28 JUNI 2021

Faculty of Behavioural, Management and Social Sciences

BSc Industrial Engineering & Management

DESIGNING THE CURRENT ERP SYSTEM OF GIETART KALTENBACH

LISA NONHOF

S2132451

UNIVERSITY OF TWENTE.

GIETART KALTENBACH GROUP

Bachelor thesis Industrial Engineering and Management

Designing the Current ERP System of Gietart Kaltenbach

Author:

L.G. Nonhof (Lisa)

l.g.nonhof@student.utwente.nl

University of Twente
BSc Industrial Engineering and Management
Postbus 217
7500AE Enschede
Tel. (053) 489 9111

Gietart Kaltenbach
Gietart Hengelo
Pruisische Veldweg 20
7552AC Hengelo
Tel. (074) 245 2452

First supervisor University of Twente
P.C. Schuur (Peter)

Supervisor Gietart Kaltenbach
S. Toxopeus (Stephan)
CEO

Second supervisor University of Twente
B. Gerrits (Berry)

Preface

Dear reader,

In front of you lies my bachelor thesis 'Designing the Current ERP System of Gietart Kaltenbach'. This research has been executed at Gietart Kaltenbach as a graduating assignment for my bachelor Industrial Engineering and Management at the University of Twente. I worked at Gietart Kaltenbach from February 2021 till July 2021. This thesis aims on improving the ERP design so it provides the correct and reliable data for the business processes.

First of all, I would like to thank Gietart Kaltenbach for giving me the opportunity to come to the company in these extraordinary circumstances. A special thanks to my supervisor Stephan Toxopeüs, who guided me through the research. Without his extensive feedback and his patience, I would not have been able to write this thesis. Moreover, I would like to thank Stephan Toxopeüs, Stefan Kok, Bert Breukelman and Floor Veuger for the weekly meetings, where we had interesting discussions. I have gained a lot of insights and I am very grateful for that.

I would also like to thank Peter Schuur, my supervisor from the University of Twente. He provided me with extensive and clear feedback, which helped me improving my thesis a lot. He was also engaged with my wellbeing during the research, which was very pleasant. I enjoyed working with you. I would also like to thank Berry Gerrits, my second supervisor from the UT, for checking the quality of the research.

I also want to thank all my colleagues at Gietart, especially the Engineering department, who supported me during the research. I experienced working at Gietart Kaltenbach as very pleasant, where I was welcomed with open arms. Thanks to everyone who was willing to help and answer any question I had.

Also, a special thanks to Ceret van der Vegt, my buddy during the research. Thanks for the support and feedback during the research. We kept each other motivated during the research.

I hope you enjoy reading this thesis and it provides new insights.

Lisa Nonhof

June 2021

Management Summary

Gietart Kaltenbach designs, engineers and produces several types of shot blasting machines for steel service treatment. These machines are used to remove the unwanted corrosion and the metallic waste on finished goods (Sikka, 2021).

Motivation

The reason behind this research is that Gietart is not able to give reliable information to the customer regarding the progress and the cost price of the project. This is caused by shortcomings on three different aspects. The first shortcoming in the current situation is that Gietart is not able to realize and use an accurate project planning. The second shortcoming is that the current cost price model and cost allocation are outdated and do not match the structure of the organisation. It is unknown whether the cost price of a project covers the total costs. Therefore, Gietart Kaltenbach has no insight in the profitability of the project types. The third problem is the absence of a clear pre-calculation and post-calculation method.

Research Question

Following the Heerkens method (2017), the following core problem is found: 'The ERP does not provide the correct/reliable data'. Solving this problem supports Gietart in achieving the earlier defined goals. Therefore, the main research question addressed during this research is formulated as follows: '*To achieve its defined goals, which criteria must Gietart's ERP meet regarding the design and working method?'.* The three goals of Gietart Kaltenbach are:

1. To realize a project planning.
2. To design a transparent cost price model, where the price of the customer specific options can easily be determined.
3. To be able to realize an accurate pre-calculation and post-calculation, which can be compared.

Methods

To answer the main research question, several methods are used throughout the research. At the start of the research, we conducted a context analysis in order to understand the situation in the company better. Through qualitative research, we were able to gain more insight into the current situation and the shortcomings regarding the ERP, the project planning, the cost price model and the pre/post-calculation. These shortcomings translated into a desired situation of the planning, the cost price model and the pre/post-calculation. To fulfil the desired situation for these processes, a list of requirements/criteria for the ERP was set up. In this research, we already elaborated on several criteria, such as the production order structure and settings in the ERP. In order to test whether the new design of the ERP solves the core problem, a quantitative analysis into the process times of all production orders of the Sprint ECO is performed.

Results

At the start of this research, the list of requirements/criteria was considered the main deliverable. Table 1 shows the end list of requirements/criteria the ERP must meet in order for Gietart to achieve its goals.

Table 1: List of requirements/criteria of the ERP

Criterion nr.	Criterion name
1.	**Defining one production order structure for all projects**
	It must be possible to implement the production order structure for all types of projects. There must be only one production order structure.
2.	**Defining the module level within the production order structure**

	The module level within the production order structure must balance the level of detail and the effective steering level. This structure must support both the planning and cost price model. The module level must be based on the concept 'the highest manageable unit'.
3.	**Determining relevant departments and tasks in the ERP**
	The departments and tasks implemented in the ERP must match the ones on which both the planning and the cost price model are based. Having a clear structure in the departments and tasks prevents the fragmentation of the manhours.
4.	**Receiving accurate manhours on the post-calculation by the ERP**
	The ERP must provide accurate manhours of the measurable production tasks on the post-calculation of each production order.
5.	**Receiving a clear cost overview of a project by the ERP**
	The ERP must provide a clear pre-calculation and post-calculation. These calculations must be easily comparable, which implies that the structure of the pre-calculation and the post-calculation must be similar. It is important that the pre-calculation and the post-calculation provide insight into the important (estimated) cost types. The structure of the calculations is based on the cost components implemented in the ERP. That is why, there must be a clear and relevant list of cost components.
6.	**Registering the manhours of unforeseen activities separately**
	There must be task available in the ERP, on which unforeseen activities can be registered. These manhours must not be registered on a production task. It must be clear on the post-calculation that some deviations in manhours must not have influence on the pre-calculation.
7.	**Implementing accurate hour rates in the ERP**
	The hour rates of the departments, machines and employees must cover the total costs. These hour rates must cover all costs for that specific task/department including indirect costs such as rent, depreciation and electricity. The way the costs are allocated, and the hour rates are retrieved, must match the structure of the organisation.
8.	**Receiving accurate WIP and backlog by the ERP**
	The ERP must give input for an accurate work in progress (WIP) and backlog. Gietart wants to be able to communicate the WIP and the backlog to customers and within the company.

Recommendation

In order to successfully implement the new ERP design, the following most important actions are recommended:

1. In order to receive accurate and reliable data from the ERP, it is recommended to design the ERP taking the defined list of requirements into account.
2. The new production order structure must be the basic engineering method. All the employees must understand this new production order structure.
3. The cleaned-up new list of departments, tasks and cost components configured during this research needs to be implemented into the ERP. It is important that the 'old' tasks/departments/cost components numbers are reused as much as possible.
4. During the research a quantitative analysis into the process time of each testable production orders was executed. It is important to test the ERP when the complete list of requirements/criteria is considered and implemented. It is important to test whether the data provided by the ERP is accurate and reliable after the adjustments are made. This can be done by comparing the data provided by the ERP with the quantitative analysis.

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Reader's Guide

Chapter 1: Introduction & Problem Identification

This chapter introduces the company at which this research is conducted. Moreover, the motivation behind the research is discussed, the problem of the company is identified and the relevance of this problem is explained. Furthermore, it elaborates on the change management, since this research has a great impact on the organisation. This chapter elaborates on the why, the how and the what of the research.

Chapter 2: Process Gietart Kaltenbach analysis

This chapter serves as background information for this research. In order to understand this research, it is important to understand the processes and the transition phase Gietart is currently in. This chapter also introduces several concepts, which are used throughout the research.

Chapter 3: Current Situation Analysis

In this chapter the current situation around the bill of materials, the ERP, the project planning, the cost price model and the pre/post-calculation is discussed.

Chapter 4: Desired Situation Analysis & List of Requirements

In this chapter the desired situation regarding the project planning, the cost price model and the pre/post-calculation is discussed. This chapter results in a list of requirements/criteria the ERP must meet. This list is the framework and main deliverable of this research.

Chapter 5: The Design of the ERP

This chapter addresses the new design of the ERP. It proposes and explains several adjustments in the ERP. It elaborates on the new production order structure, the BOM and the settings in the ERP.

Chapter 6: Estimation of the process times

This chapter includes a quantitative analysis of the process times of each testable production order. It is used for the evaluation of the data the new designed ERP provides.

Chapter 7: Evaluating the ERP design by assessing the list of requirements

In this chapter the design of the ERP (Chapter 5) is evaluated by using the list of requirements/criteria (Chapter 4). It evaluates whether the proposed design meets the defined criteria.

Chapter 8: Conclusion & Recommendation

In this chapter the conclusion and recommendations are presented. Furthermore, suggestion for further research is made. Besides, a discussion of the limitations of the research is made. It answers the main research question.

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List of Acronyms and Definitions

Several abbreviations are used throughout this research report.

Abbreviation	Definition	Section
Backflush	Method of cost allocation	3.5 Pre-calculation and post-calculation
BOM	Bill of materials	3.1 Bill of materials CAD
BPMN	Business Process Model and Notation	Appendix C – Business Process Model & Notation
Contribution margin	$Contribution\ margin = selling\ price - variable\ cost$	4.4 Coming to the end list of requirements/criteria
CODP	Customer Order Decoupling Point	1.1 Company description
ERP	Enterprise resource planning	3.2 The Enterprise Resource Planning (ERP)
MRP	Material requirement planning	2.4 Transition from stock to demand (inventory)
PDCA cycle	The Plan, Do, Check, Act cycle is a four-step model for carrying out change (ASQ, 2021).	3.5 Pre-calculation and post-calculation
PERT	Program Evaluation and Review Technique	Chapter 6: Estimation of the process times
Process time	The time to produce a unit at a workstation.	4.1 Planning
SIC	Statistical Inventory Control	2.4 Transition from stock to demand (inventory)
Surface treatment area	The production step where the semi-finished are painted (Heizer, Render, & Munson, 2017).	2.1 Process flow
Throughput time	The time it takes for a product to go through the production process with no waiting (Heizer, Render, & Munson, 2017).	3.3 Project planning
WBS	Work breakdown structure	5.2 Production orders

Table 2: Definitions of abbreviation

Chapter 1: Problem identification

This research is conducted as a bachelor thesis during a five-month internship in cooperation with Gietart Kaltenbach. This chapter focuses on the identification of the core problem within Gietart Kaltenbach. First, we find more out about the company the research is conducted. Then, the problems Gietart is dealing with are identified, which result into a core problem. This core problem is translated into a main research question with its corresponding sub research questions. To answer the research question, the problem-solving approach is explained. Lastly, the validity and the reliability of this research is discussed.

Sections:

1.1 Company description

Gietart Kaltenbach is a company that designs, engineers and produces shot blast machines for steel service treatment. The production site, which is located in Hengelo, has around 20.000 m2 and ninety employees. Gietart produces three basic kinds of shot blast machines: the Sprint, the Marathon and the Triathlon.

- The Sprint is the most standard shot blast machine that Gietart produces. There are a few different versions of the Sprint. However, for this research the focus is on the Sprint ECO, which is the most suited machine for shot blasting of tubes, profiles and sheet materials. The Sprint has the basic technique and this technique is also the basis of the Marathon and the Triathlon.
- The Marathon is larger than the Sprint and consists of larger turbines, which results in a higher throughput.
- The Triathlon is the largest machine that can be produced at the production site in Hengelo. The Triathlon distinguishes itself from the Sprint and the Marathon in functionalities. Where the Sprint and the Marathon are only able to shotblast tubes, profiles and blasts, is the Triathlon able to shotblast complete constructions.

Currently, Gietart Kaltenbach is in a transition phase from an 80% Make To Stock in combination with 20% Engineer To Order to an 80% Configure To Order and 20% Engineer To Order. Therefore, the customer order decoupling point will shift more to the upstream (left) and more activities will be on the right side of the CODP. This means there will be in an increase in the number of activities that start when an order is issued and the inventory control will be based on the Just in Time principle. This implies that the production will be project-based, so only producing after receiving a customer order instead of producing to stock in the warehouse. The 20% Engineer To Order ensures that the customer is able to adjust the machine to its preference. For each order a special design of the machine is created. The customer has multiple customer specific options, which increases the standard price of the machine. Thus, the machine is partly customizable.

1.1 Reason for research

In the current situation, Gietart Kaltenbach is not able to give reliable information to the customer regarding the progress of the particular project. They are not able to determine an accurate backlog or delivery time, since the data provided by the ERP is unreliable. When the customer asks for this information, a rough estimation is made. The problem is that Gietart lacks a holistic overview. Therefore, the ERP should provide an overview of the progress and details of the ongoing projects.

This problem is translated into an action problem. An action problem is a discrepancy between the norm and the reality, as perceived by the problem owner (Heerkens, 2017). The action problem is stated as follows:

Gietart is not able to communicate relevant information regarding the project to its customers.

1.3 Goal of the research

This research is conducted in cooperation with two other interns, where the focus of their research are on the project planning and the hour rates. The goals that Gietart wants to achieve with this complete project are as follows:

1. To realize a project planning.
2. To design a transparent cost price model, where the price of the customer specific options can easily be determined.
3. To be able to realize an accurate pre-calculation and post-calculation, which can be easily compared.

The goal of this specific research is to design the ERP system, so it provides support for achieving those three stated goals. This research forms the basis for achieving the three stated goals.

1.4 Problem Statement

In general, a company is dealing with several problems at once, which is called the problem context. Usually there is not enough time or money to solve all these problems at once (Heerkens, 2017). In this chapter several problems are discussed and the core problem for this research is decided.

1.4.1 Problem context

The main problems Gietart is currently dealing with are:

1. The cost price model and the cost allocation Gietart currently is using is inaccurate.
2. Gietart is not using a planning tool to make a project planning. Currently, the work preparation department is making manually a weekly production overview in Excel, which is based on experience rather than calculations.
3. The ERP does not provide support for the project planning, the cost price model and the pre/post-calculation. It does not provide the correct and accurate data.

Gietart is using two software programs as its main system: CAD and the ERP system BaaN. In the ERP all information regarding the complete process is stored and available for employees. However, the data regarding the processing time for each task is based on experience rather than facts. This means that the time a specific part of the machine needs, is undetermined. Furthermore, Gietart is not using a tool or software to create a production planning, which results in a lack of a holistic overview.

Another problem is that the process times of each task during the production is not monitored correctly, which makes it difficult to assign the costs correctly. Since, this overview is missing it is not possible to realize a correct post-calculation. Furthermore, currently there is no analysation process between the post-calculation and the pre-calculation. This implies that when a specific process part is more expensive, the pre-calculation for the next order immediately changes to the costs of the previous order. The lack of reliable processing times also influences the planning. Since, the time for each production task is unknown, it is difficult to make an efficient production planning.

The planning is also connected to the pre-calculation and the post-calculation. When the planning is not efficient and reliable, the production times and cost price directly influence the final cost price. More deviations between the pre-calculation and the post-calculation will occur. As a result, that Gietart is not able to give an exact delivery time indication to its customers.

A must for creating a reliable production planning and cost price model is reliable data. Without the correct and reliable data, it is difficult e to create a reliable planning and determine an accurate cost price. In the current situation, the ERP does not provide this correct and reliable data.

1.4.3 Problem cluster

Figure 1 shows the problem cluster for this specific research only. It starts with the fact that the process times are not accurate, since they are based on experience rather than facts. These inaccurate process times are entered in the ERP system. Moreover, the production orders as input of the ERP are chosen incorrectly, since they are not in line with the production. As a result, that the ERP system does not provide the correct data on which the production planning and the cost price model are based. Therefore, the cost price of the shot blasting machines is currently unreliable, which results in an inaccurate pre-calculation to the customers. Furthermore, since Gietart is currently unable to make a reliable production planning, the delivery time which is contacted with the customers is also inaccurate.

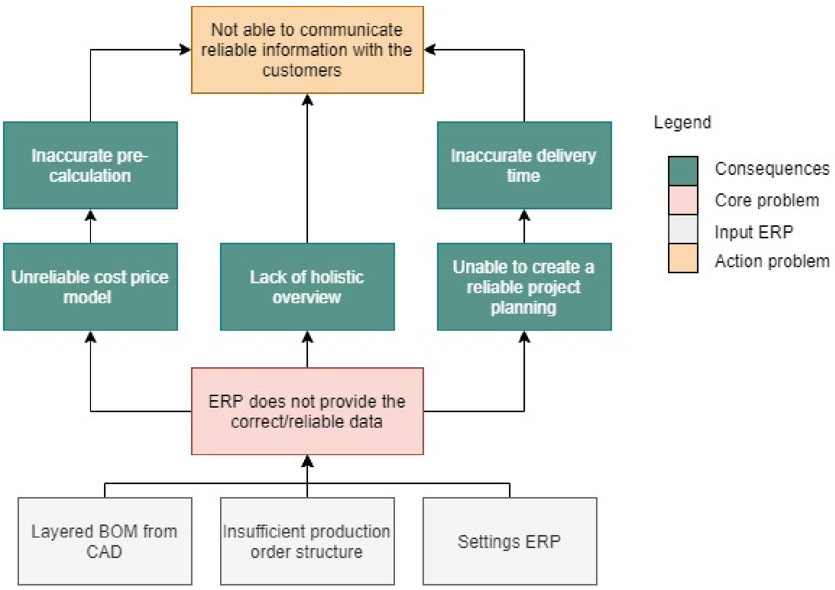


Figure 1: The Problem Cluster, where the red block represents the core problem.

1.4.4 Core Problem

Core problems are those whose solution will make a real difference (Heerkens, 2017). Since the complete project is done with three interns, three core problems are chosen.

First core problem: 'Absence of a project planning'.
The first problem is regarding the project planning. Currently, Gietart is making a weekly schedule in Excel, which is completely based on experience instead of actual data. This makes the schedule

inefficient and flexible. The planning is not able to automatically adjust based on priorities of projects or sub-assemblies.

Second core problem: 'Inaccurate cost price model and cost allocation'.
Currently, Gietart is using an inaccurate cost price model and cost allocation to determine the cost price of a project. The hour rates for each production task are outdated.

Third core problem: 'ERP does not provide the correct/reliable data'.
The core problem on which this research will focus is that the ERP system does not provide the correct and reliable data. It focuses on the lack of a structure in the ERP system that supports the business processes such as the production planning and the cost price model. It does not provide the data that is wished to perform successfully on these processes. Therefore, the core problem for this research is stated as follows:

The ERP does not provide the correct/reliable data.

This problem is chosen as core problem for this research, since this solution will have the greatest impact. The solution of this problem will also form the basis on which the planning, the cost price model and the pre/post-calculations are based on.

If this is translated in terms of norm and reality, it can be stated that in the current situation the ERP does not support Gietart in achieving its goals and in the desired situation the ERP system does support Gietart. Currently, the ERP does not provide correct/reliable data. In the desired situation the ERP will provide data that displays the reality and supports the business processes. The norm is determined by drafting a checklist with requirements the new ERP design must comply with. The company does not have insight in the current ERP design.

1.5 Scope of the research

To secure the feasibility of this research, the scope is determined. The limiting factor is the available time.
First, the research focuses on only one machine type: the reference machine. In this research the reference machine is the Sprint ECO. The Sprint ECO is a newly introduced machine on the market and is the future bestseller of the Sprint. The focus during this research is not on the machines Marathon or the Triathlon.
Second, due to the complexity of the research, this research does not focus on the last two steps of the problem-solving approach. The implementation and the evaluation of the ERP design are not in the scope of this research. The purpose of this research is to provide a recommendation about the ERP design and the working method. We create a list of requirements/criteria for the ERP. During this research, we elaborate on some of these criteria. Gietart is responsible for the implementation and evaluation of the defined criteria. However, the recommendation includes the aspects Gietart needs to focus on during the implementation of the new ERP design.
Third, this research only focuses on the ERP design and its working method. In the report, the current situation and desired situation of the cost price model, the production planning and the post-calculation with the pre-calculation are briefly discussed. This research does not include designing a transparent cost price model or creating a production planning. These researches are executed simultaneously. Only the results of these research are taken into account.

1.6 Problem Solving Approach

In this research the Managerial Problem-Solving method is used to answer research question. The MPSM is one of several systematic problem-solving approach and is applicable in various problems in all areas of expertise (Heerkens, 2017). Defining the core problem, the first phase of MPSM, has already been conducted and is discussed in previous sections. Due to the complexity of the current ERP design and process, the understanding the process is a phase that is carried out during the complete research. However, it is necessary to understand the process broadly to determine the core problem.

Phase 2: Formulate the approach

Figure 2 shows the problem-solving approach used during this research.
The step after understanding the process and defining the problem, is to formulate the approach. In this phase it is explained how the research is conducted: the steps taken to transfer the problem into a solution.

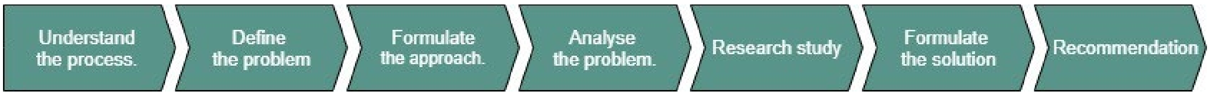


Figure 2: The Managerial Problem-Solving method

First, for all three goals several requirements are determined. The next step is to translate these requirements into criteria for the ERP. Thus, to achieve each goal, a list of criteria for the ERP is formulated. Third, a comparison between these criteria is made and when necessary, the criteria are prioritized. This results in an end list of criteria the ERP must comply with. It is important for implementing the new design successfully that principles of change management are considered.

Phase 3: Analyse the problem

To be able to solve the problem successfully, it is important to have a complete understanding of the problem. An extensive analysis of the problem is conducted to gather complete insight into all the details regarding the problem. This analysis includes observation, documentation, quantitative analysis, qualitative analysis, calculations and comparisons. For each sub question the research methods is defined
During this research, a systematic literature review is performed to gather literature which supports the research. This literature review focuses on change management. Since, this research provides a recommendation about the design and the working method of the ERP, it is important that employees are willing to work according to the new method. The literature research on change management provides an approach which prepares and supports employees in making an organizational change.

Phase 4: Formulate (alternative) solutions

During the research important trade-offs, including their pros and cons, are described. These trade-offs can be seen as alternative solutions.

Phase 5: Formulate the solution

In this phase, all the criteria for each aspect of the ERP are gathered. These criteria are compared to each other. When there are conflicting criteria, priority rules are set up in cooperation with the stakeholder. This results in a cleaned-up list with criteria the design and working method of the ERP must comply with.

Phase 6: Evaluation

The main delivery of this research is a recommendation about the structure, design and working method of the ERP. First, a set of structure rules is created on which the design should be based. Second, a working method for the new ERP design is made, to ensure that the employees know how to work with the new design. It will be a guideline for the employee in which the differences and its consequences are also explained. The structure set is assessed by a predefined checklist. It assesses whether the recommendation is in line with the requirements stated by the organization.

1.7 Research Design

The core problem stated in section 1.4.4 translated into the following research question:

To achieve its defined goals, which criteria must Gietart's ERP meet regarding the design and working method?

As stated in section 1.3 the goals of Gietart are:

1. Designing a transparent cost price model where the customers' options can easily be added and deleted.
2. The pre-calculation must be tested against the post-calculation.
3. Realising a resource/capacity planning.

The goal of this research is to answer this question. In other words, a set of objectives are set up to enable Gietart to implement the project planning, the cost price model and the pre/post-calculation. The sub questions are stated below and are used to support the research question. First, some information is gathered around the business processes to get an understanding of the company. The second, third and fourth sub questions focuses on formulating a list of criteria for achieving each of the three goals. Each sub question focuses on accomplishing one specific goal.

1. **What is the structure of the reference shot blasting machine?**

    1.1 What is the functional structure of the reference machine?

    1.2 How is the business/production process structured?

    1.3 What are the customers' specific options?

    1.4 What is the structure of the bill of material in CAD-Creo?

    1.5 What is the structure of the bill of material in the ERP?

The first sub question is answered by qualitative research: documentation, observation and interviews with employees of Gietart. The purpose of these questions is to provide insight into the final product and the process of creating it. This is a descriptive research.

2. Which criteria must Gietart's ERP meet regarding the design and working method in order to design a transparent cost price model?

    2.1 How is the cost price model currently designed?

    2.2 What are the requirements for the design of a transparent cost price model, where customers' options can easily be added and deleted?

    2.3 What are the criteria for the ERP design to fulfil these requirements?

This sub question focuses on the requirements needed to achieve the first goal. Through documentation, observation and theory this question is answered. It provides insight into the ideal ERP design when only the cost price model is considered. It is a quantitative research, since data analysis are executed to gain insight into the current data. The main research population is the Finance department and the CEO.

3. Which criteria must Gietart's ERP meet regarding the design and working method in order to test the pre-calculation against the post-calculation, where the options are recalculated?

    3.1 How are the pre-calculation and the post-calculation currently calculated?

3.2 What are the requirements for determining and recalculating the cost price and the price of customers' options?

3.3 What are the criteria for the ERP design to fulfil these requirements?

This sub question focuses on the requirements needed to achieve the second goal. This sub question is also answered by documentation, observation and literature. It provides structures rules for the design of the ERP when only the pre-calculation and the post-calculation is considered. The main research population is the Finance department and the CEO.

4. Which criteria must Gietart's ERP meet regarding the design and working method in order to realize a project planning?

4.1 How is the project planning currently created?

4.2 What are the requirements the project planning must meet?

4.3 What are the criteria in the ERP for fulfilling these requirements?

This sub question focuses on the requirements needed to achieve the third goal. This sub question will also be answered by documentation, observation and theory. It will provide structures rules for the design of the ERP when only the production planning is considered. The main research population is the operations manager and the production employees.

5. What are the priorities of the criteria?

5.1 Which criteria are conflicting?

5.2 How can the conflicting criteria be adjusted in such a way that it still supports achieving the goal?

This sub question compares the finding criteria and determine compromises when necessary. Through comparison and observation this question will be answered.

6. What are important principles of change management for implementing a new working method in the main software in an industry company?

The literature research on change management provides an approach which prepares and supports employees in making an organizational change.

1.8 Theoretical Framework: Principles of Change Management

A systematic literature review is conducted to answer the following question:

What are the important principles of change management?

There are two important principles to remember regarding change management according to Anderson and Ackerman (2002):

1. The key drivers during a transitional change in the organization are the mindsets of the leader and employees.
2. Organizational transitions are a more comprehensive, continuous process rather than a short term, one time step.

John Kotter has, after several years of experience in consulting van organizations, developed a three-step framework for leading change (Kotter, 1992):

1. Defrost the status quo.
    a. Establish a Sense of Urgency
    b. Create the Guiding Coalition

   c. Develop a Change Vision
   d. Communicate the Vision for Buy-In
2. Take actions that bring about change.
   a. Empower Broad-Based Action
   b. Generate Short-Term Win.
   c. Never Let up
3. Anchor the changes in the corporate culture.

Defrost the status quo
The first stage, 'Defrost the status quo', consists of four steps.

The first element is 'To Establish a Sense of Urgency'. Many leaders skip this critical step, since they believe that employees are already convinced of the urgency when it is just presented. As a result, that the efforts form employees decrease rapidly. It is important that the management is able to make the employees believe that the current situation is more dangerous than the risks this change might cause. According to John Kotter (1992), at least 75 percent of the employees should be convinced of the urgency in order to succeed. A way to increase the sense of urgency is to identify with a key group of people about all the factors involved and brainstorm about the way to counter each specific factor. Then, it is important to develop an action plan in which all the necessary steps are determined to implement the ideas. This ensures that the reasons behind the change and the objectives for the change are clear, which is according to Ian Palmer (2002) an important aspect for the success of the change.

The next step is 'To create the Guiding Coalition'. For an organizational change to succeed, it is important that a group of leaders is dedicated to lead the organization through the change successfully. This group needs to radiate influence and power, since they need to deal with resistance. Creating a strong guiding coalition can be a difficult task. Therefore, in general the following three key principles are considered:

- The most effective partners usually have strong position power, broad experience, high credibility and real leadership skill (Kotter, 1998).
- The guiding coalition must encompass all perspectives; a diverse group of people to ensure all views and voices are considered.
- It is important that the guiding coalition is working as a team and not as a collection of individuals; real teams are built on sharing a vision and commitment to a goal (Kotter, 1998).

The third step is 'To Develop a Change Vision', which includes making sure that a clear direction to the future is pictured. This direction does not include a detailed time plan, it demands a tolerance for messiness, ambiguity, and setbacks, an acceptance of the half-step back that usually accompanies every step forward (Kotter, 1998). An effective change vision consists of briefly stating the goal, which should be quantifiable, and the results when this goal is achieved, including the time frame. This vision supports employees in understanding the expectations from the leaders, including the desired outcomes.

The fourth step is 'Communicate the Vision for Buy-In'. It is important that the leaders guide the individuals through the change to support the change efforts; support individuals in seeing the relationship between their actions and the results for the organization (Heckelman, 2017). Moreover, leaders must act on the vision; actions speak louder than words.

Take actions that bring about change
The second stage, 'Take actions that bring about change', consists of three steps, which focuses on securing that employees act to implement change.

The first element is 'To Empower Broad-Based Action'. The leaders are of great impact on the success of this step, since they are responsible for removing any obstacle that might get in the way for the implementation. Leaders must ensure that employees are able to develop new ideas and approaches without continuously being reminded by the old ways (Kenneth, 2002).

The second step, 'Establish Short-term Goals', encourages to plan and create short-term milestones, since short-term benefits validate efforts and maintain the level of urgency. It is proven that employees must notice results within one or two years, otherwise many will lose faith in the organizational change.
The third element of this stage is 'Never Let Up'. Leaders should keep demonstrating the progress to employees who do not immediately see the impact and the progress of the change (McKinsey&Company, 2015). This ensures that employees maintain the change effort, since the direct impact is shown.

Anchor the changes in the corporate culture
The third stage, 'Anchor the changes in the corporate culture', focuses on implementing the change permanently. It is important that the leaders connect the corporate success to the changes that are made in order to secure the permanent implementation. Moreover, new leaders need to embrace the changes, since they are able to adjust or undone the changes in the corporate culture to the old ways.

1.9 Deliverables

The main delivery of this research is a recommendation about the structure, design and working method of the ERP. First, a set of structure rules is created on which the design should be based. These structure rules are assessed by a predefined checklist. Second, a working method for the new ERP design is made, to ensure that the employees know how to work with the new design. It is a guideline of the new working method for the employees including the differences from the old ERP design and its consequences. To evaluate the new ERP design, a data analysis is executed, in which the processing times provided by the new ERP design are compared to the 'old' data.

1.10 Validity and reliability

To ensure the internal validity of the research, important problems are addressed by using at least two methods of data gathering. During the research the process times of the new machine, the Sprint ECO, are measured. The production employee carefully writes down the time spent on a specific production task. The employee is responsible for writing down any remarks regarding the time spent on that tasks; when the employee worked for example for a moment on another task or a sub assembly is lost which results in a stop in the progress of the task. Moreover, in cooperation with the operations manager and relevant production employees an estimation of all process times is made. Thus, three ways of data gathering is used during this particular subject: the data provided by the ERP, the estimation and the tracked time by the production employee. This data is compared to each other, and when necessary, the program evaluation and review technique (PERT) is used to determine the final processing times. This influences the internal validity in a positive way.

A limitation of this research is that it is only tested on one ERP system and process. The research focuses on the design of the ERP, called BaaN, for a production organization which aims for project-based producing. Therefore, the global structure of the ERP can be used to design the ERP of similar organizations. The procedure of this research, including all steps taken, decisions and trade-offs, are clearly described in the report to ensure that other researcher are able to follow it. This improves the reliability of the research. However, since it is only used in one process, the external validity can be questioned.

1.11 Summary

This chapter focused on identifying the core problem within Gietart Kaltenbach. The reason behind this research is that Gietart Kaltenbach is not able to communicate relevant information regarding the project to its customers, which is considered the action problem. After visualizing the problem context with a problem cluster, the core problem is determined: ‘The ERP does not provide correct/reliable data'. This core problem is translated into the following main research question:

To achieve its defined goals, which criteria must Gietart Kaltenbach's ERP meet regarding the design and the working method?

The defined goals of Gietart Kaltenbach are:

1. Designing a transparent cost price model where the customers’ options can easily be added and deleted.
2. The pre-calculation must be tested against the post-calculation.
3. Realising a resource/capacity planning.

This research only focuses on the ERP design and its working method. In the report, the current situation and desired situation of the cost price model, the production planning and the post-calculation with the pre-calculation are briefly discussed. This research does not include designing a transparent cost price model or creating a production planning.

This chapter also elaborated on the problem-solving approach and the research design. Through context analysis, quantitative analysis and qualitative analysis, we answered the research questions. The main deliverable of this research is a list of requirements/criteria the ERP must meet.

Next chapter focuses on providing background information of Gietart Kaltenbach, which provides support with understanding this research.

Chapter 2: The process of Gietart Kaltenbach

Gietart Kaltenbach designs, engineers and produces high quality shot blasting machines for steel surface treatment. Shot blasting is the process of removing thin surface deposits by broadcasting fine metal beads at a high pressure without causing significant damage to the surface (Substrate Technology, 2018). This chapter provides background information of the process within Gietart Kaltenbach and its organisation. Figure 3 visualizes the structure of this chapter, including the content of each section. First, the process flow and the production flow are discussed. Throughout this research the focus is on two types of shot blasting machines: The Sprint 1504 and the Sprint ECO. The structure of these machines is discussed as well. Moreover, Gietart Kaltenbach is currently in a transition phase from producing/purchasing on stock to producing/purchasing on demand. This is explained in the last section. The purpose of this chapter is to gain background information of Gietart Kaltenbach in order to understand this research better.

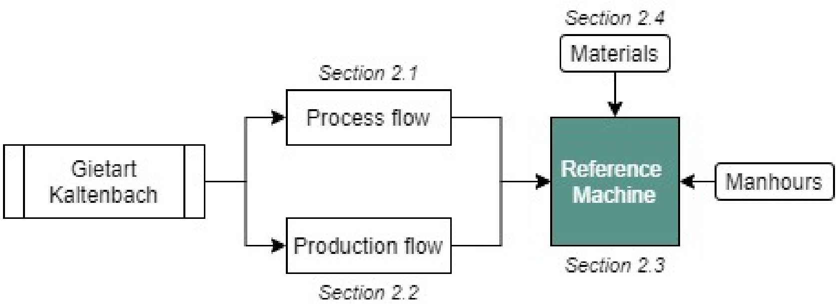


Figure 3: Structure chapter 2, where the process/production flow, materials & manhours are the input for the final product: the reference machine.

2.1 Process flow

Figure 4 represents the primary process of Gietart Kaltenbach. It shows all departments the project flows through, including the activities executed at that specific department. Each project starts at the engineering department, where the project and its layout are designed. The work preparation department is responsible for loading a particular project into the ERP including its pre-calculation, routing and post-calculation. The departments sheet metal machining, mechanical machining, welding, surface treatment area and assembly are the actual production departments. Throughout this research, these departments are mentioned. Therefore, it is useful to understand the specific activities executed at each particular department.

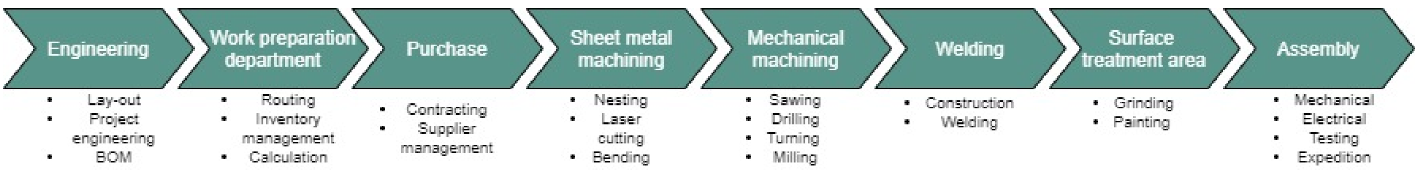


Figure 4: Operation process flow with all departments a project flows through including the activities at each department.

2.2 Production flow

Previous section elaborated on the primary process of Gietart Kaltenbach. This section focuses on the actual production departments: sheet metal machining, mechanical machining, welding, surface treatment area and assembly. The production flow elaborates on the path the reference machine follows through the factory. Figure 5 visualizes the production process of the Sprint ECO.

The first step of the production process is the sheet metal machining. The raw materials (sheets) are purchased and stored in the automatic storage of the laser cutting machine. This production step includes laser cutting, drilling, sawing and bending. These techniques are merged into one production step, since the techniques happen simultaneously. After this step, the steel sheets are sorted by production order: each transport cart represents a production order.

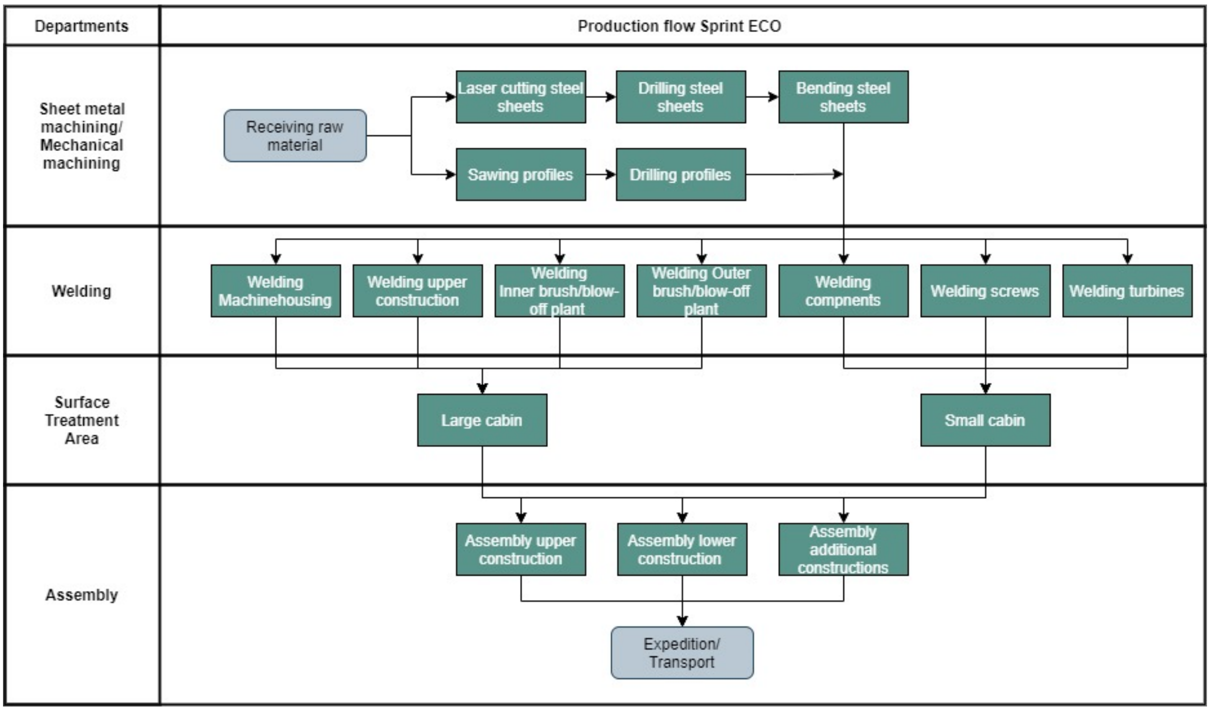


Figure 5: The production Flow of the Sprint ECO, where the departments are pictured on the left. Sheet metal machining & mechanical machining are merged, since they happen simultaneously.

The carts are transported to the next production step: welding. Each welding production order includes a technical drawing and welding order. In general, there are two employees working on the larger semi-finished products and one employee on the smaller semi-finished products. The construction of components, turbines and screws takes place in another hall.

After welding, all semi-finished products and components are painted in the surface treatment area. There is a separate painting cabin for the larger semi-finished products. All other products are painted in the smaller cabin by using the cross beams. It takes several hours for the paint to dry.

When the semi-finished products are dust dry, they are moved to the assembly hall. The main semi-finished products such as the machine housing, the brush/blow-off plant and the upper construction are assembled separately. The reason behind the separate assembly is that the shot blasting machine is transported with several trucks due to its size. The parts of the machine are prepared for shipping to minimize the chance of damage. The shot blasting machine is fully assembled at the customer.

In order to understand the construction of the shot blasting machine, next section explains the important modules of the machine.

2.3 Functional Structure of the Reference Machine

As mentioned in the introduction, Gietart Kaltenbach produces several types of shot blasting machines. In almost every industry that uses metal, a shot blasting machine is used to clean the metal sheets and constructions. The machine is used to remove the unwanted corrosion and the metallic waste on finished goods (Sikka, 2021). In order to understand the company, it is important to understand the final product the company delivers. The organization is built around the final product. Moreover, throughout this research the modules of the machine are often mentioned. In order to understand the research and the report, it is useful to zoom in on the construction of the shot blasting machine.

The reference machine is the Sprint ECO. The Sprint ECO is the future Sprint and replaces the Sprint 1504. The Sprint ECO is the successor of the Sprint 1504. It is a newly developed machine, which distinguishes from the Sprint 1504 regarding the sustainability. The functional structure of the Sprint ECO is similar to the structure of the Sprint 1504. At the start of the research there was no data available regarding the production of the Sprint ECO, since it was still in development. Due to the similarities, it is possible for the research to use the data available of the Sprint 1504.

The Sprint is the smallest shot blasting machine produced at Gietart Kaltenbach. There are various versions of the Sprint, where the greatest differences relate to the cross section of the infeed tunnel and the number of turbines. The shot blasting machine consists of several main components; the machine housing, the brush/blow-off plant, the upper construction and the additional construction. Gietart Kaltenbach also produces roller conveyors in addition to the shot blasting machine. Figure 6 shows an image of the Sprint ECO.

Figure 6: Sprint ECO drawn in Key shot (Pouwels, 2021)

Let's elaborate on the important modules of the Sprint ECO. These modules are the basis throughout this research. The important modules (and relatively large) are the machine housing, the brush/blow-off plant, the upper construction and the roller conveyors.

The machine housing

The sheets, tubes and profiles that need to be shotblasted enter the infeed tunnel of the machine housing via the roller conveyors. When entering the infeed tunnel, the construction passes the height adjustment, which measures the height of the construction.

After the infeed tunnel, the construction is transported via the roller conveyors to the machine housing. The infeed tunnel and the machine housing are separated by rubber curtains, which have the purpose of keeping the grit inside the machine housing. In the machine housing the product is shotblasted. The machine housing of the Sprint ECO consists of four turbines, which eject the grit at high speed on the construction. To prevent the machine housing of degrading, manganese sheets are welded on the inside of the machine housing. These manganese sheets can be replaced when they have been affected too much after several years. When leaving the machine housing, the product is completely stainless.

Figure 7: the machine housing almost ready for expedition. The construction enters the machine housing on the right.

Brush/Blow-off Plant

After the product is shot blasted and left the machine housing, there is still much grit and dust left on the product. There are three customers specific options from for removing the grit and dust: the brush/blow-off plant, the high-pressure blow and the water blow off. The brush/blow-off plant is the most sold option and is used throughout this research. The screw conveyor, which is located underneath the machine housing, transports the remaining grit back to the turbines.

Figure 9: The brush/blow-off plant ready for expedition.

Figure 8 The brush, which is located on the inside of the brush/blow-off plant.

Upper construction

The upper construction is located and attached above the machine housing. The upper construction ensures that the grit is cleaned and filtered. It also controls the grit supply for the turbines. The upper construction consists of multiple subassemblies. The customer several less comprehensive customer specific options in the upper construction, which mostly focuses on the automatization of the upper construction.

Figure 10: The upper construction completely assembled.

Roller conveyors

The product is transported to, through and from the shot blasting machine by roller conveyors and cross conveyors. Gietart Kaltenbach also produces these conveyors. The number of roller conveyors is completely customer specific. The distance between the roller conveyors can also be adjusted. The preference for the distance depends on the thickness of the profiles and the plates that need to be shot blasted. The cross conveyors are responsible for transporting the construction left or right.

Figure 12: The roller conveyors located before the infeed of the shot blasting machine. The shot blasting machine is located at a customer.

Figure 11: The cross conveyors, which transport the constructions sideways. The shot blasting machine is located at a customer.

This section elaborated on the structure of the shot blasting machine and serves as background information for this research. It is important to understand how the shot blasting machine is constructed in order to understand this research. Next section focuses on the inventory management.

2.4 Transition from stock to demand (inventory)

Gietart is in a transition phase from purchasing several components via the Statistical Inventory Control (SIC) to purchasing via material requirement planning (MRP) and the project resource planning (PRP). These concepts are all inventory systems in the ERP. In this section, the transition phase is explained and the consequences for the ERP are discussed. The research does not focus on this transition: this section serves as background information to get a better understanding of the company's environment. However, this transition does have a positive effect on the accuracy of the cost price. Therefore, we elaborate on this transition briefly during this research. First to understand this section, the important concepts are explained: SIC, MRP and PRP.

- Statistical Inventory Control (SIC): working with SIC means that the purchase and production are based on the stock level instead of on the demand. When the stock of a component is below the predefined stock level, the component is immediately ordered or produced. It is independent of a changing project demand. When there is a shift in demand of an ongoing project, the order is not adjusted.
- Material Requirement Planning (MRP): is an inventory control system which is based on the demand instead of the stock level. Based on the MPS, this system can accurately simulate when semi-finished products need to be produced and when components need to be purchased. If necessary, the system advises to adjust the planning of ongoing projects.
- Project Requirements Planning (PRP): gives accurate advice for the purchase and production for each project. In this planning the system also gives advice regarding purchase and production orders during shifts in ongoing projects.

Figure 13 shows the current situation around the method of purchasing and producing. A distinction is made between standard components and customer specific components. Currently, all standard components are purchased via the SIC. A consequence of producing via SIC is that the component is placed on stock by the fixed stock price. There is no post-calculation available of these components on a project. The fixed stock price is determined several years ago and is not tested since. Therefore, it is unknown whether the fixed stock price covers all costs. Since all standard components are run via the SIC, the impact on the cost price of the shot blasting machine is major. It is unknown whether the fixed stock price covers all costs, which results in an unreliable cost price. The customer specific components are currently manually entered in the ERP system.

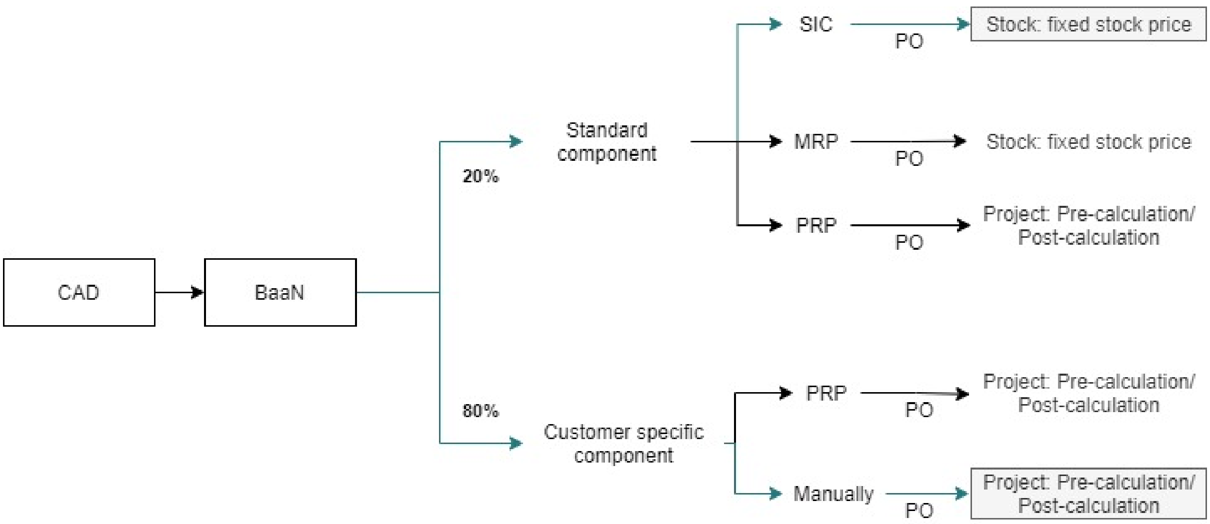


Figure 13: Current situation method of producing and purchasing, where the green line represents the current situation and the grey blocks the outcome.

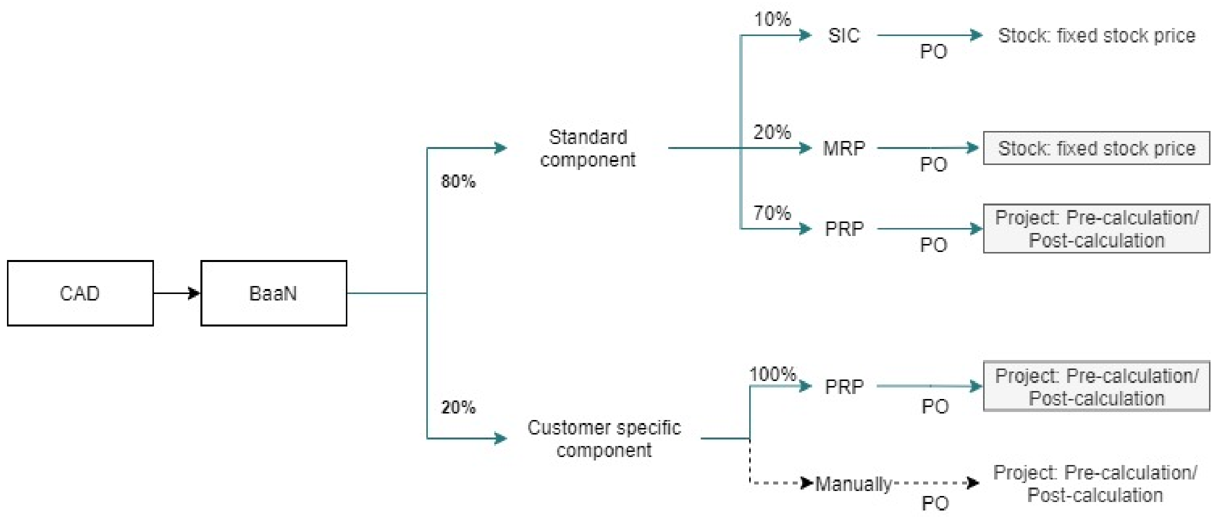


Figure 14: Future situation method of producing and purchasing, where the green line represents the future situation and the grey blocks the outcome.

However, Gietart aims to work project based. Figure 14 shows the desired situation regarding the purchasing and production. Project-based producing includes that the majority of the components are produced and purchased only when needed. This can be realized by converting from SIC to a combination of MRP and PRP. The aim is to produce around seventy percent of the standard components via the PRP. The advantage of PRP is that the component is directly linked to a project. As a result, that the post-calculation of that component is available on the project. Nevertheless, several components are still produced and purchased on stock to increase the efficiency in the production. Therefore, around twenty percent of the standard components are run via the MRP.

For the ERP system, this transition means a switch between the modules used for the purchase and production. We do not focus on this aspect of the ERP during this research. However, it does have direct impact on the goal of this research. There are several advantages of producing via the PRP:

- For each project the pre-calculation and the post-calculation are based on the activities for that particular project instead of on the fixed stock price. This way, Gietart is able to test the post-calculations, which gives them more control over the organisation.
- Financial and non-financial transactions are always linked to a project: this results in more insight into the costs of a project.

The transition from producing on stock to producing on demand influences the accuracy of the post-calculation. It enables Gietart to test the costs of more components, which gives them more control over the cost price. In the next chapter the current situation around the ERP and its outputs is discussed.

2.5 Summary

The purpose of this chapter is to provide background information about the environment of Gietart Kaltenbach. This chapter serves as support for understanding the important concepts used throughout this report. It elaborated on the reference machine and its important modules/sub-assemblies. Moreover, the business process and the production flow are discussed. Lastly, the transition phase regarding the inventory management is discussed. Gietart Kaltenbach is currently in a transition phase from producing on stock to producing on the Just in Time principle.

Next Chapter focuses on the current situation around the ERP: the BOM, the project planning, the cost price model and the pre/post-calculation. -

Chapter 3: The current situation around the ERP

Figure 15 shows the ERP concept of Gietart. The ERP concept remains the same throughout this research and functions as support for the structure of the report. In this chapter the current situation around the ERP is discussed. First, the input of the ERP is explained: the bill of materials from CAD. For improving the design of the ERP system, it is important to elaborate on its input. After all, the saying 'Garbage in, Garbage Out' (Thompson, 2016) counts.
Then, the focus is on the current typification of the ERP design and the data it provides. The outputs of the ERP that is focused on in this research are the project planning, the cost price model and the pre-calculation with the post-calculation. Each of the output is discussed in a separate section. The last section summarizes the important aspects of this chapter.

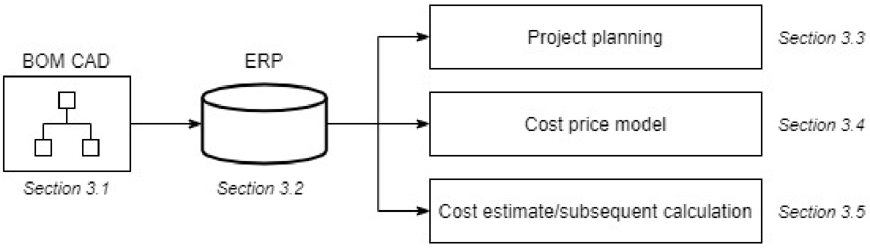


Figure 15: The ERP concept of Gietart, including the sections in which a particular aspect is discussed.

3.1 Bill of materials CAD

The input for the ERP is the bill of materials (BOM) generated by CAD. Computer-aided design (CAD) is the design of structures and devices with the aid of computer programs. In this software, the 2D and 3D technical drawings are made of all projects and machine types that are produced. In this drawing software, the structure of the complete project is determined.

Currently, the structure of the BOM is not in line with the method of production. The way the technical drawings are constructed by engineering does not match the production process. Nevertheless, the structure supports the engineering department with creating the technical drawings, since the customer specific options can easily be deleted or added. The structure is also beneficial for the service department, since it supports backorders of almost all components. Later on, in section *5.3 Bill of Materials,* we discuss how to repair the shortcomings.
The current structure in the BOM from CAD can be explained by using a daily and simple example: a bike (see example 1).

Example 1:

Let's consider a bike. A bike consists of two wheels: the front wheel and the rear wheel. Between the construction of those wheels there is no difference. Figure 16 visualizes the structure of the bike in the BOM from Cad versus the structure in the actual production.

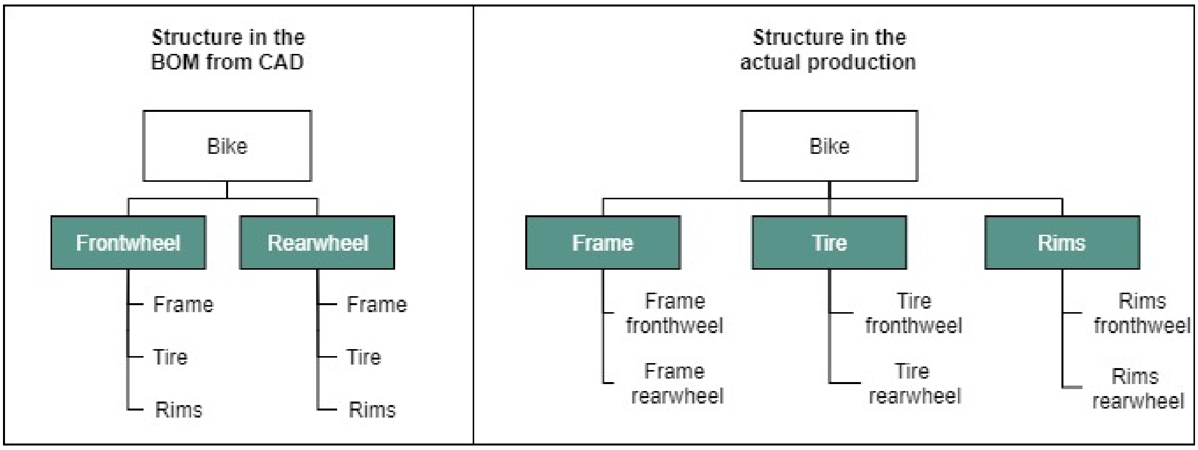
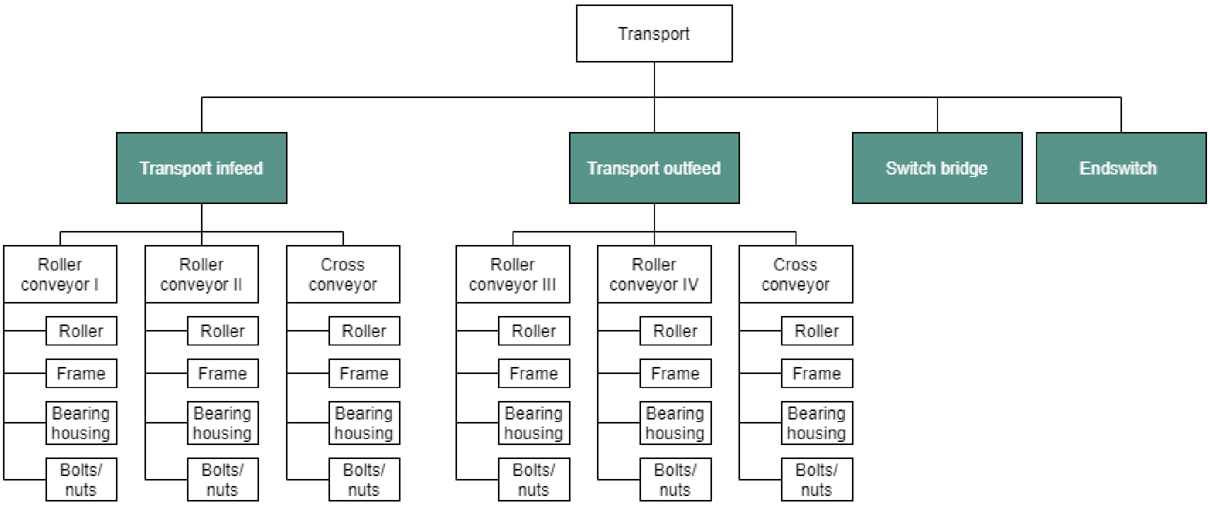


Figure 16: example of a bike, where the green blocks represent the modules.

Example 1 illustrates the difference between the structure in the BOM and the production method. These structures are not in line, which have a great impact on the efficiency of the organisation. We illustrated the structures of the BOM and the production with a simple example. Let's now illustrate it with an actual part of the BOM. Example 2 elaborates on the structure of the BOM by using the transport as an example.

Example 2:

*The difference in structure can be explained by using the transport as an example (*Example 1*). The structure of the transport in the BOM is based on the sales orders. Therefore, there are production orders for transport infeed, transport outfeed, switch bridge and end-switch. This structure in the BOM does not comply with the actual production. In reality, the transport infeed and transport outfeed are welded simultaneously, since there is no difference between the frames of the roller conveyors for the infeed and conveyors for the outfeed. This also applies for the cross conveyors: these conveyors are the same for the infeed and the outfeed. The assembly of the conveyors (rollers, bearing house and bolts/nuts) is executed for all conveyors simultaneously as well. Because of this structure, the production employee registers on the transport infeed or transport outfeed; this differs per employee. This results in inaccurate manhour registration on the transport.*



Example 2: Structure of the Transport in the BOM from CAD, where the green blocks are the modules (on the highest level).

When the machine of the specific project is designed in CAD and the technical drawings are approved, the BOM from CAD is generated. This BOM functions as the input for the enterprise resource planning. In the next section, we elaborate on the enterprise resource planning of Gietart.

3.2 The Enterprise Resource Planning (ERP)

Enterprise resource planning (ERP) is a software used by companies to manage and integrate the important parts of their business. An ERP software system can integrate all of the processes needed: planning, purchasing inventory, sales, marketing, finance, human resources, and more (Labarre, 2021). Gietart is using BaaN as the ERP software system. BaaN is known for its stability and its complete integration with multiple functionalities. The main disadvantage of BaaN compared to other ERP systems is that it is not user friendly and not visual. Nevertheless, Gietart already decided at the start of the research to remain working with BaaN instead of switching to another ERP system.

The input for the ERP is the BOM configured from CAD. In the current situation, it is difficult for the work preparation department to create effective production orders, since the structure of the BOM from CAD does not support this task: multilevel BOM. The work preparation department needs to merge several levels of the BOM into one production. In order to be able to create the production orders, the work preparation department implements the setting 'phantom'. A phantom item serves the purpose of an entire subtree (Pauquet, 2008). Figure 17 shows the structure of the phantom in the BOM. Considering Figure 17, module AB is the phantom item. This means that the materials of the purchase good A, the semi-finished product B and the raw material B1 are covered by module AB. These components appear individually on the production order of module AB. By implementing the phantoms, the BOM in the ERP matches and supports the actual production.
However, the manhours registered on module AB only cover the manhours directly worked on creating module AB, so only the first level. In the example in Figure 17, this means that only the manhours for merging A and B are registered on module AB. Thus, the manhours worked on creating the semi-finished product B are not immediately visible.

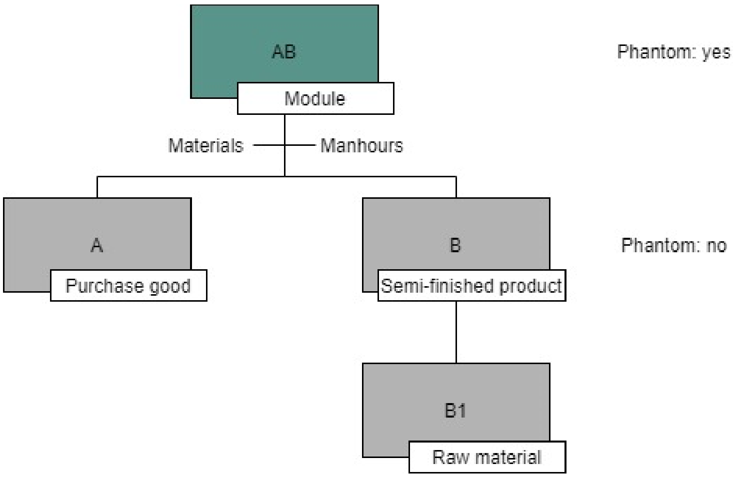


Figure 17: Phantoms in the BOM, where the phantom is applied on module AB. Module AB is the highest level in the BOM.

Due to this phenomenon, the data regarding the throughput time (in manhours) of the modules provided by the ERP are unreliable. The ERP bases the project planning, the cost price model and the pre-calculation/post-calculation (the output of the ERP) on this data.

3.3 Project planning

There are three levels for a planning, which need to be considered when talking about a planning. These levels, including its characteristics, are visualized in Figure 18. The highest and first level of a planning is the strategic level, where the board designs strategic plans to determine the desired future and the long-term goals of the organization. The second level, the tactical planning, supports the strategic planning by translating the strategic plans into specific plans relevant to a distinct area of the organization. In the operational level a day-to-day planning of each department and employee is made.

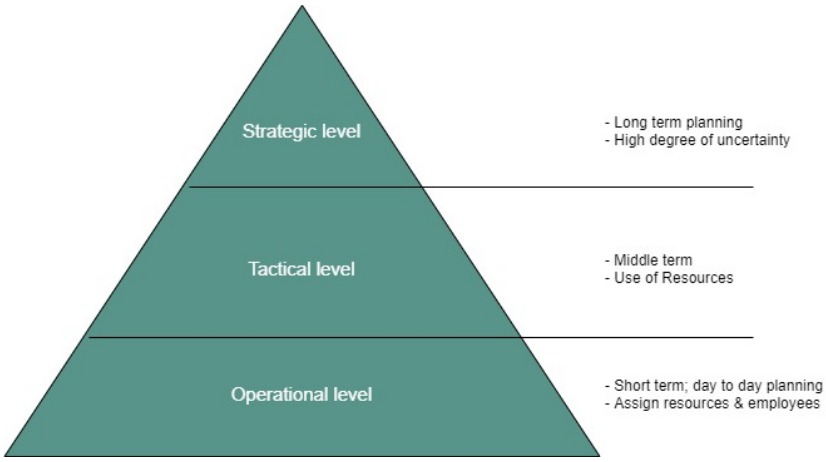


Figure 18: The levels of planning including its characteristics, where the strategic level is the highest level. The operational level planning is the most detailed planning.

Figure 19 shows the three levels on which currently a planning is based. The management determines the planning on a strategic level.
In the current situation, the planning for each project is realized on the tactical level. This planning is created and available in MS Project. According to the production managers, the planning is currently based on the critical path method: the upper construction and brush/blow-off plant. They claim that these production orders have the highest throughput time. There exists a basic tactical planning for each machine type. This planning is copied and adjusted for each project separately. The data used for this tactical planning is based on experience from several years ago. The data is not tested since then. Thus, due to the unreliable throughput times provided by the ERP and the outdated experienced throughput times, the tactical planning is unreliable.

Figure 19: Current situation of the planning levels, where X denotes the absence of the operational planning.

The operational planning is currently created manually by the production manager. This implies that the production manager assigns production employees at specific tasks weekly and creates a planning for each department. This is a visual block planning. It is created without the support of a planning tool.

3.4 Cost price model

The second important output of the ERP which is considered during this research is the cost price of a project. In order to generate profit, the cost price must cover the total costs of a project. To ensure this, all costs are allocated. Cost allocation is the process of assigning the (indirect) costs to a cost object and is used for financial reporting purposes, to spread costs among departments (AccoutingTool, 2021). The cost allocation results in hour rates for every department, machine and employee. In the current situation, the existing hour rates are outdated. There is no insight into the actual cost price of a particular project. It is unknown whether the cost price covers the complete cost. The inaccuracy of the cost price can be explained by the following reasons:

1. The throughput times of a module provided by the ERP are inaccurate.
2. The hour rates of the machines and man of each department are outdated and inaccurate.
3. The manhours of several production tasks are backflushed (see section *3.5 Pre-calculation and post-calculation).*
4. The majority of the production orders are produced on stock using the fixed stock price.
5. The surface treatment area is covered by the general costs. This surcharge is determined several years ago and not tested since.
6. Fasteners (Dutch: bevestigingsmateriaal) are directly registered on a project.

Improving the cost allocation is not included in this research. The cost price model is only considered during this research in order for the ERP to provide relevant data for the cost price and the cost allocation.

3.5 Pre-calculation and post-calculation

At the start of each project, the cost price is calculated. Pre-calculation (Dutch: voorcalculatie) is the process of estimating the total cost and other resources needed to complete the project within the timeframe. The post-calculation (Dutch: nacalculatie) is the calculation of the actual costs after the project is produced.

For explaining the current situation around the pre-calculation and post-calculation, the PDCA cycle is used as support by the author. PDCA is a four-step technique used to solve problems and to improve organizational processes. The four steps are Plan, Do, Check and Act respectively (Figure 20):

1. Plan: this step elaborates on the current situation in order to understand the nature of the problem being solved. The desired outcomes and results are also determined.
2. Do: during this step everything that has been considered in previous step is applied.
3. Check: during this step the effect of the implementation is monitored and evaluated.
4. Act: corrective actions are made in this final step.

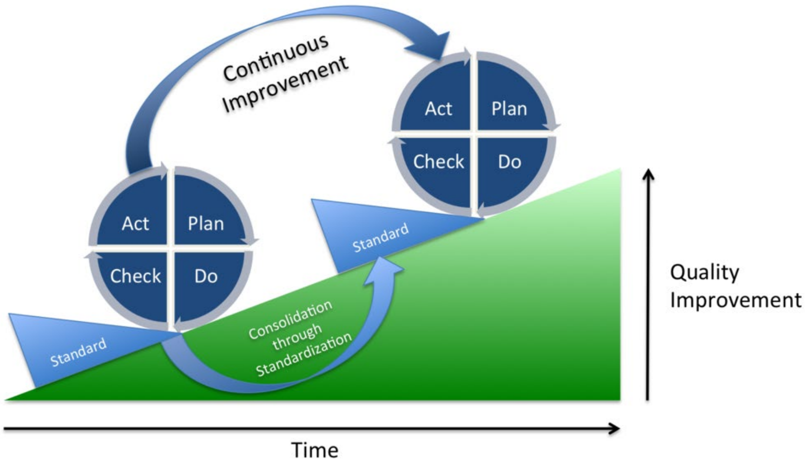


Figure 20: the PDCA cycle, which supports continuous improvement within an organisation.

Before reading this section, it is important to understand the concept 'Backflush':

- Backflush: an accounting method that records the costs associated with producing a good only after they are produced. It eliminates the detailed tracking of expenses. This allows the company to simplify its expense tracking. However, it also limits the detail of information the company retains related to individual costs for production (Liberto, 2020). For example, Gietart Kaltenbach uses backflush to determine the costs associated with the laser cutting machine. This is because several production orders are laser cut simultaneously, which makes it difficult to track the actual manhours worked on one particular production order. With backflush, the post-calculation of this production step automatically become the pre-calculation after production order is finished. The pre-calculation is determined several years ago. This means that the pre-calculation and the post-calculation are not tested.

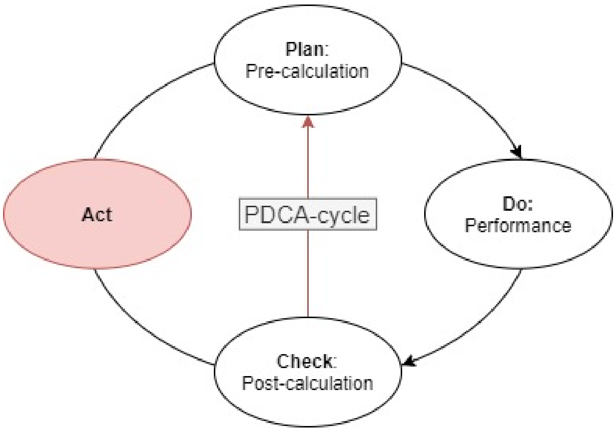


Figure 21: Plan, Do, Check, Act cycle used for the subsequent calculation, where the red line represents the current situation. The Act step is missing.

Let's start with the pre-calculation. For every project a pre-calculation is determined in order to predict its price and costs. Determining the pre-calculation by Gietart is the **Plan** in the PDCA cycle. The pre-calculation of several machine types and customer specific options are determined several years ago. The pre-calculation is not redressed after each project, instead the pre-calculation of a project is based on the pre-calculation of a past similar project. The pre-calculation is not improved.

The next step in the PDCA cycle is the actual production, which represents the **Do**. Data regarding the processing time and the throughput time of each production order is gathered. The ERP provides a post-calculation of that specific project, which is the **Check** of the PDCA cycle. However, several components of the machine are produced on stock. The prices of these components are based on the fixed stock price. Therefore, there is no post-calculation available of these parts. The fixed stock price is determined several years ago and since it is not monitored since then. Therefore, it is unknown whether the price of these components is accurate. Moreover, there are several departments where the manhours are registered by backflush. Thus, the actual throughput time of these production steps are unknown. The backflush rate is a constant and its accuracy is not tested.

The last step in the PDCA cycle (**Act**-step) is missing. The post-calculation of a project automatically becomes the pre-calculation of a future similar project. Thus, during the pre-calculation of a new project, the data of a previous similar project is used. The problem is that the post-calculation of previous project is not analysed and adjusted when needed.

There are two important consequences of the absence of a clear pre-calculation and post-calculation method. The first consequence regards the ability of measuring the productivity of the departments and its employees. Due to implementation of backflush in several departments, the productivity of these employees cannot be measured. Moreover, it is unknown on which products Gietart is currently making profit. Therefore, the organization does not know where its priority lays. This is a great risk for a company.

3.6 Summary

In this chapter the current situation around the ERP system is discussed. First, we elaborated on the input of the ERP system: the BOM generated by CAD. The structure of the BOM by CAD is not in line with the structure in the production, which causes difficulty with creating the production orders in the ERP. The ERP does not provide reliable throughput times for the modules. On this data, the project planning, the cost price model and the pre-calculation/post-calculation are based. Thus, the outputs of the ERP are based inaccurate and unreliable data.

Regarding the project planning, in the current situation there is only a planning available on the tactical level. The tactical planning is based on experience rather than on actual data. Furthermore, Gietart has no insight in the actual cost price of the projects. This can be explained by the absence of a sufficient pre-calculation and post-calculation method, the outdated hour rates, the components placed on stock by the fixed stock price and the departments based on backflush costing.

Chapter 4: The desired situation around the ERP

The goal of this research is to ensure the ERP system provides relevant and accurate data for the planning, the cost price model, the pre-calculation and the post-calculation. Previous chapter elaborated on the current situation around the ERP. This chapter elaborates on the desired situation of these outputs. This results in a list of requirements the ERP should meet. Figure 22 visualizes the interplay and relation between the outputs: project planning, the cost price model, the pre-calculation and the post-calculation including its sections.

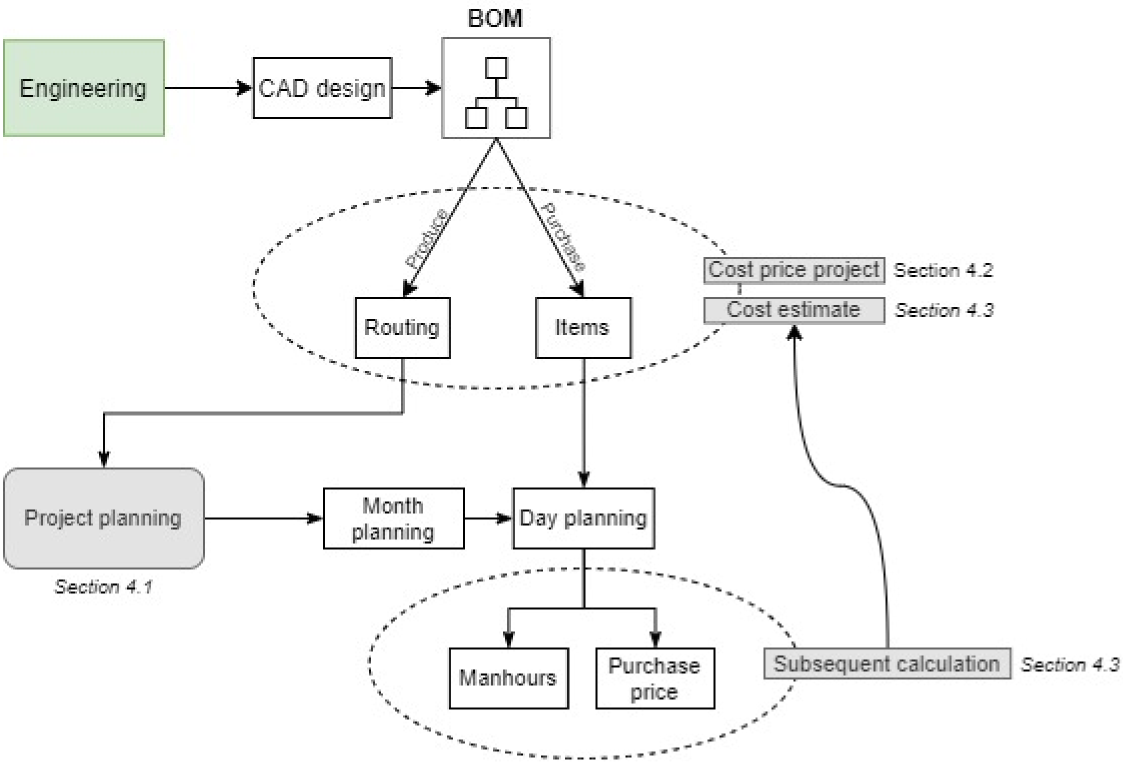


Figure 22: Relation between the BOM, planning, cost price, pre-calculation & post-calculation. The grey blocks are the aspects that are discussed in this chapter.

Each section starts with explaining the desired situation of that specific aspect on meta level in order to keep final goal of Gietart in mind. Then, the goal is discussed in more detail. Each section ends with explaining the information needed from the ERP to fulfil this goal. In the last section several criteria of the new design of the ERP are determined.

4.1 Planning

This section elaborates on the desired situation regarding the project planning. A research into the project planning has been carried out simultaneously with this research (Veuger, 2021). The result of this research is the basis for this section. The ERP must support this new planning concept.

The goal of Gietart is to create a reliable project planning, which is based on actual production data. The planning should show the progress of the ongoing projects and the work in progress. The first step is to create a basic and flexible project planning for each machine type. Thereafter, this basic planning can be optimized and improved. The planning should meet three different criteria. The first aspect is that it must be possible in the planning for different projects to react on each other. Moreover, the planning should be flexible and comprehendible for the entire organization. The focus for the planning is still on the tactical and the operational level (Figure 23).

Figure 23: The planning levels, where the focus is on the grey blocks.

The tactical planning is still created in MS project. A planning in MS Project provides overview of the ongoing projects. It shows the dependencies of the ongoing and future projects. The tactical planning provides a sample time frame in which the module must be produced. The tactical planning must be based on accurate instead of experienced throughput times. Therefore, it is important that the data (provided by the ERP), on which the planning is based, is analysed and adjusted when necessary. In the future, the input for the planning should be analysed during and after each project. This ensures the reliability and the accuracy of the tactical planning.

In addition to the tactical planning, an operational planning is created in the ERP. The tactical planning is the input for this operational planning. This increases the importance of an accurate tactical planning. The operational planning provides a day-to-day planning for each department: it is a planning in departments and tasks. The planning is based on the processing time (days) of each module. Each module must have a separate production order, on which the manhours are registered. The modules must be the highest plannable units.
The process time includes the throughput time and the waiting time. The throughput time is determined by dividing the total manhours by the number of men worked on the semi-finished product. The process time can be calculated as follows:

$$Process\ Time = \frac{Manhours}{Number\ of\ Man} + Waiting\ Time$$

It is important that the ERP provides accurate manhours, the number of men worked on that particular module and the waiting time, since the planning is completely based on this data.

The operational planning must take into account the capacity of each department, the priorities of the projects and the dependencies of production orders. Gietart prefers to use the planning tool in the ERP for the operational planning instead of MS Project. This is because the ERP already contains the routing of each production order including the corresponding throughput time of that production step. When MS Project would be used for the operational planning, the data must be copied manually to MS Project. This is time consuming and error prone. This research does not focus on the implementation of the operational planning into the ERP. It focuses on providing the accurate data on which the planning in the ERP is based.

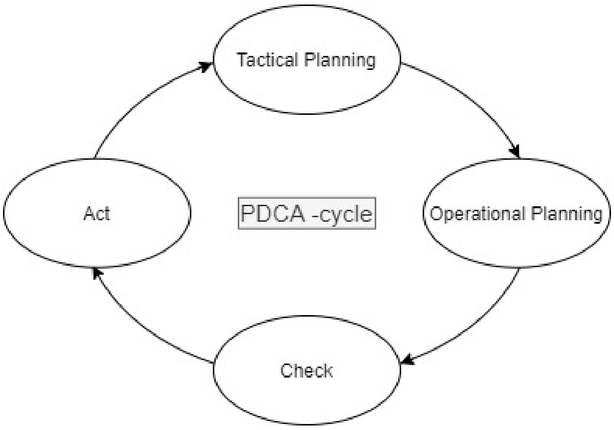


Figure 24: PDCA cycle used to visualize the interplay between the tactical planning and the operational planning.

As mentioned before, it is important to keep analysing and adjusting the tactical and operational planning to increase its accuracy. The tactical planning is the input for the operational planning. The interplay of these two planning can be explained by the PDCA cycle (see section *3.5 Pre-calculation and post-calculation*). The interplay is also visualized in Figure 24. The tactical planning is the **Plan** of the cycle. The tactical planning is used as input for the operational planning (**Do**).
During and after each project the operational planning is **checked**. In this step, the operational planning must be analysed; 'Did we follow the planning?', 'Is the time frame provided by the tactical planning sufficient?' etc. In this step the post-calculation is compared to the pre-calculation of that particular project by the operation manager. When there are great deviations between these calculations, the reason behind the difference is investigated. This can be done by talking to the involved. The production manager must implement the deviations in the tactical planning (**Act**), when it is considered as a constant deviation. This cycle is a continuous process and makes sure the planning stays accurate.

This new concept of the project planning has influence on the design of the ERP system. The criteria for the ERP only considering the project planning are stated in the next section.

List of requirements for the project planning
There are three criteria the ERP must meet in order to successfully implement the project planning:

- The ERP must provide accurate throughput times in order to determine the processing times on which the planning is based.
- The departments and production tasks in the ERP must match the ones on which the planning is based.
- There must be a clear structure in production orders, since these are the planning modules. The planning modules should be the highest manageable/plannable units.

These criteria are taken into account when determining the complete list of criteria in section *4.4 Coming to an end list of requirements/criteria.* Next section elaborates on the second output of the ERP: the cost price model.

4.2 Cost price model

First, this section focuses on the desired cost price model on meta level. Thereafter, it elaborates on the reasons two, five and six behind the inaccurate cost price already mentioned in section *3.4 Cost price model*. Reason one is discussed throughout the report. Reason three is discussed in section *3.5 Pre-calculation and post-calculation.*

Reason four is already explained in section *2.4 Transition from stock to demand (inventory).*

The goal of Gietart is to have an accurate cost price of a project. To achieve this, the cost allocation must be improved and result in accurate hour rates. These hour rates must cover all costs for that specific task/department including indirect costs such as rent, depreciation and electricity. Moreover, it must be possible to determine the price of the important customer specific options. There must be a balance between important and less important customer specific options. An important customer specific option is an option that is 'often' sold. This way, Gietart is able to be more transparent to its customers about the cost price of the project. When a customer specific option is considered important, the throughput time (in manhours) must be registered on that production order. Furthermore, Gietart wants to be able to communicate the work in progress (WIP) and the backlog to customers and within the company.

First, let's elaborate on **reason two**: the outdated hour rates. A research regarding the hour rates is conducted at the same time as this research. The cost allocation is improved and adjusted in order to comply with the current processes. The results of that research are accurate hour rates for the machines and man at each department. For each department a cost unit is determined on which the hour rate is based on (Table 3). It is important for this research that the cost units and the planning units' match. The ERP must provide the information needed for these cost units.

Table 3: The cost units for each department.

Department	Cost Unit
Sheet metal machining	Net laser cutting time
Welding	Manhours
Surface Treatment Area	m2 surface
Assembly	Manhours

In the desired situation, two aspects are changed regarding the method of cost allocation: the surface treatment area (**reason five**) and the fasteners (**reason six**).
The first aspect is the surface treatment area. It is chosen that the manhours and the materials for this department need to be directly registered on a project instead of via the general expenses. The reason for this is the relatively high cost of the surface treatment area on a project. To have control over the cost price, it is important that these expenses can be monitored and analysed. An hour rate is determined for this department, with the m2 surface that needs to be painted as the cost unit.

The second aspect is about the fasteners, such as the bolts and nuts. In the future situation, the fasteners are covered by the general expenses. The reason behind this choice is based on the relatively low costs of these components and the increase in complexity of the BOM. In total there are 185 unique fasteners. This means that at least 185 positions in the BOM are covered by these components, which is around four percent of the total BOM positions. Table 4 shows the total costs of the fasteners in which a distinction is made between purchased and produced fasteners.

Table 4: Costs fasteners per project

Total purchased	€ 140,00
Total produced	€ 16,78
	€ 156,78

These components are relatively cheap compared to the cost price of the shot blasting machine. To simplify the BOM, it is chosen to move the fasteners to the general expenses by using a surcharge.

This new design regarding the cost price model results in several criteria of the ERP. In order to determine the cost price like it is suggested in this section, the ERP must meet some criteria. These criteria are stated below.

List of requirements cost price model

The desired situation regarding the cost price model results into seven criteria for the ERP:

- The ERP must provide accurate manhours of the departments in order to determine these costs.
- There must be a clear structure in production orders, since this supports the cost modules. For the finance department, it is interesting to have detailed data. The important customer specific options must be a cost module.
- The ERP must provide an overview of the costs of a project. In this overview a distinction between the cost types must be made clear and relevant cost components.
- The new hour rates must be implemented into the ERP.
- The ERP should show the WIP and backlog.
- The net laser cutting time must be accurate (driver Activity-based costing).
- The ERP must provide the m2 surface of the production orders (driver Activity-based costing).

These criteria are taken into account when determining the complete list of criteria in section *4.4 Coming to the end list of requirement/criteria.* Next section elaborates on the desired situation regarding the pre-calculation and the post-calculation.

4.3 Pre-calculation and post-calculation

In this section the desired situation regarding the pre-calculation and post-calculation is discussed. Section *3.5 Pre-calculation and post-calculation* already elaborated on the current situation around the pre-calculation and the post-calculation. The absence of a clear pre and post calculation method is a short coming. We already concluded that the Act step of the PDCA-cycle is currently missing, which means that the post-calculation is not analysed.

In the desired situation, all steps of the PDCA-cycle have to be executed. The post-calculation (Check) must be analysed and compared to the pre-calculation (Plan). When there are great deviations between these calculations, the cause of this deviations must be determined. If this deviation can be considered as constant, the pre-calculation of this production order must be adjusted. In order to make it easier to determine whether a deviation can be considered as a constant, it is useful to introduce a new task on the production order: unforeseen tasks. The production employees can register their hours on this task when unexpected activities take place. These hours do not have to be charged on the project. Examples of these unexpected activities: a dysfunctionality/mistake in the technical drawing, the absence of materials (the employee goes searching for them) or a breakdown of equipment where the employees go to fix it. This way, the pre-calculation and the post-calculation of a project are always tested against each other. This increases the reliability and accuracy of the calculations.

As mentioned in section *3.5 Pre-calculation and post-calculation* the fixed stock price and the backflush also have a great influence on the accuracy of the pre and post calculation. In section *2.4 Transition from stock to demand (inventory)* the transition Gietart is currently dealing with is already discussed. This transition ensures that less components are produced via stock, which implies that less components are charged by the fixed stock price. This means that Gietart is able to determine the post-calculation of more components. Moreover, Gietart is currently investigating where they want to remain working with backflush (see section *3.5 Pre-calculation and post-calculation*) and where they want to track the expenses with a more detailed method. This is an ongoing project, and the decisions still need to be made. Remain working with backflush has a negative effect on the accuracy of the cost price of a project.

This new method for the pre-calculation and the post-calculation results in several criteria of the ERP. In order to implement this new method, the ERP must mee some criteria. These criteria are stated below.

List of requirements pre-calculation/post-calculation

In order to successfully implement the new method for pre and post calculation, the ERP must meet the following criteria:

- The ERP must provide accurate manhours of each task of the production order.
- The structure in the production orders must be used for all projects in order to compare and analyse the manhours of a production order.
- There must be a task, on which unforeseen tasks can be registered, in order to have actual manhours of a production order.

These criteria are taken into account when determining the complete list of criteria in the next section: *4.4 Coming to the end list* of requirements/criteria *.*

4.4 Coming to the end list of requirements/criteria

In this section a list of requirements/criteria for the ERP is lined up. These criteria ensure that the ERP is able to support the three earlier stated goals of Gietart *(section 1.3 Goal of the research)*:

1. To realize a project planning.
2. To design a transparent cost price model, where the price of the customer specific options can easily be determined.
3. To be able to realize an accurate pre-calculation and post-calculation.

Table 5 (next page) shows the criteria for the ERP. We defined eight important criteria for the design of the current ERP system. The importance of each criterion for this research is determined. It is also stated when a specific criterion is considered as achieved. This table forms the framework of this research.

Table 5: End list of requirements/criteria of the ERP, including for each criterion: its explanation, its result, its measurability and its importance.

Criterion nr.	Criterion name	Importance
1.	**Defining one production order structure for all projects**	**3**
	It must be possible to implement the production order structure for all types of projects. There must be only one production order structure. *It results in* one structure which is used throughout the whole company. This enables Gietart to compare different projects. *It is achieved when* we are able to implement the structure of the production orders for all machine types.	
2.	**Defining the module level within the production order structure**	**3**
	The module level within the production order structure must balance the level of detail and the effective steering level. This structure must support both the planning and cost price model. The module level must be based on the concept 'the highest manageable unit'. *It results in* production orders on which the planning can be based. The production orders also support with determining the cost price of the project. *It is achieved* when the production orders are plannable and when the production orders support with determining the cost price of relevant modules.	
3.	**Determining relevant departments and tasks in the ERP**	**2**
	The departments and tasks implemented in the ERP must match the ones on which both the planning and the cost price model are based. *It results in* a clear structure of departments and tasks in the ERP, which enables the realization of the project planning in the ERP and the allocation of the department costs. Having a clear structure in the departments and tasks prevents the fragmentation of the manhours. *It is achieved when* the ERP includes only relevant departments and tasks. It should be a cleaned-up list of the departments and tasks. *It is measurable by* analysing the number of times the task or department is used in a year. On all departments and tasks, at least ten manhours must be registered. When several departments or tasks are not often used in a year, it is likely that these are unnecessary.	
4.	**Receiving accurate manhours on the post-calculation by the ERP**	**3**
	The ERP must provide accurate manhours of the measurable production tasks on the post-calculation of each production order. *It results in* an overview and insight into the total number of manhours worked on a particular production order. This results in a more accurate pre-calculation of this production order in the future. *It is achieved* when the measurable manhours provided by the ERP are in line with the reality. *It is measurable by* comparing the manhours provided by the ERP with the estimation of the manhours that is made in *Chapter 6: Estimation of the throughput times.* Between these two data sets of the manhours, there must be at most a deviation of 10%.	
5.	**Receiving a clear cost overview of a project by the ERP**	**2**
	The ERP must provide a clear pre-calculation and post-calculation. These calculations must be easily comparable, which implies that the structure of the pre-calculation and the post-calculation must be similar. It is important that the pre-calculation and the post-calculation provide insight into the important (estimated) cost types. The structure of the calculations is based on the cost components implemented in the ERP. That is why, there must be a clear and relevant list of cost components. *It results* in being able to compare the pre-calculation with the post-calculation easily. *It is achieved* when there is a clear structure for the pre-calculation and the post-calculation implemented, where only relevant cost components are used.	

	It is measurable by analysing the number of cost components that are used in a year. At least 90% of the cost components must frequently be used during a year. When a cost component is not used within a year, it is likely that this cost components is unnecessary.	
6.	**Registering the manhours of unforeseen activities separately**	**2**
	There must be a task available in the ERP, on which unforeseen activities can be registered. These manhours must not be registered on a production task. It must be clear on the post-calculation that some deviations in manhours must not have influence on the pre-calculation. *It results in* more accurate manhours of a production order, which implies that manhours caused by unforeseen activities are not charged. It improves the analysis and comparison of the pre/post-calculation. *It is achieved when* the production employees are able to register on this task and understand when they need to register the hours on this task. *It is measurable by* examining whether the employees understand the purpose of the task. At least 80% of the employees must give the correct answer. Moreover, it is useful to analyse the number of manhours registered on the task compared to the number of manhours actually used for unforeseen activities. This must be analysed instantly. The deviation between the comparison of the registered and actual manhours may be a maximum of 10%.	
7.	**Implementing accurate hour rates in the ERP**	**1**
	The hour rates of the departments, machines and employees must cover the total costs. These hour rates must cover all costs for that specific task/department including indirect costs such as rent, depreciation and electricity. The way the cost is allocated, and the hour rates are retrieved, must match the structure of the organisation. *It results in* accurate manhours, which cover the total costs. *It is achieved when* the cost allocation structure is in line with the organisational structure. *It is measurable* by analysing whether the contribution margin (Dutch: dekkingsbijdrage) actually covers the indirect costs. The difference between the total contribution margin and the indirect costs (contribution margin – indirect costs =) must not be a negative number.	
8.	**Receiving accurate WIP and backlog by the ERP**	**2**
	The ERP must give input for an accurate work in progress (WIP) and backlog. Gietart wants to be able to communicate the WIP and the backlog to customers and within the company. *It results in* insight into the progress of the ongoing projects, which enables Gietart to have more control over the processes. *It is achieved when* the WIP and backlog provided by the ERP represent the reality. *It is measurable by* comparing the WIP and backlog provided by the ERP with the actual WIP and backlog at a specific moment in time. The deviation between the WIP/backlog provided by the ERP and the real WIP/backlog may be a maximum of 10%.	

This list of requirements for the ERP forms the basis for the new design of the ERP and its working method. This list of requirement summarizes the important aspects of this chapter. It also serves as basis of the recommendation to Gietart Kaltenbach. In *Chapter 7: Evaluating the ERP design by assessing the list of requirements,* we evaluate the proposed design by using this list of requirements. In next section the proposed design of the ERP is discussed.

4.5 Summary

This chapter elaborated on the desired situation of the project planning, the cost price model and the pre/post-calculation. In order to realize this desired situation of each aspect, the ERP must meet some criteria. For each of the three aspects a list of requirements for the ERP is determined. In the last section all those criteria are merged into the end list of requirements/criteria for the ERP. This list has a high importance for this research, since it serves as basis of the design of the ERP. This list is also the main deliverable of this research. It is important to evaluate this list of criteria when creating the new design of the ERP. Next chapter elaborates on the new design of the ERP.

Chapter 5: The ERP Design

This chapter focuses on the actions regarding the ERP design that need to be taken in order to receive accurate data from the ERP. The greatest adjustment is in the input of the ERP system: the BOM configured from CAD resulting in different production orders. To determine the new structure in the production orders several aspects are taken into account: the spare/wear parts, the level of the cost modules and the level of the planning modules. First in section *5.1 Spare/wear parts*, the importance and the influence of the spare and wear parts is discussed. The new structure of the production orders and the trade-offs made are discussed in section *5.2 Production orders*. The BOM configured from CAD needs to be adjusted so it supports the new structure in production orders, which is discussed in section *5.3 Bill of Materials*. Moreover, several adjustments in the settings of the ERP need to be executed, which is explained in section *5.4* .

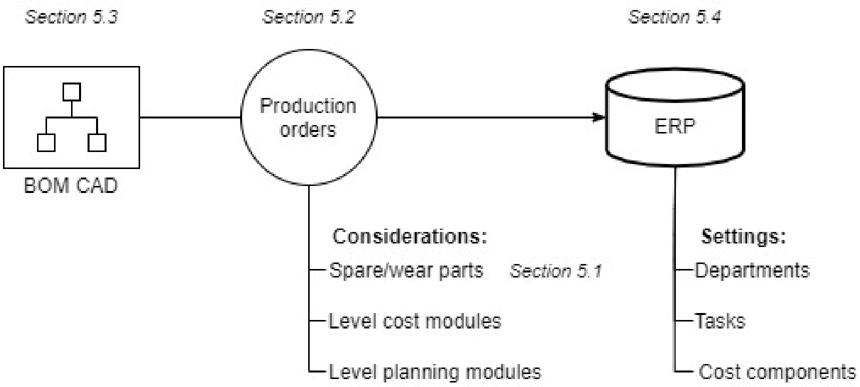


Figure 25: Structure of Chapter 5. The focus is on the production orders, BOM and the settings in the ERP

5.1 Spare/wear parts

In this section the spare and wear parts of the machine are determined. In order to design an effective structure in the production orders, it is important to understand which parts are spare and wear. First, the two concepts are explained. Then, it is discussed which parts we consider wear and spare. This is determined in cooperation with the service department.

To understand this section, it is important to first elaborate on the two important concepts: wear part and spare part.

- **Wear part**: parts that are designed to wear out or fail with repetitive use and will require periodically repair or replacement. (Law Insider, 2020).
- **Spare part**: a new part that is used to replace a part that is broken or damaged.

Let's consider the bike as an example again to explain the difference between a wear part and a spare part.

<u>*Example 3:*</u>
A bike has a front wheel and a rear wheel. The tires of the bike have to withstand a lot. The tire may puncture, or the tire can wear out completely so it no longer has grip. It is certain that the tires have to be replaced at some point. The tires of the bike are wear parts. A bike also has two handles. The chance that these parts need to be replaced is less likely. Only in special situations these parts need to be replaced. Therefore, the handles of a bike are a spare part.

It is important for the service department that we consider the wear parts when determining the level in the production orders. The service department is responsible for the backorders of customers. The wear parts are quite often backordered. The wear parts are produced on stock, which means that these parts need to be engineered and produced as a production order. An example of a wear part in the shot blasting machine are the manganese sheets in the machine housing. These sheets protect the machine housing from the grit, since the grit is shot into the machine housing at a very high speed. These manganese sheets wear out and need to be replaced after several years (depending on usage). Next section elaborates on the next structure of the production order taken the wear parts into account.

5.2 Production orders

In this section the work breakdown structure, which focuses on the production orders, is discussed. A work breakdown structure (WBS) is a visual, hierarchical and deliverable-oriented deconstruction of a project (Projectmanager, 2021). *Appendix C – The work breakdown structure for the production orders* shows the WBS including all production steps for each module. The modules also represent the new structure of the production orders. It is important for this research to elaborate on the production orders, since the production orders are the basis for the available data: the input for the ERP. There must be a clear structure in the production orders in order to receive the correct data. The production orders should support the project planning, the cost price model, pre-calculation and the post-calculation.

To determine the production orders several aspects need to be taken into account:

1. The production employees must be able to register the manhours on these production orders easily.
2. To simplify the planning, the modules should be on based on the highest manageable level.
3. For the cost price model, the modules should be as detailed as possible, which implies the lowest manageable level.
4. The important customer specific options need to have a separate production order in order to be transparent to the customer about the price of the option.
5. For the After Sales, the wear parts need to have a separate production order, since they are backordered quite often.

These aspects are all considered when we determined the new structure in the production orders. In cooperation with the operation manager, the production manager, the R&D manager, the service manager and the work preparation department this new structure in the production order is created. In this section, we elaborate on these production orders for each department. This section is divided into four sections. Figure 26 visualizes the structure of this section. Each section represents and elaborates on one production step. The first section focuses on the production orders of the assembly, since this step yields the final product.

Figure 26: Structure of this section, where the assembly is discussed first and the sheet metal machining as last.

Each section is constructed in a similar way. First, the current situation regarding the production orders of that specific production step is discussed. Then, the problems concerning these production orders are elaborated. Thereafter, the trade-off is determined on which the solutions are based. The (alternative) solutions are discussed as well. As last, the final solution is discussed.

5.2.1 Assembly

In this section a distinction between the mechanical and the electrical assembly is made. Currently, there are four production orders for the final mechanical assembly of the machine: the machine housing, the brush-blow off plant, the upper construction and additional constructions. The working hours of the production employees are registered on these production orders separately. Regarding the electrical assembly, there are many production orders: for each relatively large module one production order.

This structure in production orders for the mechanical assembly has one major dysfunctionality. During the final assembly of the machine, several components of the modules are being assembled simultaneously. For example: an employee assembles the rollers in the machine housing and the brush-blow off plant simultaneously, since these are exactly the same. This is time reducing and increases the efficiency in the factory. However, the question with these current production orders is on which of these three production orders should the employee register. Currently, it depends on which employee is working on the assembly: it differs per employee. This makes it impossible to compare the post-calculations of several projects accurately. Moreover, another disadvantage of this structure in the production orders is that production employees need to switch many times between the production orders on which they are registering. This is error prone and time insufficient.

The trade-off that is made considers the user friendliness for the production employees and the capability of determining the cost price for the customer specific options. The production orders must comply with the production. However, the hour registration drivers must also make it possible to determine the cost price of the important customers' options.

Therefore, we decided to work with three production orders for mechanical assembly. The machine housing and the brush-blow off plant are merged into one production order for assembly: the lower construction (1). The production order upper construction (2) and transport (3) stay. This new structure eliminates the dysfunctionality described above and also reduces the number of times the employee needs to switch between the production orders. However, the mechanical assembly time spent on smaller specific customer option is not tracked and registered, which makes it more difficult to determine an accurate cost price of this option. The advantages of this new structure outweigh this disadvantage. Moreover, the new structure suggests only one production order for the electrical assembly on which all actions can be registered.

Regarding the electrical assembly, we decided to have two production orders. The electrical assembly takes around forty manhours. The production employee works on the electrical assembly of the complete shot blasting machine rather than on specific modules. Therefore, there is one production order for the complete electrical assembly. The second production order is used when the shot blasting machine is tested. Thus, two production orders: electrical assembly and testing. The next department, we focus on is the surface treatment area.

5.2.2 Surface treatment area

Before the final assembly, all semi-finished products are painted at the surface treatment area. A distinction between the sizes of the semi-finished products is made. The larger assemblies, such as the machine housing and the brush-blow off plant, are painted in a specific, large cabin. Every project consists of at least four of these assemblies. The smaller semi-finished products are painted in the small cabin by using crossbeams on which the smaller parts are hung.

In the current situation, the hours worked in the surface treatment area on the machine assemblies are not directly charged on a project. These manhours are considered to be covered by the general expenses. This means that the employees do not have to register on a production order and the manhours are not tracked. The surcharge percentage that is currently used, cannot be checked and analysed whether it represents the actual costs: it is unknown whether the percentage is accurate and whether is covers the costs. The advantage of the costs covering by the general expenses is that the employees do not have to switch between registering on several production orders.

The trade-off that is made considers the user friendliness for the employees in the surface treatment area and the possibility of determining the price of this department for each project. The wish of Gietart is that these manhours and materials are directly registered on a project. The reason behind this wish concerns the possibility of monitoring and analysing the performance of the surface treatment area. Moreover, registering the manhours and materials directly on the project supports Gietart in the transition to a project-based production.

For the large cabin it is possible to directly register on a project, since only one semi-finished product can be painted at the time. The expected average processing time of an assembly in the large cabin is around four hours. However, there is one major difficulty with directly registering on a project concerning the small cabin. To increase the efficiency of the surface treatment area, several assemblies are painted simultaneously. The painter sorts the assemblies by colour at which no distinction between assemblies of the projects and assemblies for service is made. When the number of assemblies for a specific colour is sufficient, the assemblies are painted. As a result, that the painter is working on several projects and service production orders simultaneously. This makes it difficult to expect that the manhours are directly registered on a project accurately.

Two options are considered to solve this problem. The first option concerns a surcharge for the small cabin and registering the manhours for the large cabin directly. Thus, the first option is a mix of the current situation and the wish of Gietart. The advantage of this option is the user-friendliness for the employee; the painter does not have to register on a project when painting the smaller assemblies. The disadvantage with this solution is that a surcharge percentage is still used, which cannot be checked and analysed. The second option focuses on registering the manhours for the small cabin as well. The painter should register on the dominant project when painting in the small cabin. The dominant project is the project of which most of the parts in the painting area belong to. This option makes the task for the painter slightly more difficult. However, this way it is possible to directly register the working hours on a project, which makes it possible to analyse the surface treatment area. The second option has been chosen by the organization.

This new structure in the surface treatment area means that the production orders need to be defined. There is only one production order for the small cabin, due to the complexity of directly registering this on a project let alone on a steel construction. For the large cabin it is chosen to have four standard production orders: for each semi-finished product.

5.2.3 Welding

There are several problems regarding the structure of the production orders in the welding department. It is important that data regarding this department specifically is accurate, since it adds the most value to the shot blasting machine (together with the assembly department). The department has a big share in the total manhours worked on the complete project. Therefore, it is important the shortcomings of the current production order structured are solved.

The first problem of the production order structure of the welding department is the misleading names of some production orders. This can be explained by introducing the production order for the upper construction. The upper construction consists of eight semi-finished products. Figure 27 pictures the expectation of the hours registered on this production order. The name of the production order suggests that the production order upper construction represents all hours worked on the complete upper construction, including the hours on each semi-finished product. Thus, the hours worked on sub assembly II for example are expected to be part of the hours registered on PO upper construction.

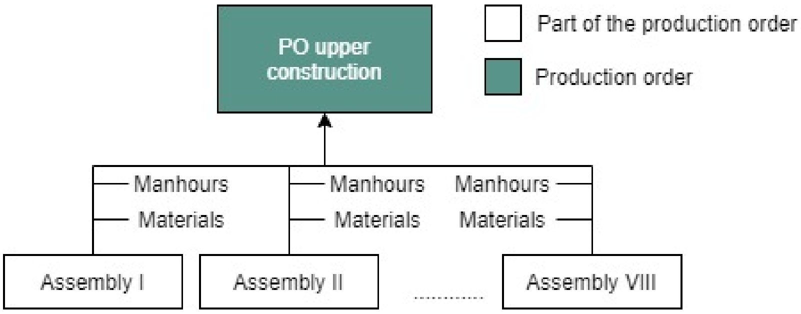


Figure 27: Expectation PO Upper Construction, where all the manhours of the assemblies are registered on PO Upper Construction

However, the hours that are actually registered on this production order do not cover the complete manhours for the upper construction, since the total number of hours registered on the production order is far too low. It turns out that the hours registered on the PO upper construction only include the hours worked on the additional parts. The hours worked on each assembly is not included the PO upper construction. The actual structure for the production orders is pictured in Figure 28. The misleading name of the production orders results mostly in confusions when determining the cost price. Due to these misleading names, it is difficult to analyse the processing times of several assemblies.

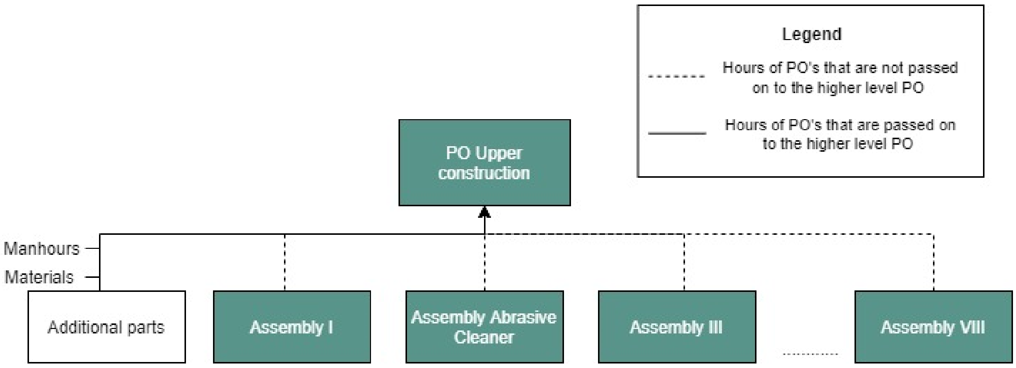


Figure 28: Reality PO Upper Construction, where the PO Upper construction only consists of the hours of the additional parts.

Furthermore, there are many construction production orders for one assembly. Considering the abrasive cleaner, an assembly in the upper construction, there are currently around five production orders for only this assembly. Figure 29 pictures the structure of production orders for the abrasive cleaner. The steel construction is the main part of the abrasive cleaner, which also has the highest processing time of this assembly. The other three production orders have a relatively short processing time; in general, the construction takes an hour at most. Thus, the hours worked on this particular assembly is spread over four production orders, while for such an assembly it can easily be on one production order. This structure in production orders is used throughout the whole production, so not only for the abrasive cleaner. The current structure makes it difficult to determine the exact number of manhours needed for this relatively small assembly. Moreover, the employees responsible for determining the cost price and analysation of the post-calculation do not have knowledge about this current structure.

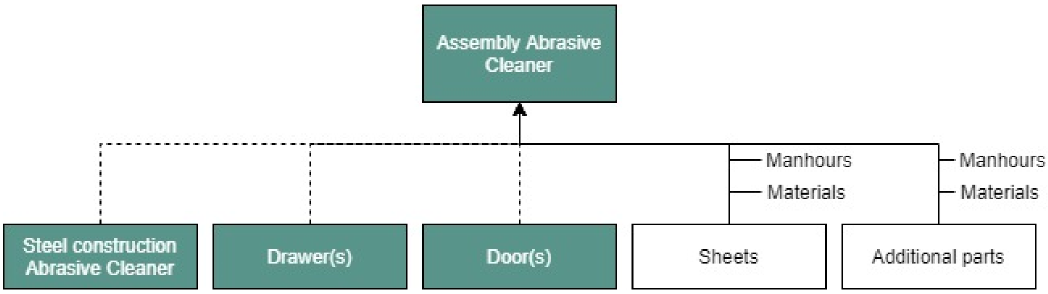


Figure 29: Assembly structure Upper Construction

It is clear that the current structure in production orders does not provide a reliable basis for the structure in the ERP. The trade-off for a new structure in the production orders that is made considers the total number of construction production orders and the level in the BOM on which the hours are registered. It is not preferred to have a large number of production orders, since this increases the number of times the production employee needs to switch between production orders. However, for determining the price of an option and creating the production planning, it is useful that data regarding the processing times of this specific part are available. A balance in the number of production orders and the level of the hour registration drivers in the BOM is found.

The new structure of the construction production orders consists of fewer and clearer production orders. The structure is based on the actual production process and flow in the factory. Each steel construction that goes separately to the surface treatment area is now considered a production order. Each of these steel constructions are standard semi-finished products. As Figure 30 shows there is only one production order for the abrasive cleaner in this new structure. The abrasive cleaner, including the drawers, doors and all additional parts, is an assembly that goes separately to the surface treatment area. The doors and drawers for example do not go to this area on its own.

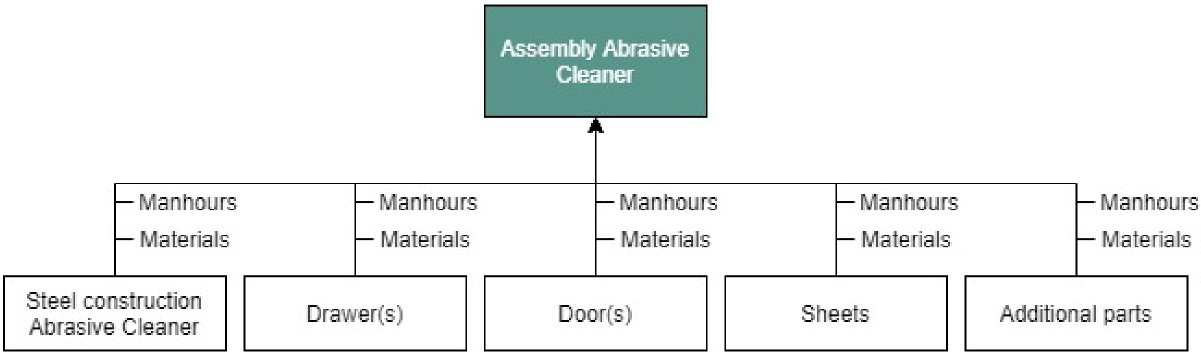


Figure 30: New structure PO Abrasive Cleaner

Due to the high processing times, the larger customers' options, such as the refilling container, have a separate production. This makes it possible to determine the cost price of important customer specific options. Moreover, the production orders are designed in such a way that it provides support for the planning and the cost price model: the production orders are the plan and cost units. Next section elaborates on the first production step: the sheet metal machining.

5.2.4 Sheet Metal Machining

The sheet metal machining department is responsible for drilling, sawing, bending and laser cutting. Many sheets need to undergo at least one of these operations; drilling, sawing or bending. The manhours worked on these production steps are based on backflush with the number of operations as variable. The production orders for drilling/sawing/bending are similar to the construction production orders. This is because, each production order is placed separately on a cart. The current structure for drilling/sawing/bending is adequate and therefore unchanged. Currently, in the laser cutting department multiple construction production orders are merged into one laser cutting production order. Let's look at the example of the upper construction again. There is only one laser production order for the upper construction, which includes all eight subassemblies. The reason behind these production orders concerns the changeover time of the laser machine and the efficient use of the raw material sheets. To reduce the changeover time of the laser machine and increase its efficiency, sheets with the same thickness are grouped. Moreover, the laser programmer nests the sheets in the most efficient way possible to reduce waste. Therefore, a laser production order comprises several construction production orders. The manhours for laser cutting are also based on backflush with net cutting time as variable, since several projects and services are cut simultaneously. The current structure in production orders is adequate for the laser cutting and also provides support for the creating the planning and determining the cost price. Therefore, the current production orders in this production step are not adjusted.

5.3 Bill of Materials

In previous section we determined the new structure in the production orders. In order to implement these production orders in the ERP, the BOM of CAD must support these production orders. In section *3.1 Bill of materials CAD* the current structure of the BOM from CAD is discussed already. The shortcoming of the structure in the BOM from CAD is that it is not in line with the production. In this section three adjustments in the BOM from CAD are discussed, where two changes are quite comprehensive. These adjustments make sure the new structure in production orders can be realized.

The first adjustment regards the layering of the BOM from CAD. In the new structure of the BOM, the number of levels in the BOM is decreased: the BOM is less layered. This makes the BOM from CAD more comprehendible. It also decreases the number of production orders that needs to be made. It is not necessary to use phantoms anymore with the new structure. We contacted the CAD-Service, so they can implement this new BOM structure. This new structure in the BOM from CAD does mean that Engineering has to change their drawing method. For every new project, the engineering department must actually engineer the design of the project: this supports project-based producing.

The second adjustment regards changing the structure of the BOM from CAD so it is in line with the production. As explained in section *3.1 Bill of materials CAD* the transport was used to illustrate the difference between the BOM structure and the production structure. The

Example 3:

Consider example 2 mentioned in section 3.1 Bill of materials CAD. Example 2 elaborated on the current structure in the BOM from CAD by using the transport as an example. Figure 31 *pictures the current structure of Transport in the BOM from CAD again, where there is a difference between the transport infeed and the transport outfeed.*

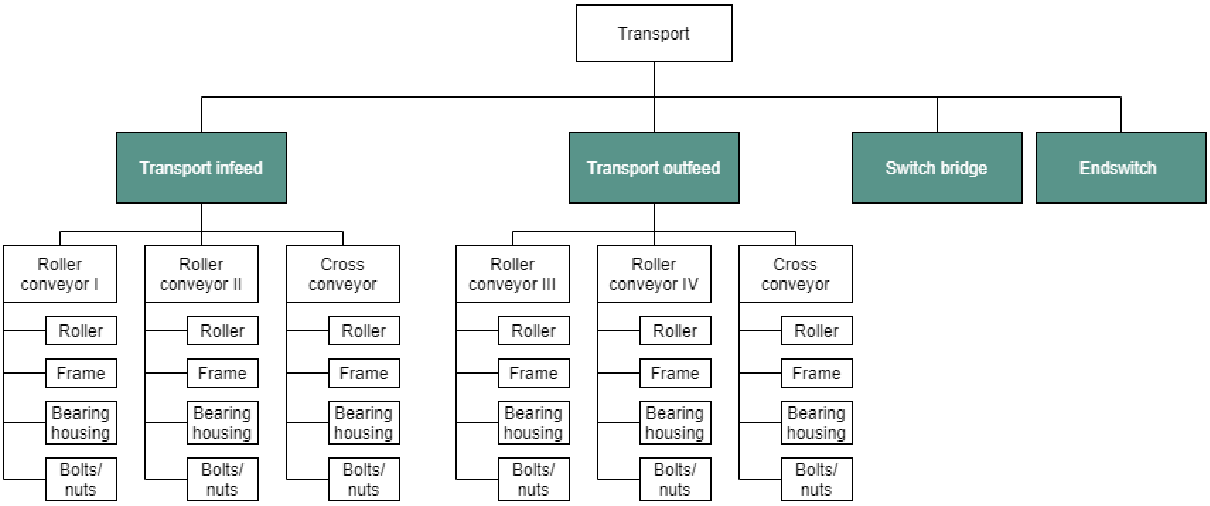


Figure 31: Current structure of the Transport in the BOM from CAD, where the green blocks are the modules (on the highest level).

Let's elaborate on the desired structure in the BOM from CAD for it in order to be in line with the production. Figure 32 *shows this new structure of the BOM regarding the transport. The BOM must be engineered in such a way it supports the production process. In the production all the roller conveyors for the complete transport of that project are produced simultaneously. Thus, there is no distinction between the infeed roller conveyors and the outfeed roller conveyors. This means that there is one laser production order for all the frames of the roller conveyors. Moreover, there is only one production order for the complete assembly of the roller conveyors. The same concept applies for the cross conveyors. With this structure the*

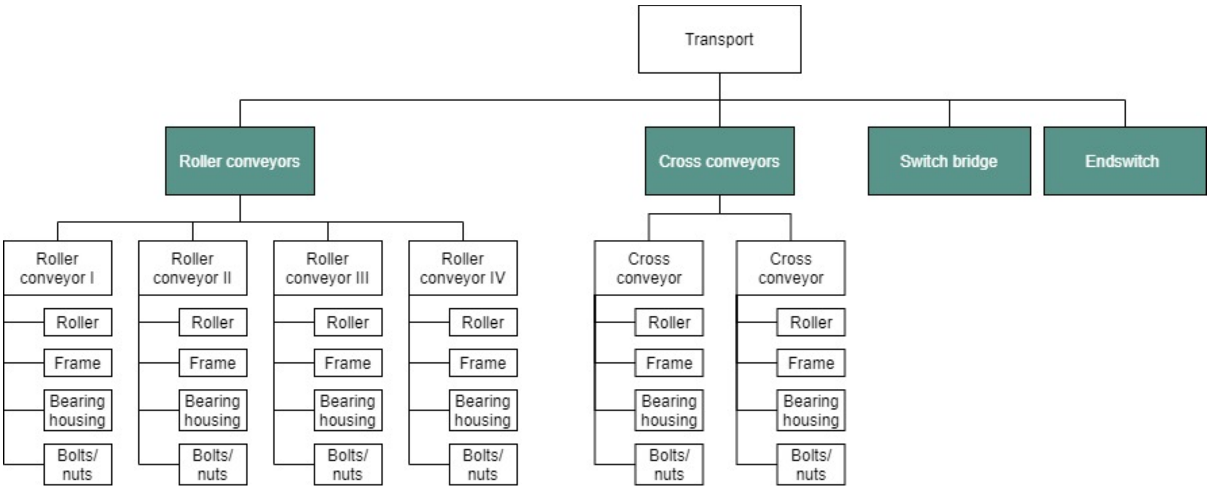


Figure 32: The desired structure of the BOM from CAD, which supports the production. The green blocks represent the modules.

The third adjustment regards the fasteners. As mentioned in *4.2 Cost price model* the fasteners are covered by the general expenses instead of directly charging the fasteners on the project. This means that the fasteners can be removed from the BOM, which simplifies the BOM.

In this section the adjustments in the input of the ERP is discussed. Next section elaborates on the some particular settings that need to be adjusted in the ERP itself.

5.4 Settings ERP

In previous section the new structure in the BOM is discussed. In this section two 'settings' in the ERP are discussed: the departments and the production tasks. As mentioned in section *4.1 Planning*, the operational planning is based on departments and tasks. After some research, it is shown that currently there are many departments and tasks implemented in the ERP. For successfully implementing the operational planning in the planning tool in the ERP, it is important that the departments and tasks match the ones available in the ERP. The next step is to link these tasks to the cost components in order to get a relevant overview of the costs of a project.

Let's first elaborate on the department aspect. During the research for this section the focus was only on the departments of the engineering and the actual production. Gietart Kaltenbach is creating a department planning in a planning tool in the ERP. Moreover, the hour rates of several departments are already determined. It is important that these departments are also implemented into the ERP. The departments, on which the planning and the cost price model are based, are the ones that are used throughout the company. These are already pictured in *Figure 5* section *2.1 Process flow.* In the current situation there are many more departments available in the ERP. Table 4 shows the new departments which are suggested for implementation in the ERP. There are several merges and adjustments made in the current number of departments to get this new structure of departments. Let's elaborate on the important changes:

1. In the current department structure, the welding department and the assembly department are considered as one department in the ERP. This is remarkable, since these two departments add the most value to the shot blasting machine. Both departments also have a large share on the total manhours worked on a project.
2. Currently there is a separate department for the production steps laser cutting and bending in the ERP. In the new structure these production steps are included in the department: sheet metal machining. This new structure Is in line with the production.
3. In the current department structure in the ERP, there are three departments for the mechanical machining. There is no difference between these departments. Therefore, two of these departments are deleted.

Let's now focus on the available tasks in the ERP. There are two types of tasks: the tasks which are directly linked to a project and the tasks which are not. On a production order, it is determined which tasks that particular order needs to undergo: the routing of that order. The production employee directly registers the hours worked on that particular task for that production order. This makes the manhours per production task per production order visible on the project. These are the tasks which are directly linked to a project. For the activities that do not have to be charged on a project directly, there exist several additional tasks.

There are several problems with the current task structure in the ERP. The first problem is regarding the number of tasks available in the ERP. In the current situation there are around 130 number of tasks for the actual production (excluded the general tasks and finance tasks). This way, it is difficult to gain clear insight into the manhours. The second problem is that the name of several tasks are misleading. This makes it difficult for the production employee to understand on which task they need to register. The second problem is that for some production steps there exist more than one task and there is no difference between the purposes of these tasks. In order to implement an operational planning on task level in the ERP, it is important that there is a clear structure in the tasks in the ERP.

In cooperation with the operation manager, the work preparation department and the production managers, we determined a new structure in tasks. This task structure supports the planning. It also influences the cost price in a positive way, since the manhours are less fragmented. The new tasks are shown in Table 4. There is one adjustment in particular we need to elaborate on:

In the new task structure, there are two new tasks added: modification and rework. The purpose of these tasks is that unforeseen activities are registered separately, since these costs should not directly be charged. The employees can register their hours on one of these tasks when an unforeseen activity occurs. Let's first explain the concepts modification and rework.

- A modification is a change or alteration, usually to make something better (Vocabulary, sd). The task modification focuses on functional mistakes of the production order. Modification is mostly caused by a mistake of the engineering. An example of a modification is when the dimension of a part is incorrect. The engineering department needs to do a modification on technical drawing.
- An unforeseen activity is rework when the production employee actually needs to re-do an activity. Rework is caused by a mistake of the production employee. An example of rework is when a part is not welded correctly. The production employee needs to recover his mistake. This is considered rework.

These tasks make the post-calculation of a project more consistent and comprehendible. It makes the analysation of the post-calculation easier, since it is easier to determine the deviations in the manhours worked on a particular production order. This provides more insight into the production and the actual manhours. Table 6 shows this cleaned-up list of departments and tasks with the corresponding numbers in BaaN.

*Table 6: The departments and tasks structure in the ERP with its corresponding ERP numbers. These are the tasks and departments only focusing on the actual production: the other departments and tasks are excluded during this research. * means that the number still needs to be determined.*

Department	Department number ERP	Task	Task number ERP
Mechanical Machining	200	○ Drilling/sawing automatic ○ Drilling backflush ○ Sawing backflush ○ Turning backflush ○ Turning ○ Rolling ○ Milling	○ 2000 ○ 2101 ○ 2104 ○ 2002 ○ 2007 ○ 3019 ○ 2101
Sheet metal machining	250	○ Laser cutting backflush ○ Bending backflush	○ 2500 ○ 2600
Welding	300	○ Welding ○ Welding robot	○ 3000 ○ 3020
Surface Treatment Area	400	○ Painting	○ 4000
Assembly	*	○ Assembly ○ Expedition ○ Testing ○ Electrical Assembly	○ 3055 ○ * ○ 3080 ○ 3070
Other		○ Rework ○ Modification	○ * ○ 3005

The next step is to draft a list of relevant cost components. These cost components form the basis of the pre/post-calculation. Each of the production tasks must be linked to these cost components.

Unfortunately, due to the time frame of this research, it was not possible to determine the relevant cost components. These cost components need to be determined in cooperation with the Finance department. This list of cost components needs to be used for both the pre-calculation and the post-calculation in order to be able to compare those calculations.

5.5 Summary

The previous section elaborated on the production orders for each production step. In order to receive the correct data from the ERP system, the structure of the production orders is adjusted. This new structure of production orders ensures that the employees are able to register their working hours correctly, which supports in receiving the correct data from the ERP. It is important that this structure in the production orders is from now on the standard method for the work preparation department. In this new production order structure the following aspects are taken into account: the wear/spare parts, the important customer specific options, the user-friendliness in the production, the cost price model and the planning.

The following adjustments in the production order structure are proposed:

- One production order for the expedition, on which the hours for the packing and sealing of the machine for the transport can be registered. The materials needed for the expedition must be linked to this production order.
- Three production orders for the mechanical assembly: the machine housing and brush/blow-off plant are merged into the production order lower construction (1), the upper construction and the additional constructions.
- One production order for the electrical assembly of the complete project.
- One production order for the testing of the complete project.
- One production order for the small cabin of the surface treatment area. Each module that is painted separately at the larger cabin needs a production order: machine housing, inner frame brush/blow-off plant, outer frame brush/blow-off plant and the frame upper construction.
- Each steel construction that enters the surface treatment area separately, is considered a production order at the welding department.
- The production orders at the sheet metal machining must be in line with the production order's at the welding department: all materials used for the production order machine housing must be undergo the production steps turning and bending simultaneously.

In order to implement this new production order structure, the BOM in CAD must be adjusted. In the new structure of the BOM, the number of levels in the BOM is decreased: the BOM is less layered. The second adjustment regards changing the structure of the BOM from CAD so it is in line with the production.

For successfully implementing the operational planning in the planning tool in the ERP, it is important that the departments and tasks match the ones available in the ERP. The new following departments need to be implemented in the ERP: mechanical machining, sheet metal machining, welding, surface treatment area and assembly. A cleaned-up list of production steps is created. Two important production tasks, which ensure the accuracy of the post-calculation, are added: modification and rework.

In the next chapter a estimation of the throughput times of the production orders are estimated.

Chapter 6: Estimation of the throughput times

In this chapter an estimation of the manhours of each production order is made and explained. It is clear that currently the ERP does not provide accurate manhours. It is important that the output of the ERP is evaluated when the new design and working method is implemented. The performance of the new design should be evaluated. This can be done by comparing the data provided by the ERP with the estimation of the manhours, which is made in this section. Thus, this section provides the basis for evaluating the criteria 'The ERP must provide accurate manhours of each task of the production order' when the new ERP design is implemented. First the methods, on which the estimation is based, are described. In Appendix X the estimated manhours of each production task for every production order are discussed.

There are several sources available within Gietart to make an accurate and reliable estimation of the manhours of the reference machine. The manhours for each production order per production step can be based on the data provided by the ERP, the estimation by the production employees and the manually measured hours. The sources are briefly explained below.

- **Manhours ERP:** The manhours registered on the production orders of a project are retrieved from the ERP. The post-calculations from two Sprint 1504 projects are taken for the estimation of the manhours. Due to the similarities between the Sprint 1504 and the Sprint ECO, the data of the Sprint 1504 can be used for the estimation of manhours of the Sprint ECO. However, there are several important production orders that are not directly linked to a project but are produced on stock. The manhours registered on these orders need to be examined separately. At least two different production orders are analysed.
- **Estimation by the production employees:** The manhours of each task of every production order is estimated by the two production managers. Since, the estimation is based on the experience of two employees, the estimation is more reliable than when it is made by one employee.
- **Measured hours:** During the research, the newly developed machine, the Sprint ECO, is introduced. The manhours of this machine are manually measured by the author during the research. Unfortunately, not all production orders were produced during the time frame of this research. Therefore, this data is not complete.

Data from these three sources are not available for all production orders. It is not possible to base the manhours of the production orders on just one of these sources. Therefore, it is chosen to use the Program Evaluation and Review Technique (PERT) in some situations. Program Evaluation Review Technique (PERT) is a project management planning tool used to calculate the amount of time it will take to realistically finish a project (Wrike, 2021). By using PERT a reliable estimation of the number of manhours can be determined. The PERT formula is as follows:

$$Manhours = \frac{O + 4M + P}{6}$$

The variables of the PERT formula are defined as follows (Heizer, Render, & Munson, 2017):

Optimistic time (O) =	time an activity will take if everything goes as planned.
Most likely time (M) =	time an activity will take assuming very unfavourable conditions.
Pessimistic time (P) =	most realistic estimate of time required to complete an activity.

The throughput times of each production is pictured in *Appendix E – Throughput times in manhours per module*. *Appendix D – Data gathering throughput times (manhours)* elaborates on the method of the data gathering.

This estimation of the throughput times is used for two purposes. The first purpose of this data is to provide insight into the actual throughput times. This makes it easier for the work preparation department to create a reliable pre-calculation of a production order. The work preparation department bases from now on the pre-calculation on this data. Moreover, it is used to evaluate the new design of the ERP. It can be used to analyse whether the data provided by the newly designed ERP is accurate.

Chapter 7: Evaluating the ERP design by assessing the list of requirements

This chapter evaluates the proposed ERP design (*Chapter 5: The ERP Design)* by using the previously defined list of requirements/criteria (section *4.4 Coming to the end list of requirement/criteria*). In this chapter, for each criteria of this list it is evaluated whether the proposed ERP meets the criteria.

Sections:

7.1 The criteria the proposed ERP design meets

This section elaborates on the criteria which are the proposed ERP design meets. It focuses on the criteria that are already implemented into the ERP: criteria one and criteria two.

Criterion 1: Defining one production order structure for all projects

During this research a new production order structure is defined. A condition of the new production order structure is that is it applicable for all projects: it must be possible to implement the new production order structure for all types of machines. The new production order structure is based on the sub-assemblies that go separately to the welding. Moreover, it considers the customer specific options and the wear parts. The general idea of this production order structure is easily applicable for all machine types. When implementing the production orders structure for a machine type, it is important that the wear parts and important customer specific options of that specific machine type are determined beforehand. The production orders for each machine type will probably slightly differ, since the modules of the machines have small differences. However, the idea behind the production order structure is applicable for all types of projects.

Criterion 2: Defining the module level within the production order structure

At the start of this research, we soon came across the following problem: the fragmentation of the manhours due to the large number and unclear structure of the production orders. During the design of the new production order structure, we determined the module level within the production order structure. In the new production order structure, each sub-assembly that goes separately to the welding department is considered a module. Thus, each sub-assembly that is welded separately is considered a production order. We defined these sub-assemblies, which are pictured in Appendix X. The production orders are the plannable units, so it the production order structure support with creating the project planning. Moreover, the production orders are also the cost units. The manhours of each important customer specific option and each wear parts are registered separately, which makes it possible to determine the cost price of that particular component.

7.2 The criteria that still needs to be implemented in the ERP

This section elaborates on the criteria that are partly met: criteria three, criteria five and criteria six. The basis for these criteria is made during the research. Only the implementation into the ERP and the evaluation still needs to be performed.

Criterion 3: Determining relevant departments and tasks in the ERP

In section *5.4 Settings ERP,* we lined up a list with relevant departments and production tasks. This list is drafted in cooperation with the operation manager, the work preparation department and the production managers. It is important that this list of departments and tasks represents the actual departments and production tasks used in the production. However, unfortunately we were not able to implement the new list of departments and tasks in the ERP within the time frame of this research. It is recommended that the BaaN specialist working at Gietart focuses on the implementation. After some time, the list of departments and tasks must be evaluated to analyse whether all tasks are necessary.

Criterion 6: Registering the manhours of unforeseen activities separately
In the department and task list, two interesting tasks for these criteria are added: modification and rework. The idea is that the production employees register their working hours on these tasks, when these hours do not have to charged directly to the customer. These unforeseen activities are pictured separately on the post-calculation of a project. This provides more insight into the production process. As mentioned before, we were not able to implement the list of departments and tasks into the ERP within the time frame of this research. After the implementation of this list in to the ERP, it is important the meaning and the purpose of the tasks modification and rework are made clear. This should be done by presenting several circumstances with the intended task. It is important that the production employees know exactly when to register their working hours on these two tasks.

7.3 The criteria the proposed ERP design does not meet (yet)

This section elaborates on the criteria that the proposed ERP does not meet (yet): criteria four, criteria seven and criteria eight. Criteria four and criteria eight are met when the other criteria are successfully implemented into the ERP. To meet criterion seven a new research must be started.

Criterion 4: Receiving accurate manhours on the post-calculation by the ERP
This criterion is (hopefully) the immediate result of the implementation of the other criteria. When the new production order structure is completely implemented into the ERP for all machine types, then it is likely that the manhours provided by the ERP are accurate. However, to actually test the accuracy of these manhours, they must be tested. This can be done by comparing the manhours provided by the ERP with the estimation of the manhours which is made in *Chapter 6: Estimation of the process times.* The deviation between these two datasets the deviation must be a maximum of 10%. Otherwise, the cause of this deviation must be analysed/investigated.

Criterion 5: Receiving a clear cost overview of a project by the ERP
Unfortunately, within in the time frame of this research it was not possible to create a list of cost components. These cost components need to be determined in cooperation with the Finance department. This list of cost components needs to be used for both the pre-calculation and the post-calculation in order to be able to compare those calculations.

Criterion 7: Implementing accurate hour rates in the ERP
At the start of this research, another research into the cost allocation and the hour rates was executed. However, due to circumstances that research is not finished. Therefore, there are no accurate hour rates available yet, which makes it difficult to implement these into the ERP. It is recommended to restart the research into the cost allocation and the hour rates.

Criterion 8: Receiving accurate WIP and backlog by the ERP
This criterion is a result of a successfully designed ERP. When this criterion is met, it contributes to the solving of the action problem of this research: ‘Gietart is not able to communicate relevant information to its customers’. Within the time frame of this research, it was not possible to implement the proposed ERP design completely. When all the criteria of the ERP are met, the ERP should provide an accurate WIP and backlog. It is important to test, whether the WIP and backlog provided by the

ERP represents the reality. This can be tested by comparing the WIP and backlog provided by the ERP with the actual WIP and backlog. The deviation between this comparison may be at most 10%. When the difference is below 10%, this criterion is considered as achieved. When the difference is higher than 10%, the cause of this difference must be investigated. Then, this criterion is considered as not achieved.

7.4 Summary

This chapter evaluated the list of requirements/criteria of the ERP. A distinction is made between the criteria it meets, the criteria that still need to be implemented and the criteria it does not meet (yet).

The following are met with the proposed ERP design:

- Criterion 1: Defining one production order structure for all projects
- Criterion 2: Defining the module level within the production order structure

The following criteria need to be implemented into the ERP still:

- Criterion 3: Determining relevant departments and tasks in the ERP
- Criterion 6: Registering the manhours of unforeseen activities separately

The following criteria are not met (yet):

- Criterion 4: Receiving accurate manhours on the post-calculation by the ERP
- Criterion 5: Receiving a clear cost overview of a project by the ERP
- Criterion 7: Implementing accurate hour rates in the ERP
- Criterion 8: Receiving accurate WIP and backlog by the ERP

Chapter 8: Conclusion & Recommendations

Within this thesis, we determined several criteria the ERP must meet in order to provide accurate data for both the planning, the cost price model and the pre/post-calculation. Through analysing the current processes and its shortcomings, a suggestion for the new ERP design is made. Within this research, we elaborate on the majority of the criteria we determined. In this chapter the conclusions and the recommendations of this research are presented. It also elaborates on possible further research subjects, which resulted from evaluating the list of requirements/criteria of the ERP. As last, a discussion is made where limitations of this research are discussed.

Sections:

8.1 Conclusion

The motivation behind this research is that Gietart is not able to give reliable information to the customer regarding the progress and the cost price of the project. This bachelor thesis presents an improvement on the following core problem: 'The ERP does not provide the correct/reliable data'. This core problem is translated into the following main research question:
'To achieve its defined goals, which criteria must Gietart's ERP meet regarding the design and working method?'
The defined goals of Gietart are:

1. To realize a project planning.
2. To design a transparent cost price model, where the price of the customer specific options can easily be determined.
3. To be able to realize an accurate pre-calculation and post-calculation, which can be easily compared.

To answer this research question, several sub-questions have been formulated and are answered throughout this research. First, a qualitative research was executed to gain knowledge on the current situation around the design of the ERP, the project planning, the cost price model and the pre/post-calculation. During this qualitative research, the desired situation of the ERP, project planning, cost price model and pre/post calculation is determined. This resulted in a list of requirements/criteria the ERP must meet. Moreover, a quantitative analysis is done on the process times of all production orders of the Sprint ECO. For this quantitative analysis, the manhours of the Sprint ECO are manually measured. The purpose of this analysis is to gain insight into the process times of the production orders. It can also be used to test whether the data provided by the newly designed ERP is accurate.

The following conclusions regarding the shortcomings can be stated:

- The current structure of the BOM from CAD is not in line with the method of production. The way the technical drawings are constructed by engineering does not match the production process. This structure in the BOM causes shortcomings in the production order structure.
- In the current situation, the manhours are fragmented over the large number of production tasks available. Creating a planning on production task level is impossible with this large number of production task.

The following conclusions regarding the new ERP design can be stated:

- A new production order structure is determined. The module level within the production order structure balances the level of detail and the effective steering level. This structure supports both the planning and cost price model. The module level is based on the concept 'the highest manageable unit'. It must be possible to implement the production order structure for all types of projects.
- In order to successfully implement the new production order structure, the structure in the BOM configured by CAD (the input of the ERP) needs to be adjusted. In the new structure of the BOM, the number of levels in the BOM is decreased: the BOM is less layered. The second adjustment regards changing the structure of the BOM from CAD so it is in line with the production.
- A cleaned-up list with only relevant tasks and department enables both the realization of the project planning and the allocation of the department costs.
- A cleaned-up list of relevant cost components is made. The ERP must provide a clear pre-calculation and post-calculation. These calculations must be easily comparable, which implies that the structure of the pre-calculation and the post-calculation must be similar. It is important that the pre-calculation and the post-calculation provide insight into the important (estimated) cost types. The structure of the calculations is based on the cost components implemented in the ERP.
- To increase the reliability and accuracy of the pre-calculation, a pre/post-calculation method is discussed. This method implies that the post-calculation must be analysed and compared to the pre-calculation of the project. When there are great deviations between these calculations, the cause of this deviations must be determined. If this deviation can be considered as constant, the pre-calculation of this production order must be adjusted.
- The hour rates of the departments, machines and employees must cover the total costs. These hour rates must cover all costs for that specific task/department including indirect costs such as rent, depreciation and electricity. The way the costs are allocated, and the hour rates are retrieved, must match the structure of the organisation.

Next section elaborates on the recommendations for Gietart Kaltenbach.

8.2 Recommendation & Further Research

Based on the evaluation of the list of requirements/criteria (*Chapter 7: Evaluating the ERP design by assessing the list of requirements*), we set up a list of recommendations for Gietart Kaltenbach. Some of the recommendations translated into further research. First the list of recommendations is discussed:

- In order to receive accurate and reliable data from the ERP, it is recommended to design the ERP taking the defined list of requirements into account.
- During the research, we already recommended to adjust the BOM structure in CAD. The new structure has fewer level, which means that the BOM is less layered. Moreover, the new BOM structure is in line with the production process. We have contacted the CAD-Service and they will perform the adjustments, which makes it possible to engineer the machines in the proposed way.
- The new production order structure must be the basic engineering method. All the employees must understand this new production order structure.
- The new list of departments, tasks and cost components configured in section *5.4 Settings ERP* needs to be implemented into the ERP. It is important that the 'old' tasks/departments/cost components numbers are reused as much as possible. When a number is unnecessary, the number must be set offline instead of deleted. Otherwise, the

hours registered on these tasks/departments/cost components in past projects are deleted. This influences the pre/post calculation of past projects negatively.
- All of these recommendations include great changes that will require a lot of adaptability of the employees. During the implementation and further researches, it is important to take into account the preferences of the employees. The employees must be actively involved during the changes by the board.
- In *Chapter 6: Estimation of the process times* an estimation is made for the process times of each testable production order. It is important when all the recommendations above are implemented/taken into account that the data provided by the newly designed ERP is tested. It is important to test whether the data provided by the ERP is accurate and reliable after the adjustments made. It is useful to know whether the core problem 'The ERP does not provide correct/reliable data' is solved. This can be done by comparing the data provided by the ERP with the estimation made in *Chapter 6: Estimation of the process times.* The deviation between these data sets must be at maximum 20% (taking into account the learning curve, since it is a newly developed machine). Then, we successfully solved the core problem.

This research is conducted in a scope of fifteen weeks. Therefore, several recommendations were translated into a further research. It is recommended to start a research on the following aspects:

- As explained throughout this research, several components/modules are placed on stock using the fixed stock price. The fixed stock price is determined several years ago and not tested since. The post-calculation of these is components are absent. In order to receive complete insight into the actual costs/hours of a project, it is useful to decrease the number of components which are placed on stock by the fixed stock price. It is recommended to start a research on decreasing the number of components placed on stock by the fixed stock price.
- The manhours of several departments are determined via backflush (section *3.5 Pre-calculation and post-calculation).* The backflush is determined several years ago and not tested since. Gietart has no control over the departments that are backflushed. Therefore, it useful to start a research that focuses on finding alternative methods of accounting for the departments that currently use backflush.
- It is recommended to start a research that focuses on the hour rates of the machines, employees and departments. The cost allocation must be improved in order receive hour rates that covers the total costs (including the indirect costs) of Gietart.

8.3 Contribution

This section elaborates on the theoretical and practical contribution of this research.

8.3.1 Theoretical contribution

During this research, a literature study into the change management is performed. This concept has already been stated by Kotter (1992). Therefore, the theoretical contribution focuses more on the method of redesigning an ERP system in a production oriented company. It provides a framework for the redesign of an ERP system including the considerations that need to be taken into account. It also provides the method on how to great a list of requirements/criteria.

8.3.2 Practical contribution

This research is performed at Gietart Kaltenbach. The practical contribution of this research are the list of requirements/criteria, the design and implementation of the new production order structure, the list of tasks/departments/cost components in the ERP and the estimation of the process times of all production orders of the Sprint ECO. This research contributes to the reorganization of Gietart Kaltenbach.

8.4 Discussion

There are two aspects that limit the accuracy of this research. These limitations are explained below:

- During this research, we defined a new production order structure in cooperation with the involved. This production order structure is accepted by Engineering, the work preparation department, Finance, After Sales and the Production. However, during the implementation of the new production structure it is likely problems will occur. It is likely that in the reality several components still need to have a separate production order. Therefore, it is likely that small adjustments are implemented in the production order structure we proposed during this research.
- During this research, we manually measured the manhours on the production orders of the newly developed shot blasting machine: The Sprint ECO. The quantitative analysis into the process times is partly based on the data we measured. However, since this is the first time this shot blasting machine is produced, it is possible that the actual needed manhours are lower than we measured. This can be explained by the learning curve of the employees. This has a negative impact on the accuracy of the quantitative analysis.

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Appendices

Appendix A – Systematic Literature Research

A.1 Research questions and definitions

Research question: What are the important principles of change management?
Change management: Plan, initiate, realize, control, and finally stabilize change processes on both corporate and personal level (Recklies, 2001).

A.2 Inclusion and exclusion criteria

Table 7: Inclusion criteria

Nr.	Criteria	Reason for inclusion
1	Industry companies/organizations	The focus is on industry organizations
2	Transitional change	The organization is going through a transitional change

Table 8: Exclusion criteria

Nr.	Criteria	Reason for exclusion
1	Not-cited research	Cited research indicate quality
2	Language different than Dutch or English	Translating a paper is difficult and error prone.
3	Research only applicable to large enterprises	The research is conducted in a relatively small company. In general, the work culture in a small company differs from a large enterprise.

A.3 Databases

The databases that will be used for this research are Google Scholar, SCOPUS, Web of Science and Business Source Elite.

A.4 Search terms and strategy

Table 9: Search terms and strategy

Key concepts	Synonyms/related terms
Change management	“Managing change”
Post-Implementation	“implementation”, “pre-implementation”
John Kotter	
Ackerman Anderson	

First, the focus will be on change management in general. Articles exploring change management will likely immediately focus on theories and the value it can add.

A.5 Search log

Table 10: Search log

Platform	Search strings	Hits	Date search	Scope
Google Scholar	"Change Management"	4.000.000	7-4-2021	Articles
Google Scholar	"John Kotter"	28.400	7-4-2021	Articles
Google Scholar	"John Kotter" & "Change management"	34.500	9-4-2021	Articles
Google Scholar	"Change Management" & "Ackerman Anderson"	5.300	9-4-2021	Articles
Web of Science	"Change Management"	382.617	12-4-2021	Title, keywords, abstract
Web of Science	"John Kotter"	38	12-4-2021	Title, keywords, abstract
Web of Science	"John Kotter" & "Change management"	19	12-4-2021	Title, keywords, abstract
Web of Science	"Change Management" & "Ackerman Anderson"	2	12-4-2021	Title, keywords, abstract
Business Source Elite	"Change Management"	3795	12-4-2021	Scholarly journals/books
Business Source Elite	"John Kotter"	1246	12-4-2021	Scholarly journals/books
Business Source Elite	"John Kotter" & "Change management"	6	12-4-2021	Scholarly journals/books
Business Source Elite	"Change Management" & "Ackerman Anderson"	1	12-4-2021	Scholarly journals/books
SCOPUS	"Change Management"	78276	7-4-2021	Title, keywords, abstract
SCOPUS	"John Kotter"	69	7-4-2021	Title, keywords, abstract
SCOPUS	"John Kotter" & "Change management"	45818	9-4-2021	Title, keywords, abstract
SCOPUS	"Change Management" & "Ackerman Anderson"	0	9-4-2021	Title, keywords, abstract

The results from 'Change Management' were compiled by Google Scholar, Web of Science, Business Source Elite and SCOPUS, which resulted in many hits. An inspection into the articles yielded that many articles without "John Kotter" and "Ackerman Anderson" were too broad for the use of this study. Therefore, the search term is narrowed down. Moreover, several articles were not accessible. Table 11 presents the articles used in for the literature study.

Table 11: Literature used for this study

	Authors	Title	Year
1	Anderson, Dean; Ackerman, Linda	Beyond Change Management: Advanced Strategies for Today's Transofrmational Leaders	2002
2	Heckelman, Wendy	Five Critical Principles to Guide Organizational Change	2017
3	Kenneth, H.	Leading Change: A model by John Kotter	2002
4	Kotter, John	Winning at Change	1998
5	Kotter, John	Corporate Culture and Perfomance	1992
6	McKinsey&Company	Changing change management	2015
7	Palmer, Ian	Who says change can be managed? Positions, perspectives and problematics	2002

A.6 Concept matrix

Table 12: Concept matrix

Article nr.	John Kotter Principles	McKinsey&Company Principles	Anderson & Ackerman Principles
1			■
2	■	■	■
3	■		
4	■		
5	■		
6		■	
7	■	■	■

A.7 Integration of theory

See section 1.8 of the report.

Appendix B – Business Process Model & Notation

The business process from a customer request to delivery of the machine is visualized using the Business Process Model and Notation (BPMN). This is visualized in Figure 33 and Figure 34.

visualizes the business process where it starts with the customer order and ends with the transport of the order. Gietart cooperates with an agency, which is located in several countries. The agency receives all the requests for shot blasting machines and makes some suggestions for a suited company for this specific order. Then, the sales department of Gietart makes, in cooperation with the agency, the quotation for the machine. In this part of the process, the customer has several quotation requests at companies. Therefore, the customer is still able to decline the quotation and choose another company. When the customer is still interested in Gietart the next step is to determine the customer's options and to investigate the environment for the machine at the customer's plant. As mentioned before, the customer is able to add several options at additional costs to the layout and the structure of the machine.
At the same time, the engineering department of Gietart is looking at the floor map of the customer's factory to determine a sufficient spot for the shot blasting machine. When both the options and the environment are determined a sales design is created. The R&D department designs the machine to the customer's preference. This is the last moment a customer can choose to decline the offer. When the order is approved and the deposit has been made, the design phase can start.

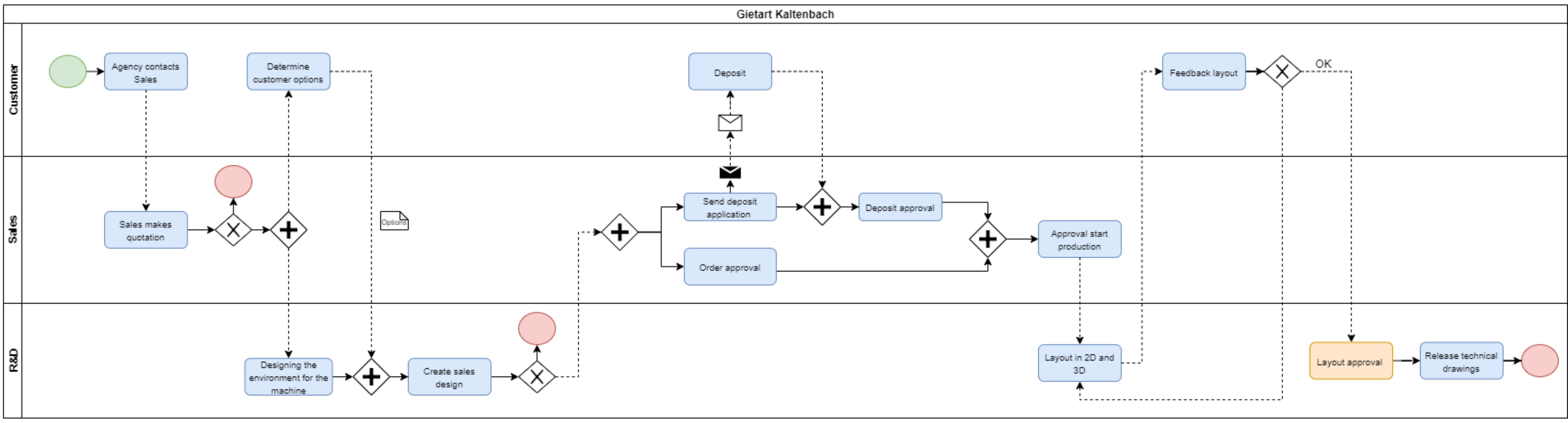


Figure 33: Business process; customer, Sales and R&D

The R&D department will create 2D and 3D design of the machine using the software CAD. Moreover, they make a 3D design of the customer's factory and the new machine located in it. CAD stands for Computer Aided Design (and/or drafting, depending on the industry) and is computer software used to create 2D and 3D models and designs (Smartdraw, 2021). The layout will be sent to the customer for the approval. The layout approval is in important step in the business process. This step indicates the start of the production of the shot blasting machine. The technical drawings are released and dumped in the ERP system. Afterwards, these drawings will be programmed by the Plan & Engineering department for the laser machine. Then the production starts. The Sprint 1504 follow the following steps: lasering, sawing, bending, drilling, construction, welding, painting and assembly consecutively. During the production, the transport papers, the transport company and loading lists are arranged.

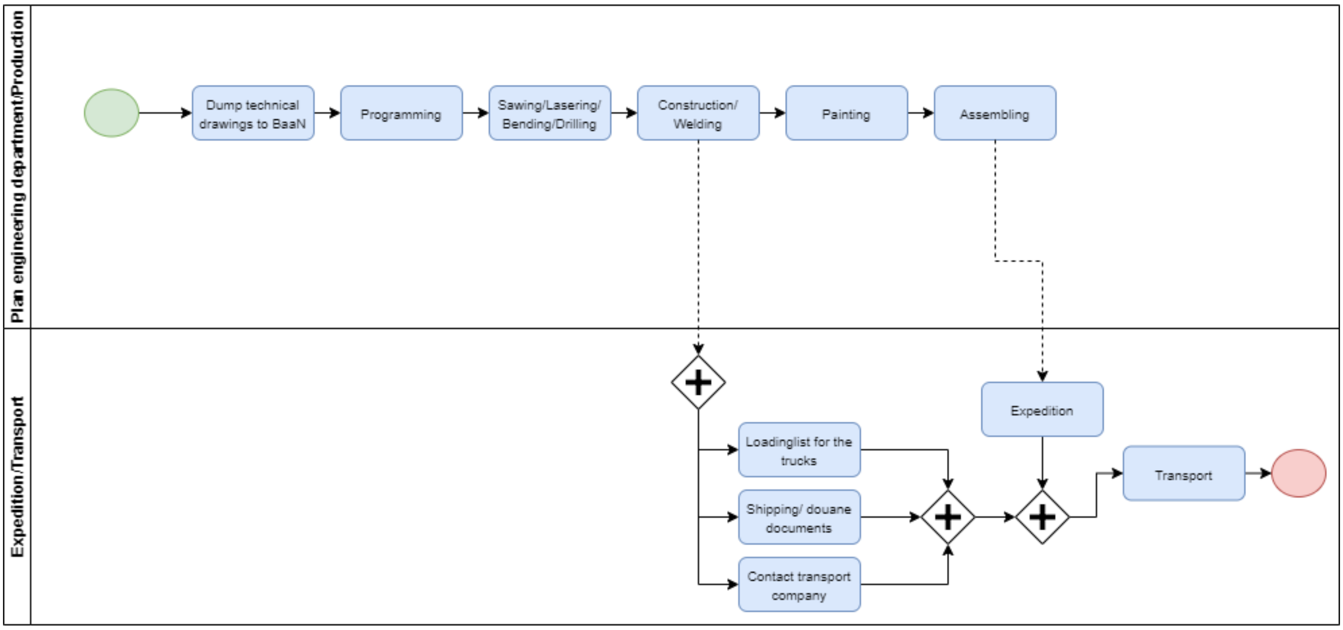
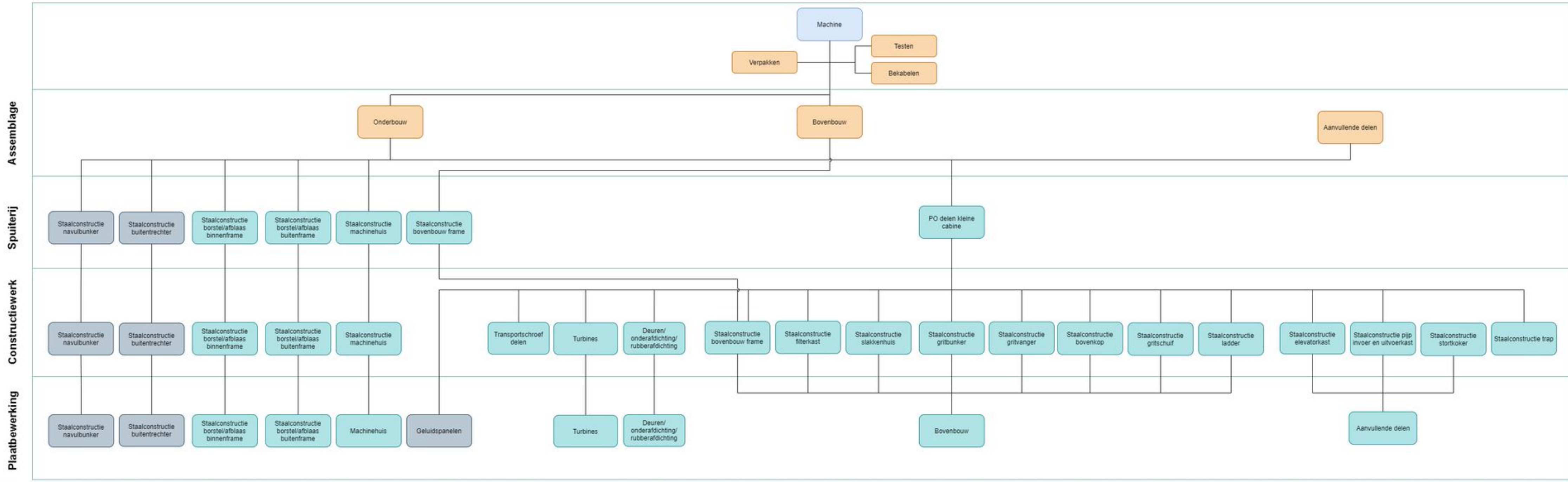


Figure 34: Business process; work preparation, engineering, production

Appendix C – The work breakdown structure for the production orders

The work breakdown structure of the production is pictured below. The production order structure is visualized in Dutch, since it is a direct deliverable for Gietart Kaltenbach.



Appendix D – Measured throughput times

During this research, we manually measured the manhours worked on a production order in order to gain insight into the actual throughput times of the newly developed machine, the Sprint ECO. Unfortunately, it was not possible to measure the manhours of all production due to the time frame of this research: not all production orders have bene produced.

Row Labels	Gemeten manuren
136949 Machinehuis KA	100
136857 Buitenframe	27
136990 Binnenframe	19
137141 HD buitenframe	22
137185 HD binnenframe	10
137367 Gritvanger	6
137492 Gritbunker	8
137460 Filterkast	14
Grand Total	**205**

Figure 35: Manually measured manhours of the production orders Sprint ECO

Appendix E – Data gathering throughput times (manhours)

In the next sections, the manhours of each production order per department are discussed. Almost all production orders are translated to Dutch, since these terms are used throughout the whole organisation. As this estimation of manhours is important for the organisation, it is useful to mention the Dutch terms in addition.

E.1 Expedition

The number of manhours worked on expedition (Table 13) is based on the estimation of the two production managers. This is because, the manhours are currently not registered on a production order; it is covered by the general costs. Therefore, the ERP does not provide manhours for the expedition. Moreover, the expedition of a Sprint 1504 is not measured.

Table 13: Manhours Expedition

Production Order	Manhours
Expedition	16

E.2 Assembly

For the mechanical assembly, the post-calculations of two similar projects are provided by the ERP. However, these manhours do not cover the complete number of manhours worked on the final assembly. The reason behind this is already covered throughout the research. Because of this the manhours provided by the ERP are lower than the actual manhours. Therefore, the manhours for final assembly are based on the estimation of the production managers.

Table 14: Manhours Mechanical Assembly

Production Order	Manhours
Assembly upper construction (Dutch: bovenbouw)	60
Assembly lower construction (Dutch: onderbouw)	120
Assembly additional constructions (Dutch: aanvullende delen)	8

Regarding the electrical assembly, there are currently several production orders. The manhours for electrical assembly on these production orders are collected and summed up. Moreover, an estimation of the production managers is also available. Since, there is more data available regarding the manhours of electrical assembly, the PERT formula is applied (Table 15).

Table 15: Manhours Electrical Assembly

Production order	Manhours
Electrical assembly	42

E.3 Surface Treatment Area

As mentioned before, a distinction is made in the surface treatment area: the small cabin and the large cabin. Currently, the manhours of the surface treatment area are covered by the general costs and not directly registered on a project. The production managers have estimated the processing time for a semi-finished product in the large cabin and the processing time of one cross beam. The throughput time is therefore based on the estimation of the production managers (Table 16).

Table 16: Processing Time surface treatment area

Painting cabin	Processing time (h)	Times needed	Total processing time (h)
Small cabin	3	30	90
Large cabin	4	4	16
			106

E.4 Welding

There are several steel constructions which are not linked to a project. Therefore, for these steel constructions three different production orders are collected from the ERP. Moreover, the estimation from the production managers is also available for these steel constructions. Therefore, there were in general four data points available. Furthermore, the machine housing and the outer frame of the brush/blow-off plant is measured once and twice respectively.

However, there is one sidenote regarding the manhours of the machine housing provided by the ERP; these manhours are not accurate for the estimation of the machine housing of the Sprint ECO. This is because in the infeed tunnel and the machine housing are produced as one semi-finished product for the Sprint ECO, which was not the case for the Sprint 1504. Therefore, the manhours provided by the ERP were not reliable for making an estimation regarding the manhours of the Sprint ECO. Thus, the estimation is based on the manually measured hours (which is done twice for the machine housing) and the estimation by the production managers.

The machine housing of the Sprint ECO is measured manually twice. The difference between the manhours can be explained by the learning curve. Any employee, regardless of the position, takes time to understand and gain experience to execute a certain task. A learning curve is a visual representation of the relation between the learning and the labour time on a certain task (Maslow, 1943). In general, when a person executes a task frequently, the labour time will decrease. The manhours worked on the second machine housing decreased with about 16% with respect to the first machine housing.

Due to the large amount of data points available, PERT is applied for estimating the manhours on welding for the other steel constructions. (Table 17)

Table 17: Manhours welding

Production order	Manhours
Steel construction machine housing (Dutch: machinehuis)	100,1
Steel construction inner frame brush/blow-off plant (Dutch: binnenframe borstel/afblaas)	15,0
Steel construction outer frame brush/blow-off plant	24,5
Steel construction upper construction frame (Dutch: bovenbouw frame)	12,0
Steel construction abrasive cleaner (Dutch: bovenkop)	17,1
Steel construction abrasive separator (Dutch: gritvanger)	7,0
Steel construction abrasive control plate (Dutch: gritschuif)	1,6
Steel construction abrasive container (Dutch: gritbunker)	7,2

Steel construction filtration box (Dutch: filterkast)	17,4
Steel construction spiral pacing (Dutch: slakkenhuis)	4,0
Steel construction additional parts (Dutch: aanvullende delen)	16,0

E.5 Sheet metal machining

The data provided by the ERP regarding the sheet metal machining are based on the backflush hours. The backflush is determined several years ago and is not tested since. The backflush hours do not cover the complete manhours worked in this production step. The time necessary for loading the laser cutting machine with the raw material and unloading the sheets are not included in the backflush hours. This data is not accurate for the project planning. A sample of four measurements was taken and this resulted in the following: the estimation time corresponds to the measured hours of the tasks. It is therefore possible to take the estimation time as processing time.

Production order	**Manhours**
Machine housing	24
Inner frame brush/blow-off plant	4,5
Outer frame brush/blow-off plant	11
Upper construction	22,5
Steel construction abrasive cleaner (Dutch: bovenkop)	17,1
Additional constructions	3,5

Appendix F – Throughput times in manhours per module

A pivot table of the estimation of the throughput times is made in Excel. The data gathering method is already explained in *Appendix E – Data gathering throughput times (manhours).*

Table 18: Screenshot pivot table Excel

Rijlabels	Som van Manuren
Assemblage aanvullende delen	**8,0**
Eindassemblage	8,0
Assemblage bovenbouw	**60,0**
Eindassemblage	60,0
Assemblage onderbouw	**120,0**
Eindassemblage	120,0
Aanvullende delen	**19,5**
Constructiewerk	16,0
Kanten/boren/zagen	1,5
Laseren	2,0
Geluidspanelen	**5,0**
Constructiewerk	0,0
Kanten/boren/zagen	3,0
Laseren	2,0
Module deuren (incl. onderafdichting/rubberafdichting)	**6,0**
Constructiewerk	4,0
Kanten/boren/zagen	1,0
Laseren	1,0
Staalconstructie machinehuis	**124,1**
Constructiewerk	100,1
Kanten/boren/zagen	6,0
Laseren	18,0
Staalconstructie binnenframe borstel/afblaas	**19,4**
Constructiewerk	14,9
Kanten/boren/zagen	2,0
Laseren	2,5
Staalconstructie buitenframe borstel/afblaas	**35,5**
Constructiewerk	24,5
Kanten/boren/zagen	2,5
Laseren	8,5
Staalconstructie bovenbouw frame	**17,0**
Constructiewerk	12,0
Kanten/boren/zagen	2,0
Laseren	3,0
Staalconstructie bovenkop	**19,6**
Constructiewerk	17,1
Kanten/boren/zagen	1,0
Laseren	1,5
Staalconstructie filterkast	**22,4**
Constructiewerk	17,4
Kanten/boren/zagen	3,0
Laseren	2,0
Staalconstructie gritbunker	**11,7**
Constructiewerk	7,2
Kanten/boren/zagen	2,5
Laseren	2,0

Staalconstructie gritschuif	**3,1**
Constructiewerk	1,6
Kanten/boren/zagen	0,5
Laseren	1,0
Staalconstructie gritvanger	**10,0**
Constructiewerk	7,0
Kanten/boren/zagen	2,0
Laseren	1,0
Staalconstructie slakkenhuis	**4,9**
Constructiewerk	3,9
Kanten/boren/zagen	0,0
Laseren	1,0
Staalconstructie navulbunker	**18,1**
Constructiewerk	11,1
Kanten/boren/zagen	5,0
Laseren	2,0
Testen en bekabelen onderbouw/bovenbouw	**42,0**
Testen/bekabelen	42,0
Transportschroeven	**11,0**
Constructiewerk	11,0
Kanten/boren/zagen	0,0
Laseren	0,0
Turbines (4 stuks)	**19,0**
Constructiewerk	16,0
Kanten/boren/zagen	0,0
Laseren	3,0
Eindtotaal	576,2