482.10	€ 293.704,27	2.16%
3	€ 329.758,88	€ 337.791,74	2.44%
4	€ 179.253,55	€ 175.132,07	-2.30%

Table 4: Accuracy analysis results Project B.

Container #	Value on invoice	Real value	Percentual difference
1	€ 964.639,65	€ 1.009.662,60	4.46%
2	€ 263.977,08	€ 268.024,60	1.51%
3	€ 175.516,69	€ 126.446,22	-38.81%

Table 5: Accuracy analysis results Project C.

Container #	Value on invoice	Real value	Percentual difference
1	€ 799.640,08	€ 947.052,89	18.43%
2	€ 310.971,34	€ 311.823,63	0.27%
3	€ 310.971,34	€ 169.653,82	-45.44%
4	€ 59.233,06	€ 52.285,48	-11.73%

What can be seen is that the first project, project A, was valued with relative high accuracy. The differences between the real and invoice values are not higher than 2.44%, indicating that the invoice value is estimated close to the real value.

In contrast to project A, the valuation of project B was significantly worse. The highest difference between the real and the invoice value was 38%, which is a big deviation.

The last project, project C, clearly highlights the need for improvements. The largest difference between the real and the invoice value was 45,44%, which can account for a lot of money. Those differences can have major impacts for the company. In the first place should the correct values be given to the customs authorities. Next to this, the insurance does need to know the exact value of a container. When a container falls off the cargo ship and the value on the invoice is undervalued by €80.000, the company loses €80.000. This is a significant financial risk.

An explanation for the good results of project A could be given from the fact that project A is a 'simple' project. The machine combination sold in this project is smaller and less complicated than projects B and C, which are projects with multiple machines and big transportation sections. Therefore, it is easier for the finance employee to execute the valuation.

The causal factors for the low accuracy are discussed in the section Causal factors.

4.4 CAUSAL FACTORS

In the cycle time and accuracy analysis, it was discovered that the cycle time efficiency is a low number, and that the accuracy of the valuation lacks a lot. In this section, causes for these outcomes are discussed. This is done separately for the cycle time causes and the accuracy causes.

4.4.1 Cycle time causes

The cycle time efficiency is only 11,24%. The biggest cause of this is the long waiting block before the finance employee can start with the valuation. The finance employee cannot start with the valuation immediately when the request comes in. He must first finish other tasks or prioritize more urgent ones. Since the valuation is just one of his many responsibilities, and no one else can perform it, it often has to wait until his other, more urgent tasks are completed.

Next to this, the task cycle time for allocating the parts in the right package and container is a time-consuming task (1 hour). This does take so long because of the lack of knowledge of the finance employee, which means that extra time is needed for the correct placement of the parts.

4.4.2 Accuracy causes

The cause for the lack of accuracy in the valuation is that the employee at the finance department does not know which part of the BOM is in which package. Some parts are easy to discover and can be placed in the right container. Some parts, however, have difficult names which are not recognized by the employee.

Next to this, the machine is split into smaller parts, which are modules. It can be the case that two or three modules are together in one package. This is not a problem, the modules and the corresponding values can be summed, and the total container value is known.
However, it is a problem when one module is dissembled further and is packed into multiple packages. For example, the module of the machine itself consist of the mechanical part of the

machine and the covers of the machine. The front and side covers of a machine are dissembled and packed into another container than the mechanical part of the machine. Now, the full value of the machine goes to the container with the mechanical parts in it and the container with the covers gets no value. To get the right container values, the value of the covers should be subtracted from the machine value and this value should be added to the right container. However, the finance employee again has too little knowledge of the machine to do this.

4.5 THE BIGGEST BOTTLENECK

To identify the biggest bottleneck, the Theory Of Constraints (TOC) is applied. The TOC finds the biggest constraints and tries to solve this. To do this, an analysis of the cycle time and accuracy of the valuation process has been conducted. These analyses involved mapping of the current process, calculating the cycle time and accuracy and evaluating where delays and errors most frequently occur. What has been discovered in the analyses is that the fact that the finance employee executes the valuation is the biggest constraint. This conclusion is based on the two observations:

- **Low valuation accuracy**
  The finance employee lacks machine knowledge and therefore struggles to allocate the correct parts into the corresponding container.
- **Long cycle time**
  The valuation is not priority for the finance employee. Additionally, It takes him long to allocate the parts in containers because of his lack of machine knowledge. This leads to delays in the valuation process.

Only minimal other causes were found for the low accuracy and long cycle time, further reinforcing that the role of the finance employee is the biggest bottleneck.

This is the first step of the Five Focusing Steps of the TOC (Gupta & Boyd, 2008). It shows that this problem needs to be resolved to get higher accuracy and to reduce the cycle time. In the next chapter, the other steps of the Five Focusing Steps are executed, which implies that this problem is explored further, and efforts are made to resolve this issue.

5 TO-BE PROCESS

In the previous section, it is discovered that the biggest constraint is the fact that the finance employee performs the valuation, who has limited machine knowledge. This is solved to improve accuracy and reduce cycle time. In this section, it is explained how the systems in the company work and which difficulties exist. With that knowledge, a solution is made.

5.1 CURRENT WAY OF WORKING

In this section, the current way of executing the valuation is explained. This is explained since the finance employee performs the valuation and the causes behind the low accuracy of his valuation should be known. This includes an explanation of the entire process of building the machines and the tools used in the process and the way of working of the employees involved.

5.1.1 modular building

The machines are built based on modular building. Modular building means that the machine is split into multiple parts, which are modules. With that, the machine can be built with those building blocks. This gives the company a lot of options to assemble the machine. All modules can be combined, and the machine can be configured exactly how the customer wants it. There are two types of modules in this company:

1. The ERP-module: These modules are engineering modules. The engineers build the machines with these modules. They are all the parts which are in a machine. Those modules have a price.
2. The Configure To Order (CTO)-module: These modules are functional/ sales modules. For example, when a machine is sold with an extra airco unit, the airco module is added to the machine. The price of a CTO-module is the sum of all the ERP-modules which the CTO-module consists of. So, the price of the CTO-module of the airco consists of the price of the ERP-module of the airco itself, the cables, etc.

When the machine is put into packages, a CTO-module can be split into multiple parts and can be placed into multiple packages. The ERP-module is never split into parts and goes into the package as a whole.
From here, there are two problems for the finance employee. The first problem is that he does not know what each module is and in which package it should be placed. The other problem is the splitting of CTO-modules into multiple containers. He does not know which percentage of a module goes into which package and therefore he does not know how much value to assign to which package.

5.1.2 Available loading tool

The placement of the packages is currently performed manually, despite the availability of an automated tool, the load list configurator, which automatically allocates the packages to containers. However, this tool is not used since the employees perceive their manual input to be more effective.

One issue with the manual process is that the employee involved can create an unlimited number of new packages. As a result, he can make packages which are not documented in the database of the company and which are not linked to modules. Consequently, these additions are not recognized by other employees or tools in the company, leading to operational inefficiencies and financial risks.

A limitation of this tool is the lack of connections between the modules and their respective package. While the addition of a new module may require an extra package, a new item can also be placed within an existing one. However, in such cases, the link between module and package is not documented. Only when a new package is created, the connection is properly registered. This inconsistency results in an unclear understanding of the content and associated value of a container.

5.1.3 Trailer vs. container transport

There is a difference between transportation with trailers and transportation with containers. Most of the time, trailers are used for EU countries and containers are used for non-EU countries. However, there are some exceptions. For example, Switzerland is a non-EU country, but transport is most of the time done with trailers. The difference between a trailer and a container is the distribution of parts. For example, a sawing machine can be transported entirely in one container, but it is split into two parts for trailer transport. This is an extra difficulty since one part can be transported in multiple ways and the distribution of value can be different.

5.2 SOLUTION

In this section, potential solutions are discussed which would solve the problem in the valuation process.

5.2.1 Module list

One potential solution would be that a list is made with all the modules and a detailed description. This list would serve as a guide for the finance employee, and he would know better which modules he should assign to which package. Next to this, having this list would make it easier for other employees to step in and execute the valuation whenever the finance employee is absent.

This solution corresponds to the second step (exploit the constraint) and third step (subordinate everything else to the constraint) of the Five Focusing Steps (Gupta & Boyd, 2008). Creating the list is an effort to exploit the constraint since more clear information is provided to the finance employee. This also includes subordinating since the other departments must work strictly and accurately to give the finance employee the best possible information.

However, since there are so many options, the finance employee would search long in the list before finding the correct option. Next to that, the list would need quite a lot of maintenance since new parts all need to be described and checked. Therefore, this solution is not suitable for the company over the long term. It would likely increase the accuracy of the valuation, but the cycle time would become even longer.

5.2.2 Automation

To reduce time and achieve higher accuracy, a tool should be developed which automatically places the modules in the right packages and which calculates the corresponding container values.

The concept of automation is discussed by Dumas et al. (2018). They introduce BPMS, which stands for Business Process Management System. BPMS enables the automation of workflows in settings where automation is not yet implemented. There are four main advantages of using software. These are workload reduction, flexible system integration, execution transparency and rule enforcement.

The first advantage, the workload reduction, is highly applicable to this project. There are three types of workload reduction which are the transporting of work, the coordination of work and the gathering of all relevant information. The last type is the most important reason in this project to automate the valuation. The finance employee has no information about the machine and does not know where to place modules.

The second advantage, the flexible system integration, is also applicable for this project. The data from different systems is not integrated right now, which can lead to inefficiencies because it must be handled manually. By implementing BPMS, those systems can be connected which enables the data to be integrated better. This will lead to greater efficiency and fewer errors.

The third advantage, the execution transparency, is relevant for this project as well. It gives information about the process, which can be operational information or historical information. Operational information refers to recent or running cases and historic information refers to completed cases. The information which can be important for the valuation process is the cycle time of the process or the status of the process. In addition, it can give information about parts of the process which are not completed yet, such as components which have not yet been allocated to a package.

The last advantage, rule enforcement, also improves the valuation process. BPMS will make sure that the process is carried out in exactly the way it is designed. With manual valuation, there is always the risk of deviation from the original design. By using BPMS, accuracy and consistency will be significantly higher.

As a result of automation, the cycle time of the valuation process will be reduced since the finance employee does not have to execute the whole valuation manually. The accuracy will increase since the modules will be automatically assigned to the right package.

5.3 Valuation tool

In this section, the way of valuing a container and the development of a tool is discussed. Additionally, a tool manual and limitations of the tool are given.

5.3.1 Way of valuing

In the previous section, the concept of automation and BPMS is discussed. This concept aligns well with the problem in the valuation process. The biggest constraint in the process is the finance employee who executes the valuation. Therefore, the valuation should be automated such that the accuracy is improved, and cycle time is reduced. This corresponds with the fourth step (elevating the constraint) of Five Focusing Steps (Gupta & Boyd, 2008). This step includes eliminating the constraint or reducing the impact of the constraint. Here, action is taken to automate the valuation process, which would eliminate the constraint.

Within the company, there is a department which develops tools for departments in the company. They automate processes which are done manually to reduce time, increase standardization, and improve the quality of those processes. This department is called CTO, which stands for Configure To Order (CTO). What CTO basically means is that a machine is configured exactly how the customer wants it. In the tooling of this department, a DNA file is used. All available data about the configuration of the machine is in the DNA file, this includes the type of machines, options on the machine and the length of the transport sections between machines.

The tool for loading the containers is also based on DNA. It reads all the CTO modules which are in the machine and calculates which packages are needed.
With that DNA, it is also known which ERP modules are in the machine. The ERP modules have a price, and the price of the CTO module is simply the sum of all the ERP modules in it.

For the valuation, the price of all the containers which are shipped must be known. The price of the container is simply the sum of all the packages inside this container. However, the price of the packages cannot be summed simply.

For that reason, a valuation tool is needed which values the different packages. As described earlier, CTO modules can be split and divided into multiple packages. That is the reason the price of the packages cannot be a simple sum.

To be able to know the price of the package, the percentage of the CTO module in every package should be known. This can be calculated with the ERP modules. An overview needs to be made which shows which ERP- modules are in which package. The percentage of the CTO module which is in that package can be calculated by dividing the price of the ERP module by total price of the CTO module.
For more clarity, an example of this calculation is added below.

The following table shows an overview of all the ERP modules inside a CTO module. The ERP modules all have unique ERP numbers. These modules are fictional and are not used in the company. However, the way of working is exactly the same.

Table 6: Modules and ERP numbers.

CTO module	ERP module	ERP Number
CTO_Drill_Base	Drill-Base	012-123
CTO_Drill_Base	Camera	012-125
CTO_Drill_Base	Housing	012-129
CTO_Drill_Base	Cables	012-135
CTO_Drill_Base	Software	012-113
CTO_Drill_Base	Fences	012-190

The following table shows the prices of the CTO module and the ERP modules. These prices are fictional as well.

Table 7: Module prices.

Module	Amount	Module_Price	Total_Price
Drill-Base	1	€ 150,000	€ 150,000
Camera	1	€ 6,000	€ 6,000
Housing	1	€ 25,050	€ 25,050
Cables	5	€ 800	€ 4,000
Software	1	€ 26,692	€ 26,692
Fences	3	€ 123	€ 369
CTO_Drill_Base	1	€ 212,111	€ 212,111

The following table shows the packages which are needed for transporting the machine. It also shows the ERP modules which are in the packages.

Table 8: Packages.

Package	Module
Base	Drill-Base
Base	Camera
Housing	Housing
Housing	Cables
Base	Software
Safety	Fences

Then, the percentage of the CTO module in the different packages can be calculated as follows:

$$Base = \frac{Price(DrillBase) + Price\ (Camera) + Price\ (Software)}{Price\ (CTO\ Drill\ Base)} = \frac{150{,}000 + 6{,}000 + 26{,}692}{212{,}111} = 86.13\%$$

$$Housing = \frac{Price(Housing) + Price\ (Cables)}{Price\ (CTO\ Drill\ Base)} = \frac{25{,}050 + 4{,}000}{212{,}111} = 13.70\%$$

$$Safety = \frac{Price(Fences)}{Price\ (CTO\ Drill\ Base)} = \frac{369}{212{,}111} = 0.17\%$$

The outcome of these calculations gives the distribution of the CTO module of the drill base across the packages. The distribution of modules in packages is fixed and will never change. The percentages can change when the prices of the modules are updated.

A package can consist of multiple CTO modules. For example, the package with safety consists of 0.17% of the CTO_Drill_Base module but the CTO_Safety_Fence module is in the package five times as well. The price of the safety fence module is again €123. Then the value of the package with safety is calculated as follows:

$$Value_{Safety} = 0.0017 * Price(CTO\ Drill\ Base) + 3 * 1 * Price(CTO\ Safety\ Fence) = €729.59$$

The factor 1 is added here since the whole CTO module of the safety fence is in that package.

After calculating the price of all the packages, those values should be translated into container values. This is done by summing the values of the packages for every container.
However, these values are still cost prices and the value on the invoice should be the sales price. The sales value of a container is calculated as follows:

$$Container\ 1 = \frac{Value_{Safety}}{Total\ costprice\ machine} * Salesprice = \frac{729.59}{360{,}254.93} * 521{,}387.96 = €1{,}055.92$$

For this calculation, only the safety package is placed inside container one. The total cost price is assumed to be €360,254.93 and the sales price is assumed to be €521,387.96.
The result of the calculation is that the value of container one is €1,055.92. This can be done in the exact same way for all containers which are shipped for this project.

5.3.2 Creation of tool

The previous section shows how the containers should be valued. Now, the valuation tool itself should be created and developed. Since all the tools in the company are made in Microsoft Excel, the valuation tool is also made in Excel.

The tool is designed to replicate and automate the valuation calculation as described above. It consists of Visual Basic for Applications (VBA) code to carry out the computations efficiently and accurately. The tool integrates input from other excel documents and calculates the values accordingly. Due to time constraints, the data for the tool is developed for only one type of machine. However, since the CTO department is already working with VBA, the tool and data for the tool can be further developed for all the machines by them.

5.3.3 Tool manual

To use the valuation tool effectively, a manual is developed, which explains all the steps needed to execute.

The following steps are taken when using the valuation tool:

1. Before using the valuation tool, an empty invoice is made by another tool. This tool is already used in the company and not explained further here.
2. First the data needed must be uploaded to the valuation tool. This includes the BOM, load list and an overview which shows which modules can be placed inside a package.
3. The tool then makes a list of all the packages of the shipment and places them in a column. Next to the column with packages, the correct container is added to the packages.
4. After that, the tool reads the overview of modules in packages and places all the modules in the package.
5. The tool then reads the BOM and places the price of the module next to the module. This will ensure that modules which are not in the configuration are not considered for the valuation since this module is not part of the BOM.
6. After this, it is checked whether all modules are identified. This will ensure that all modules are valued.
7. The tool then reads the factors of modules inside packages. For example, the factor which tells that half of the base of the machine is in package one and the other half in package two.
8. The tool then calculates the value of all the packages. All the prices of the modules are multiplied with the factor of that module inside the corresponding package.
9. The value of the package is divided by the total cost price, which gives the percentage of the total cost price in that package.
10. For every container, the percentages of the packages which are in that container are summed.
11. Those percentages are then multiplied by the sales price of the configuration.
12. A new sheet, named “Results”, is opened which shows the values of all the containers.
13. These values can then be documented in the invoice and the invoice is sent to the customs authorities.

Figure 7, shows the interface of the valuation tool. It contains a step-by-step plan for the employee who must execute it. On the left side, four buttons are added with which the tool is executed.

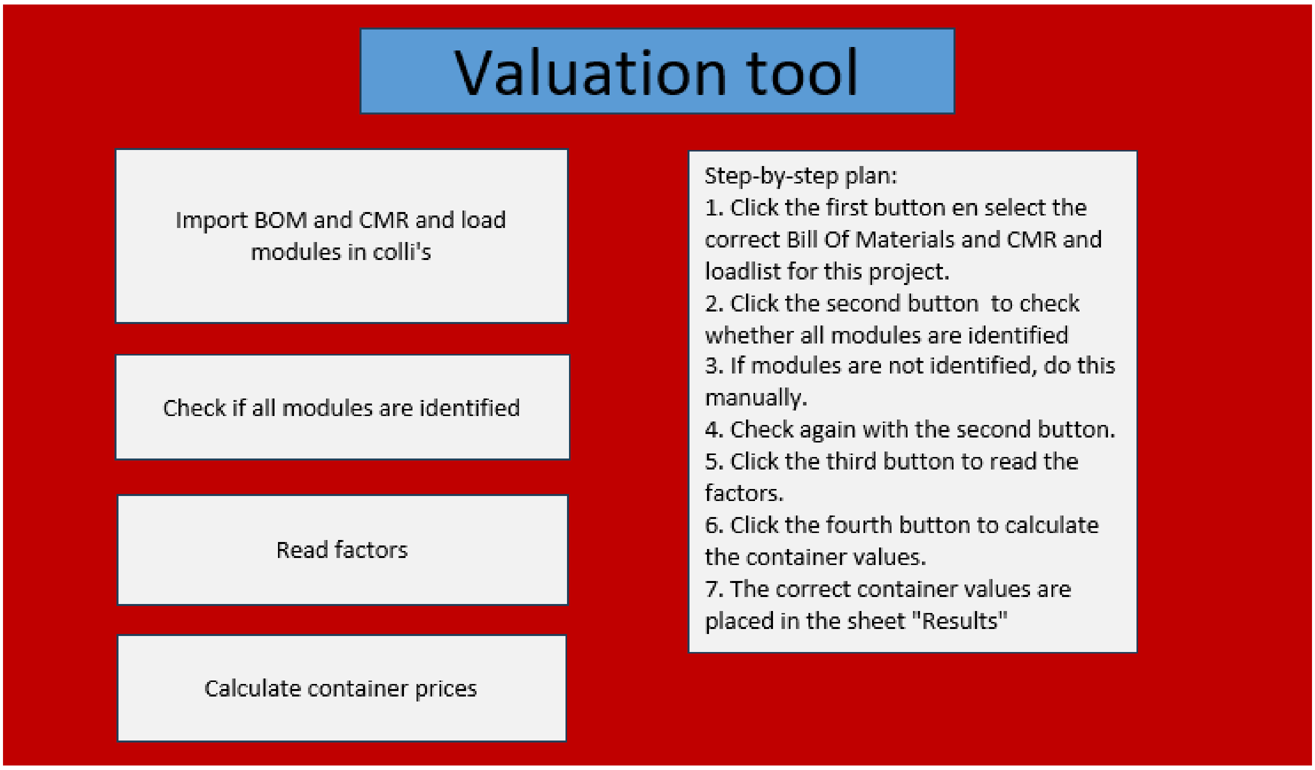

Figure 7: Interface valuation tool.

5.3.4 Limitations

Some ERP modules are still split and divided into different packages since they are too big to ship in one package. However, the employees in the workshop can make accurate estimations of the value of the ERP modules in the packages.

Another limitation is that the tool cannot handle manual steps. The tool uses the packages which are given in the load list. However, when a package with a different name is manually added, the tool will not recognize it. This implies that the loading tool should be used and that the whole container should be loaded according to that tool. This will ensure that the valuation tool works.

5.4 To-be process model

The new process model of the valuation process is based on the current valuation process (section 3.2), but the changes are incorporated into it. Figure 8 shows the redesigned process model. Appendix 8.6 shows the enlarged version of this process model. The main difference is that the whole finance department is no longer part of the valuation process. The finance department executes the valuation itself in the current process. However, with the developed tool, the transport coordinators can execute the valuation themselves. They run the tool and get the value of the containers out of it. Therefore, the dependency on the finance department is eliminated.
Another difference between the current and redesigned process is that the tool for loading the containers is used in the workshop instead of the previous way of loading the containers. The employees in the workshop can run the tool themselves and load the containers according to the solution given by this tool. The load list will be sent to the transport coordinators who can then start the valuation by applying the valuation tool. This will ensure that no manual steps are

taken before running the valuation tool. This is needed since the valuation tool will not recognize manual added packages.

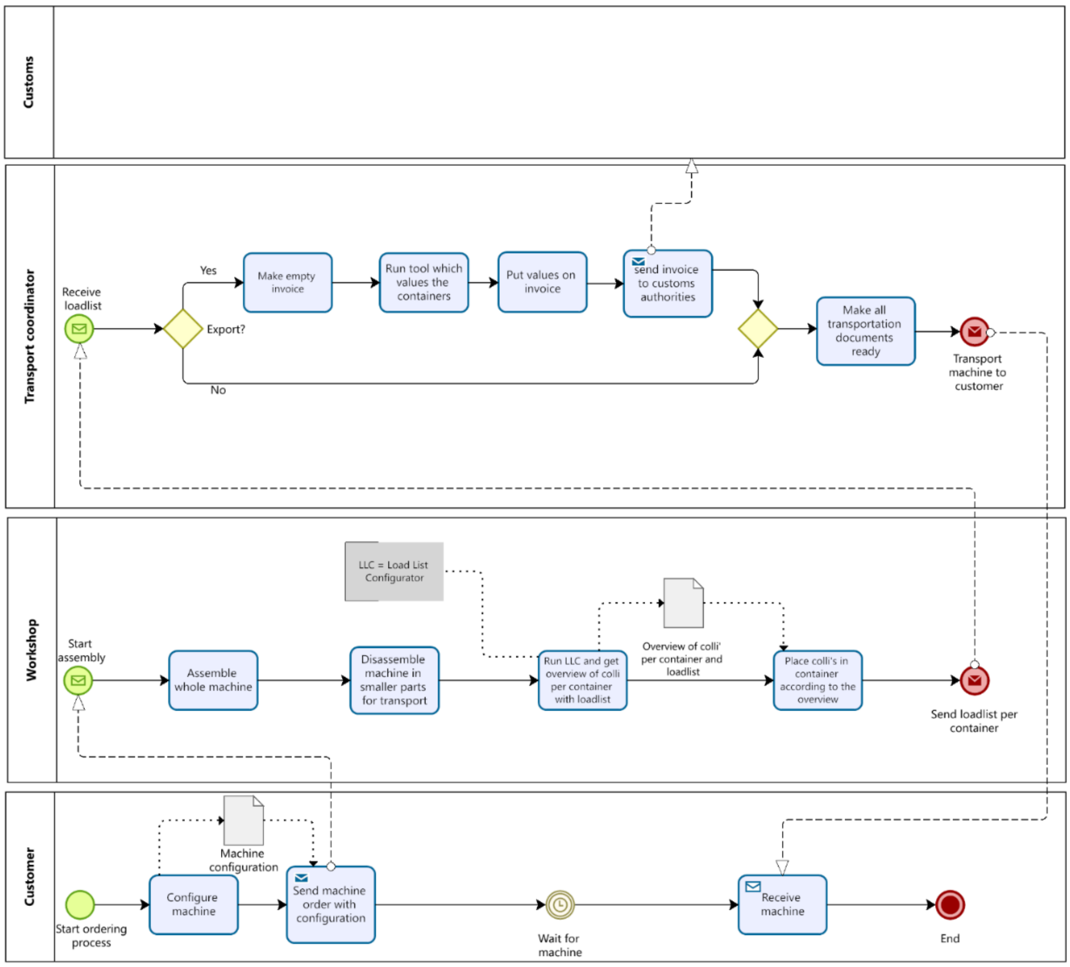

Figure 8: To-be process model.

5.5 Cycle time reduction

When implementing the redesigned process and tool, the cycle time reduces. In Table 9, the cycle times of the to-be process are documented.

Table 9: New cycle times.

Task	Cycle time
Make empty invoice and run tool which values the containers	5 minutes (1/12 hour)
Put values on invoice	2 minutes (1/30 hour)
Send invoice to customs authorities	5 minutes (1/12 hour)

With those cycle times, the total cycle time can again be calculated:

$$CT = \left(0{,}64\ x\ \left(\frac{1}{12} + \frac{1}{30} + \frac{1}{12}\right)\right) + 0{,}36\ x\ 0 = 7.68\ minutes$$

The Theoretical Cycle Time (TCT) can be calculated as well. This is the cycle time minus the waiting time. The only waiting time in the new redesigned process is 0,5 minute of letting the tool run and calculate the values. With that, the TCT is calculated as follows:

$$TCT = \left(0{,}64\ x\ \left(\frac{1}{15}+\frac{1}{30}+\frac{1}{12}\right)\right) + 0{,}36\ x\ 0 = 7.04\ minutes$$

With the TCT and the CT, the Cycle Time Efficiency (CTE) can be calculated as follows:

$$CTE = \frac{TCT}{CT} = \frac{7.04}{7.68} = 91.67\%$$

The Cycle Time Efficiency of the redesigned process is 91,67 percent. This is an increase of 80,43 percentage points compared to the original process, where the CTE was 11,24 percent. In relative terms, this is an increase of approximately 715,3%. The total cycle time has reduced by approximately 8 hours and 53 minutes.

5.6 Tool accuracy

Next to high cycle times, the low accuracy of the valuation was a problem as well. The highest percentual difference between the real value and the value on the invoice was 45.44%. With the redesigned process and the valuation tool, the accuracy will be significantly higher. Since all parts are identified and placed in the right package, there is small room for errors. The tool is finished for all machines. However, since the data for the tool is only developed for one machine, it can only be tested for this machine. When testing the tool, the accuracy is 100%. This only holds when all activities are performed as prescribed. For example, the containers should be packed exactly how the load list configurator calculates it. In comparison to the old accuracy, this is a substantial improvement. Table 10, shows the results of the accuracy analysis of the tool. These values are again multiplied by a random factor X.

Table 10: Tool accuracy analysis.

Container #	Real value	Tool value	Difference in %
Container 1	€840.246,81	€840.246,81	0%
Container 2	€164.602,55	€164.602,55	0%
Container 3	€277.232,58	€277.232,58	0%

5.7 Transition tree

In Figure 9, a transition tree, one of the TOC tools, is given. This tree shows everything needed to implement the to-be process, which is the top row of the tree. The top rows of the columns are the recommendations for implementing the to-be process and the way towards the to-be process. Since it can take some time before the valuation tool is finished, the finance employee must execute the valuation until the tool is finished. For this, a list must be made which describes all the modules such that the finance employee understands it. This is the concept as explained in section 5.2.1. Next to that, a mechanical employee should check the valuation for errors. It should be checked whether the modules are placed in the right package. The line between the valuation tool and the finance employee shows that the finance employee no longer has to execute the valuation when the valuation tool is finished. For implementing the to-be process itself, the valuation tool should be expanded and finished for every machine. After that, the tool should be explained to the transport coordinators since they are going to use the tool. Since the valuation tool does not work with manual input, the load list configurator should be used. For that, the load list configurator needs to be updated such that all relevant information about the machines and packages is in there. A crucial point is that the employees cannot make any changes manually. They should not add packages themselves since the valuation tool will not recognize those packages. The line between the valuation tool and the load list configurator shows that the valuation tool cannot be used without the load list configurator.

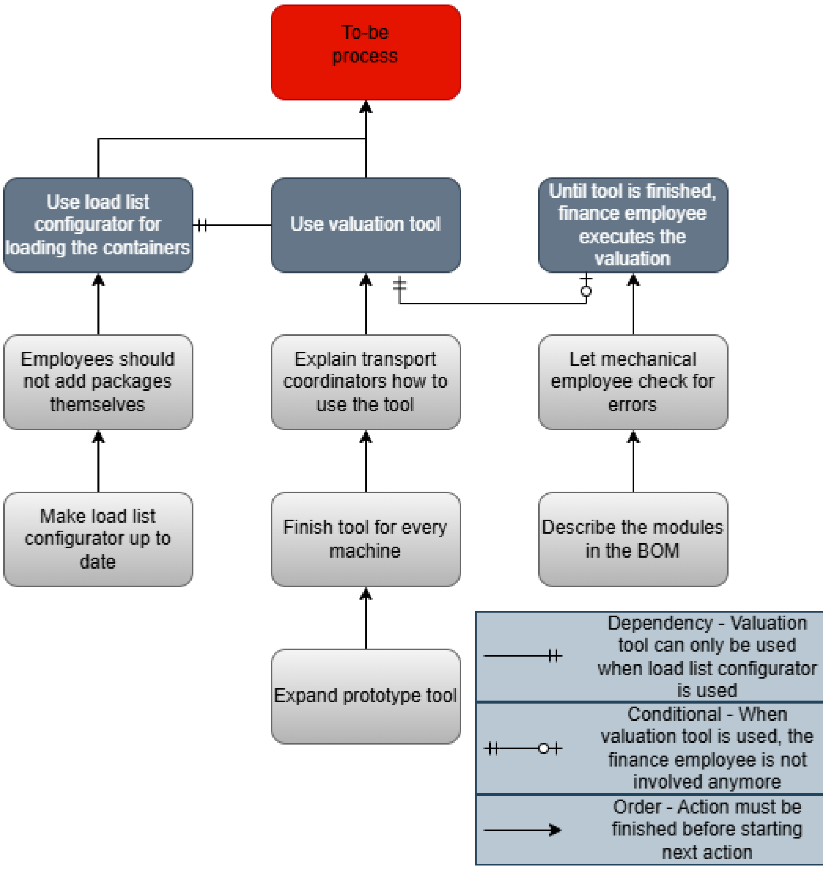

Figure 9: Transition tree.

In Table 11, the needed changes are listed with the employee/ department who is responsible for it and executes it.

During the completion and implementation of the valuation tool, the fifth step of the Five Focusing Steps is applied (Gupta & Boyd, 2008). This step involves identifying and addressing the next biggest constraint. This will ensure that the valuation process is as efficient and accurate as possible.

Table 11: Changes responsibility.

Change	Who executes it
Describe modules in the BOM	Mechanical employee
Check for errors	Mechanical employee
Until the tool is finished, execute valuation manually	Finance employee
Make load list configurator up to date	CTO department
Use load list configurator	Workshop employee
Expand and finish valuation tool	CTO department
Explain valuation tool to transport coordinators	CTO department
Use valuation tool	Transport coordinators

5.8 VALIDATION

To repeat the definition, validity refers to the accuracy of the measurement. It tells if the findings are really about what they appear to be about (Saunders et al., 2019).

During the development of the process model of the valuation process, the employees involved are asked to give feedback on it until the model really represents the reality. Next to that model, a model of the redesigned process was made. For this, the employees involved are also asked what they think about it and to investigate whether they think the solution is feasible or not.

The accuracy of the tool is evaluated in section 5.6. The conclusion of the accuracy analysis is that the tool represents reality. The calculated value of the tool is exactly the real value which shows that the validity is proven.

5.8.1 Business case

Additionally, the redesigned process is validated by a business case (Dumas et al., 2018). It outlines the necessity and value of the project and shows why changes are needed. Next to that, it assesses the financial and non-financial impact of the changes.

Problem statement

the existing process for valuing the containers for export is time consuming and inaccurate. The cycle time efficiency is only approximately 11%, with waiting times up to 12 hours. Next to that, deviations in accuracy can go up to 45%.

Objectives

To address the problems, the following objectives are set:

1. Improve accuracy to 100%.
2. Reduce cycle time and increase cycle time efficiency.

Tool overview

To achieve the objectives, a tool has been developed in excel which:

- Integrates ERP data with existing excel tooling.
- Automates the valuation process by integrating and coupling existing data.
- Eliminates manual input and minimizes errors.

- Eliminates the dependency on the finance department.

Cost-benefit analysis

Since the company already uses excel, there are no additional costs when implementing the tool in excel. Therefore, the cost-benefit analysis is solely based on employee costs. The waiting time for is excluded in the analysis, since employees can perform other tasks during that period.

The detailed calculations of the cost-benefit analysis can be found in appendix 8.7.

The costs for executing the redesigned process are approximately €5.31 per valuation
The costs for executing the original process are approximately €48 per valuation
Per valuation, approximately €42.50 is saved by implementing the redesigned process. This is a reduction of almost 90% per valuation.

Based on the transport data from 2024, 83 shipments required a valuation since they are sent to non-EU countries, leading to annual savings of €3,527.50.

The CTO department will further expand and complete the tool before implementing it. One CTO employee is expected to spend one week on the development of the tool. Based on the average yearly salary, the development costs are €2,032.36. The estimation is that one CTO employee will need one hour per month to maintain the performance of the tool. Based on the average yearly salary, the maintenance costs are €610 annually. After subtracting these, the net savings are €885.14 in the first year and €2,917.50 in the subsequent years.

Risk assessment

The main risks are the following:

- Resistance to change from employees who are used to the existing process.
- Potential mismatches between ERP and excel data if the systems are not updated together.

These risks can be avoided by training the employees and giving them insights into the need for the redesigned process. Additionally, the data should be checked periodically such that there are no mismatches.

Proof of tool

The initial tests of the tool show that the accuracy of the tool is 100% when all activities are performed as prescribed and therefore gives the correct output. The cycle time of the valuation process reduces from approximately 9 hours to less than 8 minutes. The cycle time efficiency improves from approximately 11% to almost 92%. This shows that the redesigned valuation process is more efficient and reliable.

Implementation plan

The implementation of the valuation tool consists of the further development and completion of the valuation tool. For this, a transition tree and a table with the employees responsible are provided. Next to that, the load list configurator should be updated and used. Before the tool is completed, the finance employee should get a list, which describes all the modules in the BOM, such that his valuation is more accurate. A mechanical employee will check whether the finance employee made errors or not.

Conclusion

The redesigned valuation process demonstrates improvements in both accuracy and cycle time compared to the original process. By integrating ERP data with excel, the tool eliminates manual input, removes dependency on the finance department, and reduces errors.

Initial tests show that an accuracy of 100% is achieved when all activities are executed as prescribed and that the cycle time is reduced from approximately 9 hours to under 8 minutes, where the cycle time efficiency increases from 11% to 92%. The net savings of the redesigned process are estimated to be €885.14 in the first year and €2,917.5 in the subsequent years.

Risks such as employee resistance and data mismatches may exist, but these can be avoided by employee training and data checks. The implementation plan ensures a smooth transition, including the expansion and completion of the valuation tool and measures before the tool is finished.

In conclusion, the valuation tool is a cost-effective, accurate and efficient solution for the container valuation process.

6 CONCLUSION AND LIMITATIONS

6.1 CONCLUSION

In this section, the research questions and the main research question are answered. Next to that, the answers will shortly be discussed. Finally, some limitations and future research topics will be discussed.

Sub-question 1: *"What does the current valuation process model look like?"*

The current process was modelled using BPMN (Figure 3: Process model valuation), which shows the sequence of activities, and the departments involved in the valuation process, including the workshop, transport coordinators and the finance department. The model has been checked and validated by the employees involved in feedback sessions, ensuring the model represents reality.

Sub-question 2: *"What is the accuracy of the valuation?"*

The accuracy analysis, discussed in section 4.3, revealed significant deviations between the real container value and the value on the invoice, where the percentual differences reach up to approximately 45%. These deviations can have big financial consequences for the company. These findings underscore the need for a more accurate valuation process.

Sub-question 3: *"How much time does the valuation take?"*

The cycle time analysis, discussed in section 4.2, revealed an average cycle time of approximately 9 hours, with a cycle time efficiency of approximately 11%. The primary cause for the low cycle time efficiency and long cycle time is the long waiting period before the finance employee can start with the valuation since he first must finish other, more important tasks.

In section 4.5, it was found that the biggest cause for the low accuracy and long cycle time is the fact that the finance employee executes the valuation since he has too little machine knowledge to execute the valuation.

Sub-question 4: *"What should the new valuation process model look like, based on literature?"*

Based on BPM, Lean Manufacturing, and the Theory Of Constraints, the valuation process is redesigned. The new process eliminates the dependency on the finance department and shifts the responsibility to the transport coordinators who can execute the valuation with a newly developed automated tool. This tool, based on the concept of BPMS, integrates existing company data and documents to automatically calculate the container values. The redesigned process is modelled in a BPMN model (Figure 8: To-be process). A new cycle time analysis was executed in section 5.5, which showed that the new cycle time is around 7.7 minutes with a cycle time efficiency of almost 92%. Additionally, a new accuracy analysis, discussed in section 5.6, demonstrated that the accuracy of the tool is 100%. However, this level of accuracy will only be obtained if all activities are carried out exactly how they are prescribed. For instance, the containers must be loaded exactly in the same way as the load list configurator calculates it. Those new values show a substantial improvement over the current process and validate the effectiveness of the redesigned process.

Sub-question 5: *"How should the new valuation process be executed?"*

For the execution of the redesigned valuation process, a manual is provided in section 5.3.3, which offers a step-by-step explanation of the valuation tool. With that, the employees can read the manual themselves and use the tool effectively. In addition, a transition tree is given in section 5.7, outlining all the changes needed for implementing the redesigned process. It includes the completion of the tool and the procedures to be followed before the valuation tool is fully operational.

Main research question: *"What is a clear and relevant implementation plan to structure the container valuation process such that the value accuracy is improved, and cycle time is reduced?"*

In this thesis, the research question has been answered. First, the current situation has been visualized and analysis. From there on, the biggest bottleneck was found and eliminated. With the help of automation, the cycle time is reduced, and the accuracy is improved. This redesigned process has been visualized with a BPMN model. To change from the current process to the redesigned process, an implementation plan is developed. This implementation plan is the transition tree which shows everything needed to implement the valuation tool. The discrepancy between the norm, a structured valuation process, and reality, an unstructured valuation process, has significantly reduced. This is evidenced by meeting the requirements of the company, namely an accuracy of at least 95% and a cycle time reduction of at least 50%.

The impact of this project for the company is substantial, particularly in terms of efficiency and risk reduction. By reducing the cycle time, improving the accuracy and eliminating the dependency on the finance department, the process becomes faster and more reliable. Since the company already has its own tooling department, CTO, it is easy for them to further develop and maintain the valuation tool, ensuring its long-term use and benefits. While the business case, discussed in section 5.8.1, shows an annual saving of approximately €2,917, the greater value lies in the improvement of accuracy, reduction of cycle time and elimination of dependency on the finance department.

6.2 RECOMMENDATIONS

In this section, some recommendations for the company are given.

1. **Development and maintaining of tool**
   The company should further develop and maintain the valuation tool to adapt changes in the company or data. This will ensure its long-term efficiency and accuracy.
2. **Reintegrate load list configurator**
   To fully support the redesigned process, it is important that the load list configurator is updated and integrated into the process. This ensures that the valuation tool can be used optimally.
3. **Link ERP and CTO modules**
   For the valuation tool to function optimally, it is essential that the data links between the ERP and CTO modules are up to date and maintained. This needs to be done since the factors are calculated based on ERP and CTO modules. This will help to prevent errors and improve the accuracy of the process.
4. **Provide training for transport coordinators**
   The effective execution of the redesigned process and the proper use of the valuation tool requires the transport coordinators to be well-informed and adequately trained.

Training will equip them with the necessary knowledge and skills to operate the tool correctly.

5. **Monitoring bottlenecks**
Once the redesigned process is fully implemented, monitoring is needed to identify and resolve any new bottlenecks. This supports the further optimization of the valuation process.

6.3 LIMITATIONS

In this section, some limitations which may impact this project are discussed.

The first limitation is that the valuation tool is not yet fully developed and therefore cannot be evaluated to its full extent. As a result, practical reliability, effectiveness, and efficiency cannot be validated at this stage. Although initial tests demonstrate reliable and efficient results, they do not provide an accurate reflection of reality. Further development and testing will reveal the tool's full functionality and potential.

The second limitation is that the assumption is made that the employees involved give the right information. The second limitation is the fact that the analysis involves interaction with humans. Humans can make unintentional errors and can forget important data. However, it is assumed that the employees give accurate and complete information.

The third limitation is that there is no historical data for the time analysis. The required data is obtained by observations and interviews. The employees try their best to give the most realistic cycle time for their tasks, but it may not be the exact value.

6.4 FUTURE RESEARCH

Future research should aim to develop generic solutions to problems similar to those addressed in this thesis. While the current approach was targeted specifically at the problems of the company, other companies may face comparable issues related to manual data input, inefficiencies, and excessive interdepartmental dependencies. Investigating standardized methodologies that can be applied across different industries would yield significant value.

In particular, future studies should focus on problems regarding valuation processes. There is little research available on this topic, and as a result, no standard valuation methods are currently provided. Research into this domain could lead to the development of standardized valuation approaches.

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8 APPENDIX

8.1 APPENDIX A: BPM LIFECYCLE

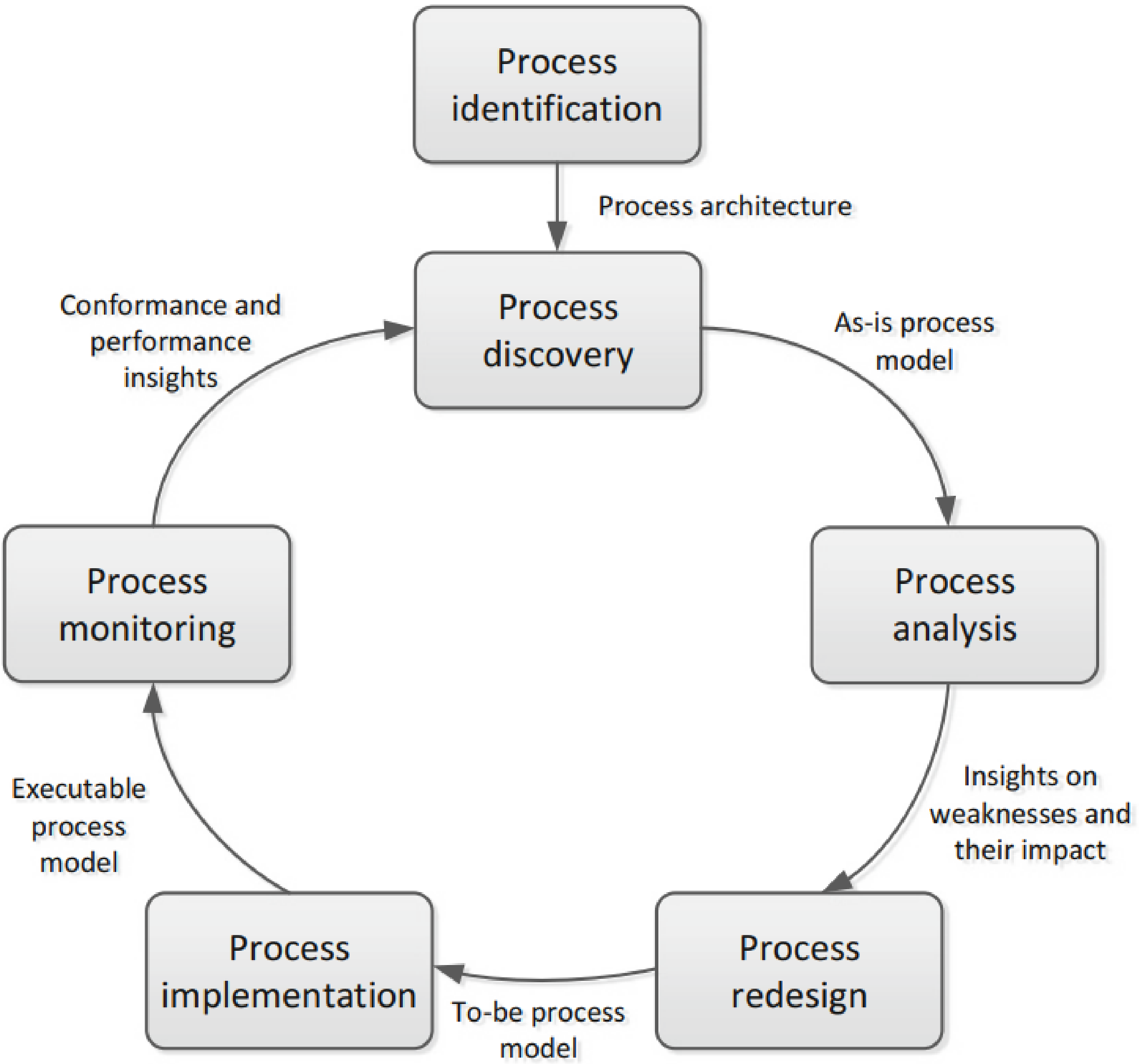
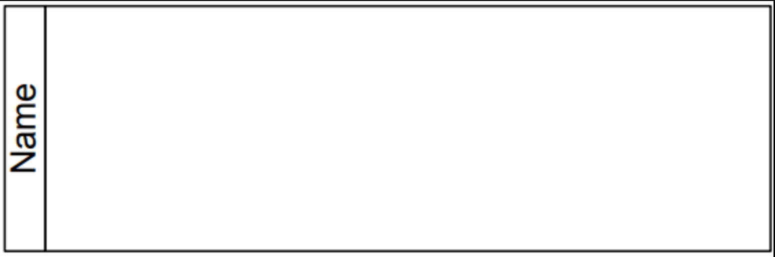
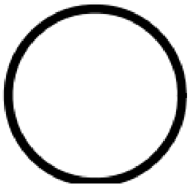


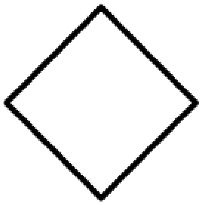
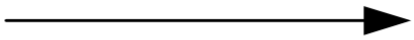
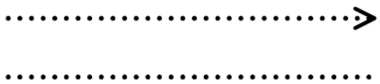
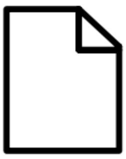
Figure 10: Enlarged BPM life cycle (Dumas et al., 2018).

8.2 APPENDIX B: BPMN EXPLANATION

In this appendix, some elements of the BPMN language which are used in the process models of this project are explained (*About the Business Process Model and Notation Specification Version 2.0.2*, n.d., p. 27).

Table 12: BPMN elements explanation.

Element	Explanation	BPMN notation
Pool	Representation of a person or department.	
Event	Something that happens during the process. There are events which start something, events where something happens during the process and events which end something.	
Intermediate timer event	This intermediate event represents a delay or waiting period.	
Message start event	This is a start event which starts when a message comes in.	
Message end event	This is an end event which ends when a message is send.	

Activity	An activity is an action or task that is performed in the process. These activities can also include sending and receiving messages.	
Gateway	A gateway is a decision point which controls how the sequence flows split and merge. This is based on conditions or decisions.	
Sequence flow	This shows the order in which activities are performed.	
Message flow	This shows the flow of a message between participants.	
Association	This is used to link information or data to activities or tasks.	
Data object	This is data which is needed or produced by activities in the process.	
Data store	This is a data storage where data can be read from or written onto.	

8.3 Appendix C: Systematic Literature Review

8.3.1 Definition of knowledge question

The chosen theoretical perspective is BPM. Two process models need to be made for the current valuation process and the new valuation process. In BPM, there are several languages with which the process can be modelled. Some examples of languages are UML, BPMN or petri-nets. The question is which language can be used best.
Following from that, the knowledge question for the systematic literature review is:

"Which BPM language can be used best for process modelling?"

8.3.2 Key concepts

The key concepts which will be used in the systematic literature review are the following:

Table 13: Key concepts.

Key concept	Related terms	Broader terms	Narrower terms
Process modelling	Business process modelling, process mapping	Process management	Workflow diagram
Language	Modelling language, notation	mapping	BPMN, UML
BPM	Workflow management	Business process management	BPMN, UML, petri net

Process modelling is the first key concept. It is chosen because a process model is used to show how processes work or should work.

BPM is a key concept as well. This is chosen because BPM is the theoretical perspective, and BPM has a lot of process modelling languages to choose from. BPM is quite a broad term, but the next concept will narrow it down more.

The last key concept is language. It is chosen because we want to use a language to model the processes.

The concepts BPM and language are not merged to 'BPM language' as BPM is the greater picture of managing processes and BPM language only refers to the modelling part of the processes. However, for this research, we want to keep the bigger picture of managing the valuation process.

8.3.3 Inclusion & Exclusion

In this section, the inclusion and exclusion criteria which will be used in the systematic literature review will be documented and explained. These criteria will be used such that the articles will be more relevant for answering the knowledge question.

8.3.3.1 *Inclusion criteria*

Table 14: Inclusion criteria.

Inclusion criteria	Justification
Peer-reviewed	Peer-reviewed articles are chosen because those can be considered to be more reliable and valid. Next to this, they are more accurate
Full access to article	To read the article, it is important that the article is open to access
English or Dutch articles	Since the researcher is Dutch and reads only the English language next to Dutch, it is important that the articles are Dutch or English
Year range from 2000 towards today	From the year 2000 onwards, articles are published about BPM languages.

8.3.3.2 *Exclusion criteria*

Table 15: Exclusion criteria.

Exclusion criteria	Justification
Irrelevant sources	The source should provide insights into the best option for processing modelling, if a source does not provide those insights, it will not be used
Duplicates will be deleted	When there are duplicates in multiple databases, they will only be used once
Exclude grey literature	Grey literature is excluded because it is considered to be less reliable and valid.

8.3.4 Search log

The literature search is conducted in Scopus, which is a multidisciplinary, academic database which contains a lot of journal pages which are peer-reviewed. Multiple search queries have been applied and in the following table, the number of hits and the evaluation are documented:

Table 16: Search log.

Date	Database	Query	Settings	#Hits	Ranking	Evaluation
25-03-2025 10:55	Scopus	("process modelling" OR "business process modelling" OR "process mapping" OR "process management" OR "workflow diagram") AND (language OR "modelling	Search within article title, abstract, keywords	4215	Relevance	Too much, queries will be tested with less concepts

		language" OR "notation" OR mapping OR bpmn OR uml) AND (bpm OR "workflow management" OR "business process management" OR bpmn OR uml OR "petri net")				
25-03-2025 11:02	Scopus	Process AND modelling	Search within article title, abstract, keywords	881.978	Relevance	There are way too much hits, query will be narrowed down
25-03-2025 11:05	Scopus	Process AND modelling and language	Search within article title, abstract, keywords	34.828	Relevance	There are still too much hits, so query will be narrowed down
25-03-2025 11:09	Scopus	"process modelling"	Search within article title, abstract, keywords	28.594	Relevance	There are still way too much hits, so query will be narrowed down
25-03-2025 11:12	Scopus	"business process modelling"	Search within article title, abstract, keywords	5.362	Relevance	Hits reduced a lot, but still too much
25-03-2025 11:15	Scopus	"process modelling" AND language	Search within article title, abstract, keywords	3040	Relevance	Number of hits reduced a lot, but still too much
25-03-2025 11:18	Scopus	"process modelling" AND language AND selection	Search within article title, abstract, keywords	91	Relevance	Number of hits reduced significantly

25-03-2025 11:21	Scopus	"workflow diagram" AND selection	Search within article title, abstract, keywords	6	Relevance	No relevant sources
25-03-2025 11:24	Scopus	"business process modelling" AND selection AND language	Search within article title, abstract, keywords	43	Relevance	Number of hits reduced again
25-03-2025 11:30	Scopus	"process modelling" AND selection AND language AND bpm	Search within article title, abstract, keywords	7	Relevance	Number of hits reduced again to a really low number
25-03-2025 11:42	Scopus	"process modelling" AND selection AND bpm	Search within article title, abstract, keywords	33	Relevance	Number of hits increased a bit
25-03-2025 11:49	Scopus	"process modelling" AND selection AND "bpmn"	Search within article title, abstract, keywords	37	Relevance	Number of hits increased only a bit
25-03-2025 11:55	Scopus	"business process modelling" AND selection AND bpm	Search within article title, abstract, keywords	23	Relevance	Number of hits reduced again
25-03-2025 12:08	Scopus	"process modelling" AND selection AND "bpm lifecycle"	Search within article title, abstract, keywords	4	Relevance	Number of hits reduced to a too low number, no relevance
25-03-2025 12:17	Scopus	"process modelling" AND selection AND "workflow management"	Search within article title, abstract, keywords	7	Relevance	No relevant sources
25-03-2025 12:34	Scopus	"process modelling" AND selection	Search within article	13	Relevance	Number of hits

		AND language AND ("business process management" OR bpm)	title, abstract, keywords			increased a bit
25-03-2025 12-51	Scopus	"process modelling" AND selection AND ("business process management" OR bpm)	Search within article title, abstract, keywords	61	Relevance	Numbers of hits increased again. Here, 5 good sources have been found

8.3.5 Identified sources

In the following table, the sources which are found in the literature search will be documented and there will be explained what they discuss. Next to that the APA link and short reference will be given.

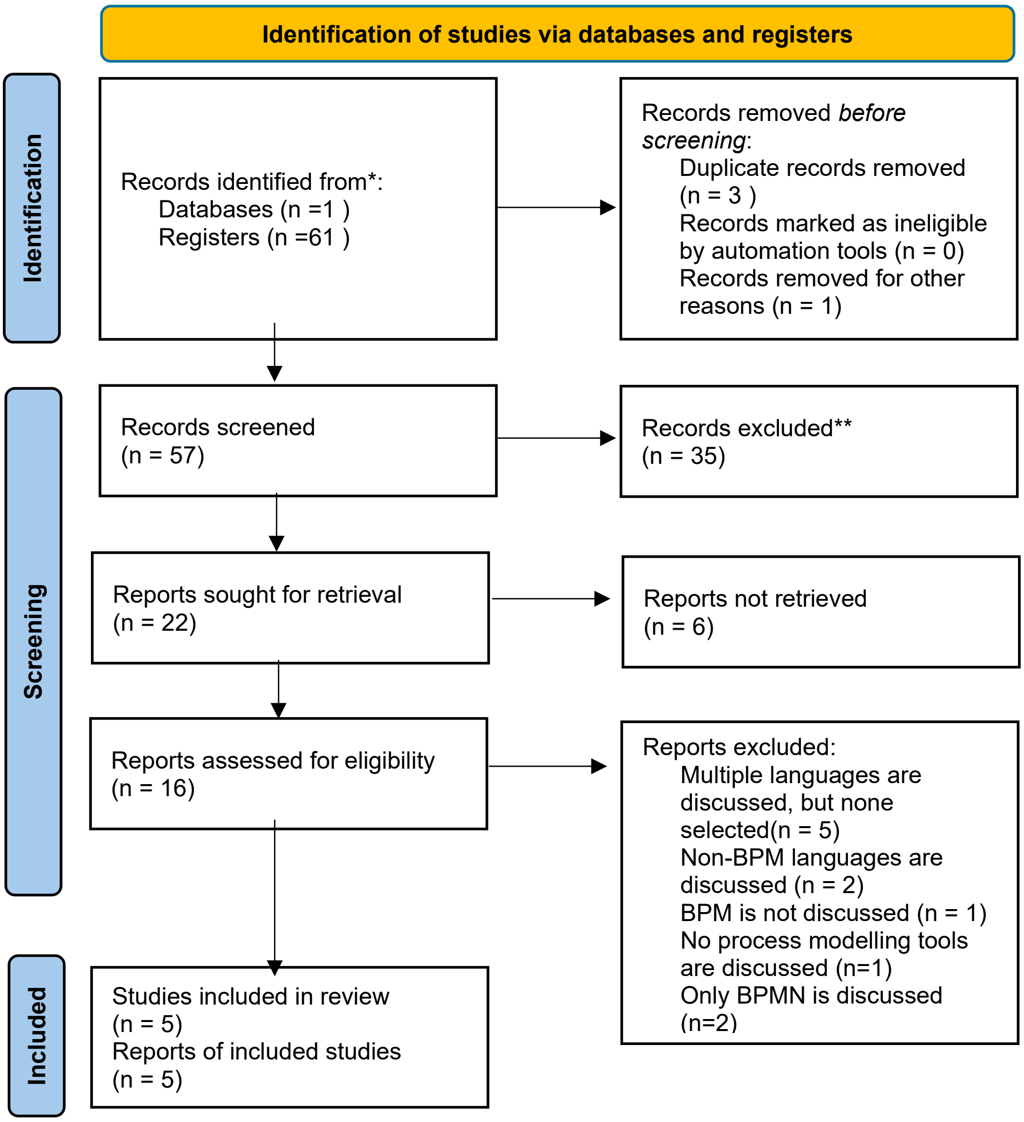
Table 17: Identified sources.

Source	Explanation	APA	Short reference
Business process modelling language selection for research modelers	This article is selected because it gives a decision model to select the best-fit BPM language	Farshidi, S., Kwantes, I. B., & Jansen, S. (2024). Business process modeling language selection for research modelers. *Software & Systems Modeling*, *23*(1), 137–162. https://doi.org/10.1007/s10270-023-01110-8	Farshidi et al. (2024)
Multicriteria framework for selecting a process modelling language	This article is selected because it compares multiple languages with criteria and chooses the best	Campos, A. C. S. M., & De Almeida, A. T. (2014). Multicriteria framework for selecting a process modelling language. *Enterprise Information Systems*, *10*(1), 17–32. https://doi.org/10.1080/17517575.2014.906047	Campos and De Almeida (2014)

A strategy based on LSP for the evaluation of specific languages for business processes modeling	This article is selected because it compares multiple languages with evaluation criteria and chooses the best.	Debnath, N., Lee, I., Salgado, C., Peralta, M., Riesco, D., Berón, M., Montejano, G., & Baigorria, L. (2012). A strategy based on LSP for the evaluation of specific languages for business processes modeling. *Journal of Computational Methods in Sciences and Engineering*, *12*(s1), S147–S160. https://doi.org/10.3233/jcm-2012-0445	Debnath et al. (2012)
Aligning the Elements of the RUP/UML Business Use-Case Model and the BPMN Business Process Diagram	This article is selected because it compares BPM modelling languages and suggests the best.	Wautelet, Y., & Poelmans, S. (2017). Aligning the elements of the RUP/UML Business Use-Case Model and the BPMN Business Process Diagram. In *Lecture notes in computer science* (pp. 22–30). https://doi.org/10.1007/978-3-319-54045-0_2	Wautelet and Poelmans (2017)
Business process modelling, implementation, analysis, and management: the case of business process management tools	This article is selected because it compares languages and chooses which language should be used as common process language	Zuhaira, B., & Ahmad, N. (2020). Business process modeling, implementation, analysis, and management: the case of business process management tools. *Business Process Management Journal*, *27*(1), 145–183. https://doi.org/10.1108/bpmj-06-2018-0168	Zuhaira and Ahmad (2020)

8.3.6 Prisma diagram

The Prisma diagram from Page et al. (2021) is used. This Prisma diagram shows how many sources were first identified. The next step is to remove the duplicates and remove the sources which are subject to the exclusion criteria. Then, the abstracts and titles are quickly screened to exclude the article which are not useful. Then, the sources which are not accessible are excluded. The reports which are left are read through to see if they can be used to answer the knowledge question. Some articles cannot be used and therefore, they need to be excluded. The reason for this is also documented. What is left are the articles which are used to answer the knowledge question.



*Consider, if feasible to do so, reporting the number of records identified from each database or register searched (rather than the total number across all databases/registers).

**If automation tools were used, indicate how many records were excluded by a human and how many were excluded by automation tools.

8.3.7 Concept matrix

A concept matrix is used to get insights into the articles which are found in the literature search. Concepts have been identified and in the concept matrix it is shown which articles contain which concepts.

The following concepts are used in the concept matrix:

1. Process modelling
2. BPM
3. Modelling language
4. Comparison between languages
5. Evaluation criteria
6. Applied to cases
7. Selects a language

These concepts follow partly from the knowledge question and the corresponding key concepts. It is important that the different languages are compared based on criteria, such that it is a fair comparison. It is also good when the theory in the articles is applied to cases because it shows how the theory can be used best. The most important concept of the article should be that it selects a language which can be used best.

Table 18: Concept matrix.

Selected article	Process modelling	BPM	Modelling language	Comparison between languages	Evaluation criteria	Applied to cases	Selects a language
Farshidi et al.(2024)	X	X	X	X	X	X	X
Campos & De Almeida (2014)	X	X	X	X	X	X	X
Debnath et al.(2012)	X	-	X	X	X	X	X
Wautelet and Poelmans (2017)	X	X	X	X	-	-	X
Zuhaira and Ahmad (2020)	X	X	X	X	X	-	X

8.3.8 Conclusion

Farshidi et al. (2024) concludes that it makes more sense for academics to argue why they did not select BPMN rather than discussing why they did choose BPMN for process modelling. They did compare multiple BPM languages and found that BPMN covers the most BPM modelling features. Those features include communication, analysis, enaction, functionality and a lot more. Campos & De Almeida (2014) compare the languages UML, EEML and BPMN. From the comparison, it could be concluded that UML and EEML are suitable languages, but that BPMN is classified as most suitable. Debnath et al. (2012) rank multiple processing languages based on LSP, which stands for Logic Scoring of Preferences. When ranking the alternatives, it came out that BPMN scored the best. Following that, the authors concluded that BPMN is the best language for modelling business processes at a competitive level. Wautelet and Poelmans (2017) compare RUP/ UML Business Use Case Models and BPMN. For multiple elements, they investigate the alignment between RUP/ UML and BPMN. Their conclusion is that BPMN can be used better than RUP/ UML at operational level. Zuhaira and Ahmad (2020) evaluate multiple languages. Based on the scores from the comparison, they conclude that BPMN should be retained as common process language to support the principle of joint understanding.

To conclude from these articles, it is clear that BPMN should be chosen as the BPM language to model the processes. Some articles highlighted that BPMN is already the most standard language to choose, but they wanted to do research because it is not the case that standards are always the best option. However, the articles show that there are good reasons for choosing BPMN as process modelling language.

With that being said, the answer to the knowledge question is that BPMN should be uses BPM language for process modelling. BPMN will be used to model the current process and the improved valuation process for this project.

8.4 Appendix D: Research design

Table 19: Research design.

Research question	Type of research	Research subject	Data gathering type	Data gathering method	Data analysis method	Deliverable
What is a clear and relevant implementation plan to structure the container valuation process such that the value accuracy is improved and cycle time is reduced?						
RQ-1: What does the current valuation process model look like?	Descriptive	Employees	Qualitative	Interviews and observations	Make a process model	Process model of current valuation process
RQ1-S1: Which BPM language can be used best for process modelling, based on literature?	Evaluative	Literature	Qualitative	Literature search	Compare alternatives	Choice for BPM language
RQ-2: What is the accuracy of the valuation	Evaluative	Database Employees	Quantitative & qualitative	Old valuations of machines in SAP Interviews & observations	Compare re-calculation to value in SAP	Trade-off between calculations
RQ-3: How much time does the valuation take?	Evaluative	Database Employees	Quantitative & qualitative	Interviews & observations	Make a time scheme of the process	Time scheme of the process
RQ-4: What should the new valuation process model look like, based on literature?	Exploratory	Database Employees Literature	Qualitative	Search in database for relevant information for the to-be process Literature search for improvements	Make a process model of the to-be process	Process model of the new valuation process
RQ-5: How should the new valuation process be executed?	Exploratory	Employees	Qualitative	Employee interview about to-be process model Expert feedback Literature search	Use feedback from employees to know what needs to be done in order to make the to-be process model work	List of activities Implementation plan

8.5 APPENDIX E: BPMN MODEL OF CURRENT PROCESS

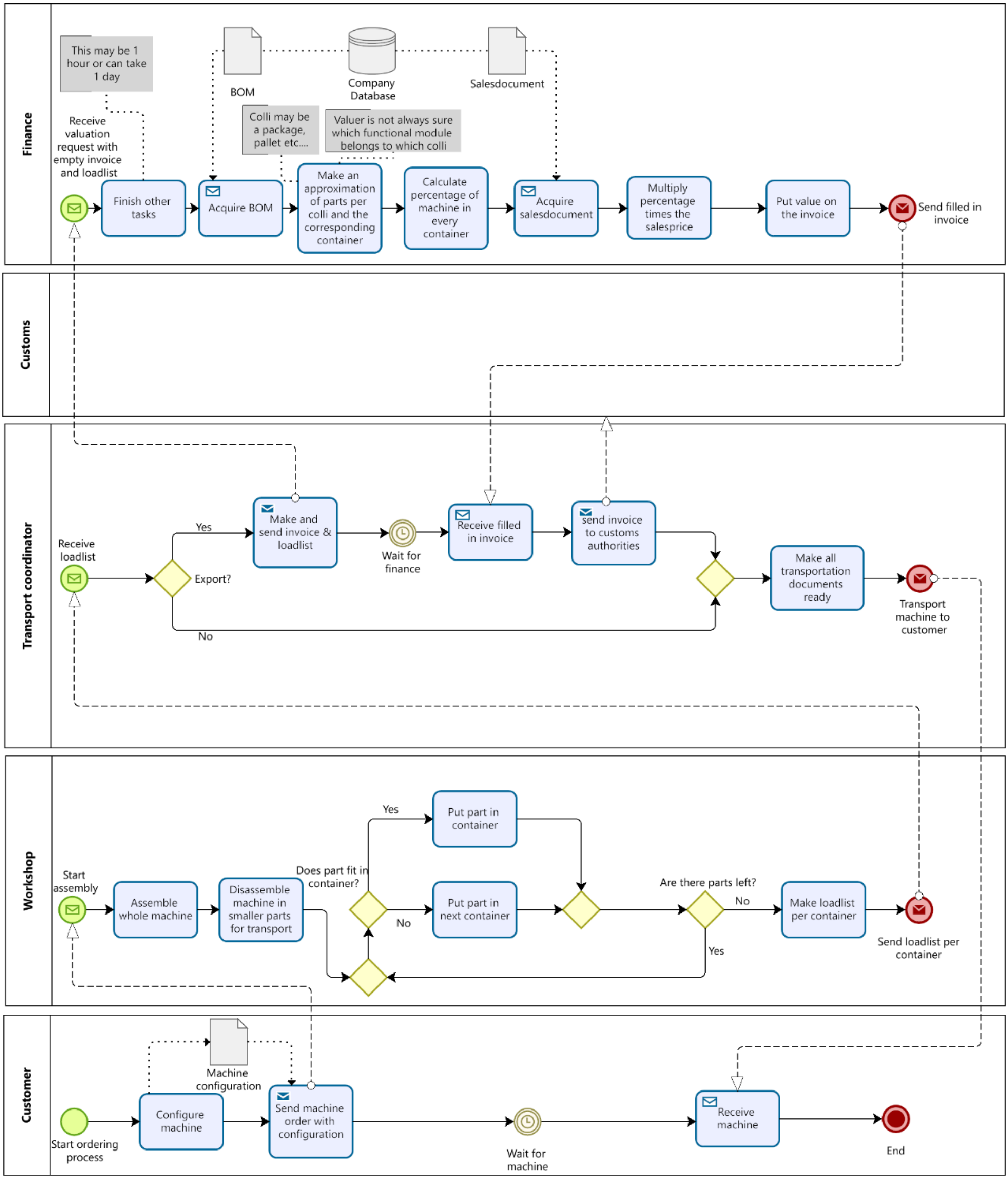


Figure 11: Enlarged version current BPMN model.

8.6 APPENDIX F: BPMN MODEL OF THE TO-BE PROCESS

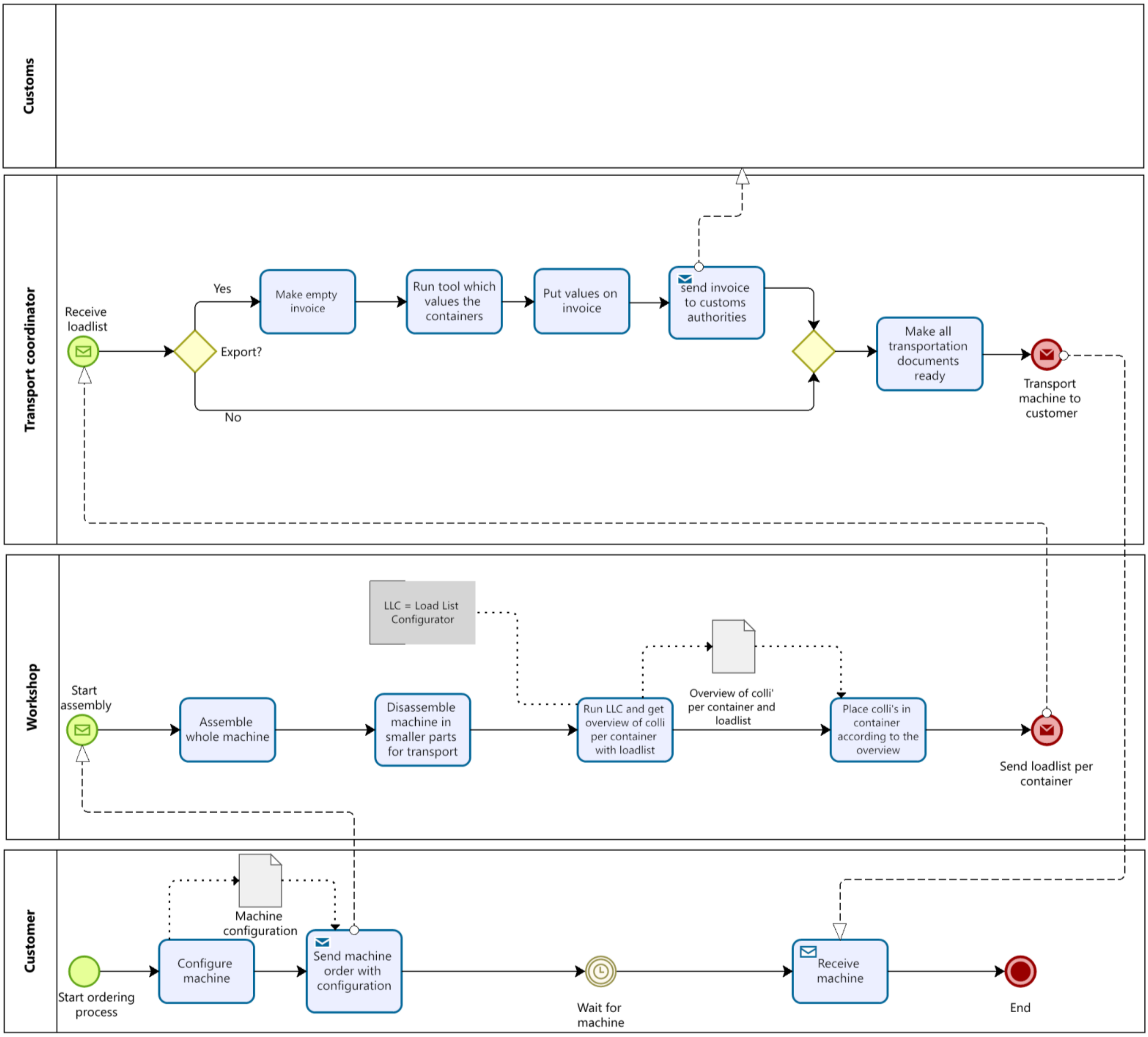


Figure 12: Enlarged version of the to-be process model.

8.7 APPENDIX G: COST-BENEFIT ANALYSIS

Since the company already uses excel, there are no additional costs when implementing the tool in excel. Therefore, the cost-benefit analysis is solely based on employee costs. The waiting time for is not used in the analysis, since employees can perform other tasks then.

Average yearly costs

The average yearly costs of employees consist of salary and overhead costs. The following costs are the sum of the salaries, and the overhead costs of the employees involved:

- Transport coordinator: €74,695.56
- Finance employee: €78,144.78
- CTO employee: €83,936.64

On average, in the Netherlands, employees work 41,3 weeks per year (Schulte Nordholt & Centraal Bureau voor de Statistiek, 2005).

With that, the number of hours and minutes worked per year can be calculated:

$$40 * 41.3 = 1{,}652 \text{ } hours\ per\ year$$

$$1652 * 60 = 99{,}120 \text{ } minutes\ per\ year$$

Since the processing time of the redesigned process is 7.04 minutes, the costs for executing the valuation by the transport coordinators are:

$$\frac{7.04}{99{,}120} * €74{,}695.56 \approx €5.31$$

Calculated in the same way, the costs for executing the original valuation process by the finance employee are:

$$\frac{1.0133}{1{,}652} * €78{,}144.78 \approx €48$$

Per valuation, approximately €42.5 is saved by implementing the redesigned process. This is a reduction of almost 90% per valuation.

Based on the transport data from 2024, 83 shipments are sent to non-EU countries and therefore need an invoice.
With that, the costs saved per year are calculated as follows:

$$42.5 * 83 = €3{,}527.5 \text{ } per\ year$$

The development costs for the valuation tool are also based on employee costs. The CTO department will further expand and complete the tool before implementing it. The expectation is that one employee of the department will need one week of full-time work to complete the tool. This implies that it will take 40 hours.

The development costs are then calculated as follows:

$$\frac{40}{1{,}652} * 83{,}936.64 \approx €2{,}032.36$$

The costs for maintaining the performance of the tool are based on employee costs as well. The CTO department will maintain the tool and ensure that the correct factors are used in the calculation. The factors are based on the price list which is estimated to be updated once every month. It will take approximately 1 hour to update the factors. The costs for maintaining the valuation tool are calculated as follows:

$$\frac{12}{1,652} * €83,936.64 \approx €610$$

Net savings in the first year: $€3,527.5 - €2,032.36 - €610 = €885.14$
Net savings in subsequent years: $€3,527.5 - €610 = €2,917.5$