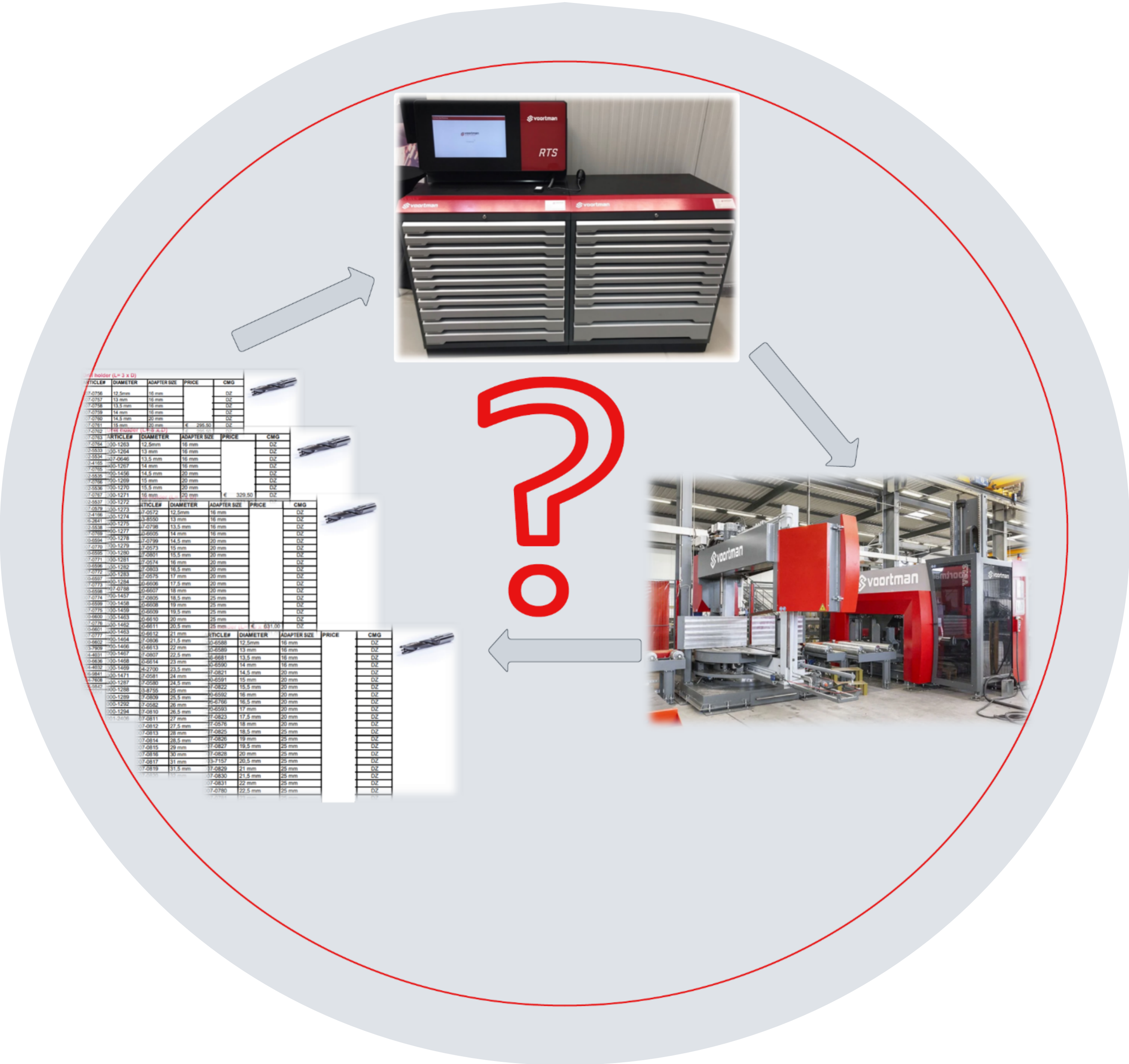

An introduction of a structured business process, making the RTS composition process structured and data-driven

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Management summary

In the literature of Business Process Management (BPM) tools are introduced and discussed to engineer or re-engineer a business process. In this thesis, the first four stages of the BPM lifecycle (Dumas et al., 2018) are applied to an action problem of the company Voortman. The problem faced is that a current business process is not well thought and structured. The current composition process is discovered with help of Business Process Modelling Notation (BPMN) modelling. Based on the as-is BPMN model, quantitative and qualitative analysis has been executed on the current process. These methods are also rooted in literature. Several activities of the process and the general structure of the process are defined as potential problems, making the process time inefficient. The recommendations to implement, with the aim to improve the current process, are mostly based on the use of data and software based solutions. Customer participation is touched upon as well. The proposed changes of the as-is model results in a to-be BPMN model of the composition process. One of the tools of the TOC TP is used to develop an implementation plan of a roadmap to change the current process into the to-be process. An inquiry into the validity of the outcomes has been executed with help of a Google Forms questionnaire consisting of Likert-scale questions. According to the responses of Voortman employees, the proposed to-be process will give an improved and structured business process.

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1. Preface

Dear reader,

With great pleasure I want to present to you my bachelor thesis of IEM. I contacted Voortman more than half a year ago and now I am writing my introduction to the research conducted at the Customer Service department. Most of the assignments have their own ups and downs, this thesis went, until now, relatively smooth.

I want to thank Voortman in giving me the opportunity to participate for a while and for the opportunity they gave me. Especially Sander Jansen and Daan Ensink for being the supervisors and their help in finding my way in the company. I want to thank Daan Brok for his input during the observations of the process. I like the experience of working in a larger organisation

Next to this, I want to thank Renata Guizzardi for being the supervisor on behalf of the University.

Good luck in reading this report,

Herbert Brink

2. Problem context

About Voortman

Voortman Steel Machinery is a family business which builds automated steel processing machines for more than 50 years. The business grew from 17 to currently more than 600 employees. Throughout the years Voortman has expanded their operations internationally. In Rijssen, where the headquarters of Voortman is situated, all the machines are still produced. Nowadays there are also offices in the USA, UK, Poland, France and Australia.

The main business of Voortman was and still is the development and production of steel processing machines. Throughout the years, service became also a strategic division. The portfolio of machines is capable in handling different kind of operations, like sawing, drilling, milling and cutting or a combination. Voortman wants to support customers, as a service, with their complete production process. This also entails advisement on and delivery of consumables.

About the assignment

One of the additional services Voortman offers to customers is a Red Tooling System (RTS) which is part of a service label agreement. The main goal of an RTS is that the inventory management of the customer is automated. This is achieved by a physical cabinet filled with specific consumables in the production hall of the customer. Software on the cabinet is used to manage the inflow and outflow of consumables. When the stock in the cabinet gets below a certain minimum level, Voortman will get an automatic order to replenish.

Consumables are parts which the operator of a machine needs to process steel. Different machines and different processes need different kind of consumables. Consumables are subject to wear, hence the importance of a correct inventory for the customer. The RTS delivery specialist determines together with the customer what specific and how much consumables a customer needs. This process is called 'the RTS composition process" However, Voortman wants to improve this process.

The composition process of RTS starter packages has to become more efficient because the number of sales for the RTS increases and will increase further during the coming years. There is a large potential market and Voortman puts more energy in selling the RTS as part of a service agreement label. Every customer needs a specific list of inventory and at this moment, the RTS composition process is manually executed and can take a lot of time per customer. In order to make the process scalable, the process should become more efficient. Therefore, it is important to execute research on the (perceived) inefficient business process.

Problem identification

To identify all problems relating the inefficient composition of starter packages, a problem cluster is created. Input for this problem cluster is gathered from different stakeholders within Voortman. In figure 1 the relationships between the problems relating to the inefficient process are mapped.

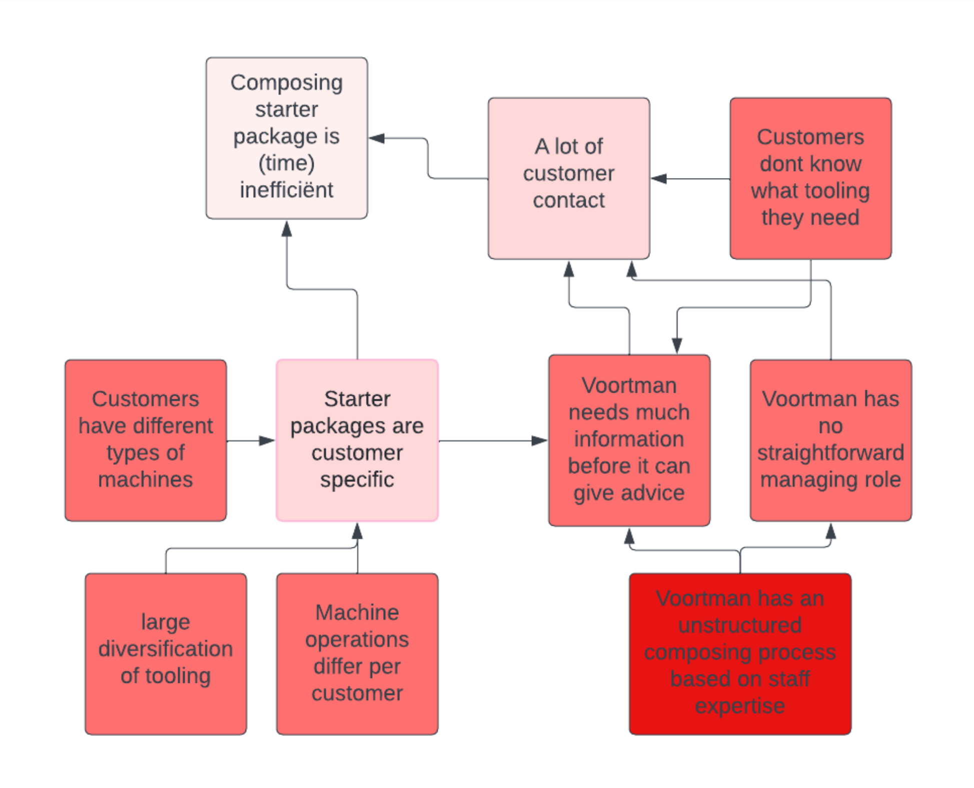


Figure 1 Problem cluster of the composition process

One of the causal problems is that the starter packages are customer specific. Therefore every customer needs a specified package, based on their individual situation. The starter packages are specific because customers have different type of machines. Next to this, there is a large diversification of consumables, there are a lot of different possible consumables which are suitable for one machine. Lastly, the machine operations which are executed vary which is another factor which determine the starter packages. It is important to note that the problems mentioned are not perse problems in itself, but are problems in relationship towards the starting problem.

The other causal problem is that the delivery specialist who creates the starter package has a lot of customer contact. This is on the one hand because some customers do not know what is needed. Therefore the delivery specialist needs a lot of information of the customer before he can give any advice on the tooling and consumables. On the other hand, both the delivery specialist and the customer are dependent on each other and a straightforward managing role of Voortman is missing. Communication goes back and forth and the sales engineer cannot manage to create fast progress. These problems are traced back to the problem that the delivery specialist has an unstructured composing process which is based on staff experience. This unstructured approach makes that Voortman is reactive instead of pro-active.

Action problem

The chosen action problem is that the delivery specialist has an unstructured composition process based on staff experience. The action problem should be a problem which the problem owner can act on in order to influence the main starting problem. This is not the case with any of the problems related to the situation that the starter packages are customer specific. The composing process is something which can be changed within the company itself.

The second reason to choose this problem is because by improving this unstructured process; the delivery specialist has a measure to become more pro-active and take a more straightforward managing role. When there is a more structured process, the customer has to follow the procedure and then the initiative lays by Voortman. Also the gathering of information of the customers can become more effective if the delivery specialist knowns what specific information is needed to give custom advice. This will eventually reduce the number of inefficient contacts and therefore make the composing time more time efficient. When the process is structured, it might also be possible to automate part of the process. This is also something that customer service, the department where the delivery specialist is working, is interested in.

Action problem definition: The delivery specialist should reduce time by having a structured process instead of an unstructured approach towards composing starter packages.

Research question:

What is a suitable plan for customer service to introduce a structured RTS composition process?

Structure means according the Cambridge dictionary ‘organized so that the parts relate well to each other’. The definition of a structured business process in the field of BPM is when ‘the business process model prescribes the activities and their execution constraints in a complete fashion’ (Weske, 2012, p. 29). A structured business process is thus according a plan which prescribes what activities have to take place and in what order of execution.

Norm and reality

At this moment, the composition process of RTS starter packages is not well-defined. Customer service will deal, based on experience, with a wide variation of new customers. There is not a clear procedure followed, although the general steps of the process are the same for every customer. With the expected increase of RTS sales, the time spent for the composition process will be too large. The process should therefore be structured and be a more time efficient process. This means that there should be a general process model which can be followed by customer service and the customer. Part of the structured process is an analysis how to use available data to improve the process.

Intended deliverables

In order to help customer service to structure their process into a more time efficient and scalable process, several deliverables are the result of this research:

1. An analysis of the current process,
2. A BPMN model for a structured to-be process,
3. A framework for a selection tool.

The analysis of the current situation gives insights into the most time consuming actions. Based on the findings of the analysis and the recommendations for improvement, a design of a business process model is proposed. Part of the change towards a structured process is the use of a selection tool. For this software available at Voortman is discussed.

Conceptual framework

In order to answer the research question and to construct the deliverables, several steps have been taken. The framework which is followed in the research design is based on the BPM lifecycle (Dumas et al., 2018).

First of all, the complete composition process is discovered in chapter 4. Based on the BPMN model which is developed in this phase, an analysis of the as-is model is executed in chapter 5. In chapter 6 the activities which are recommended to change are further discovered and changes are proposed. This means that chapter 6 has some activity discovery and analysis as well. These recommendations are used as input to develop a to-be process. In chapter 7 the implementation of the to-be model is discussed.

The selection tool for consumables is further discussed in a section of chapter 6.

In chapter 3 the theoretical background for conducting this research is given.

At the end, a conclusion of the findings of the research is given.

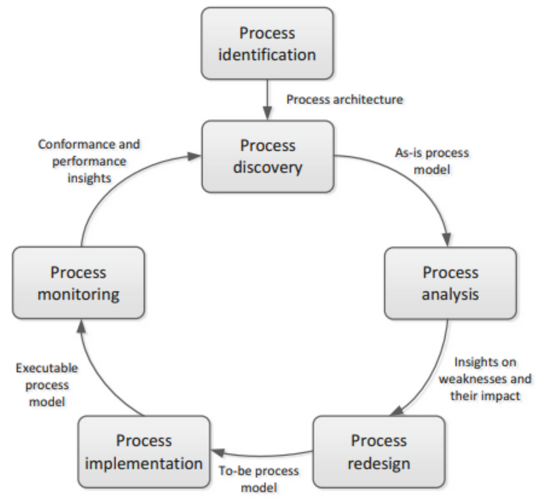


Figure 2 BPMN Lifecycle taken from (Dumas et al.,2018, p.23)

Research approach

In order to get to the answer of the research question, several sub-questions have been answered. These questions functioned as a guide of the research. The research questions are structured per chapter and follow the BPM Lifecycle, in this section the chapters and their respective research sub-questions are discussed.

Chapter 3
In chapter 3 the theoretical background is discussed. Relevant theoretical models are discussed and these are used throughout the research.

Chapter 4
In chapter 4 the As-is discovery has been executed. This was to discover the current situation to get more knowledge about the process itself. Several questions have been answered in this chapter.

Sub-question 1: *How does the current RTS composition process look like?*

In order to answer this question, the process context and the current composition process are discovered.

Chapter 5
The information gathered in the previous questions gives input for chapter 5 about the process analysis.

Sub-question 2: *What are points of improvement according the analysis of the as-is process?*

In order to answer this question, the quality of the process is analysed and a flow analysis is executed to find time-consuming activities. A fishbone analysis of the time-consuming activities gives root causes why the process is time inefficient.

Chapter 6
The process has been discovered and analysed. The activities which are points of improvement are found and the next phase is to give recommendations to improve these.

Sub-question 3: *How can customer service improve specific activities of the RTS composition process?*

In order to answer this question, a summary of the previous chapter is made. Based on this, changes are assumed which are discussed further in this chapter. Also, more background information of the process is discovered in order to understand the process. The result of this sub-question are recommendations for the to-be process.

Sub-question 4: *How should the structured to-be RTS composition process look like?*
In this question the recommendations of chapter 6 are summarised into a BPMN model of the structured to-be process.

Chapter 7
After the process redesign, the next phase of the BPM Lifecycle is the implementation of the to-be process. For this a transition tree is developed.

Chapter 8
Since the research is of an applied nature, a validation of the outcome of the research has been executed within the company. In this section the validation form and the outcome of the questionnaire is discussed.

Chapter 9
In chapter 9 the conclusion of the research is given. There every sub-question is shortly discussed with the main findings.

Research design

In this section the design of the research is given. The complete system of questions is given and the used methods, theories and possible deliverables are discussed. The table can be found in appendix A, table 6.

3. Theoretical background

Business Process Management

Business Process Management (BPM) is "the art and science of overseeing how work is performed in an organization to ensure consistent outcomes and to take advantage of improvement opportunities" (Dumas et al., 2018, p.1) This is exactly the case in this thesis. The theory of BPM exists of methods which are helpful to investigate and improve existing processes. Several of these methods are used throughout the research. The BPM lifecycle (Dumas et al., 2018, p.23) is used in the conceptual framework of the research design. Specific methods which are discussed in the book "Fundamentals of business process management " for the process discovery, analysis and redesign are used in order to develop a to-be process model. The relevant methods are discussed in the same chapter where these are applied.

Business Process Modelling and Notation

Business Process Modelling and Notation (BPMN) is a standard modelling language to model business processes. With help of BPMN the as-is composition process at Voortman is modelled and a to-be model is constructed as well. When the as-is situation is modelled, the process can be further analysed. The level of detail (Dumas et al., 2018, p.19) is dependent on the goal of the model. Since the goal in this research is to get a thorough understanding of the process, a detailed model should be developed. Bizagi modeler, a free download software, will be used to model the processes. In appendix B an overview of the modelling language is given. BPMN is used because it is straightforward to understand and is widely used, also within Voortman.

The Thinking Process of the Theory of Constraints

The Thinking Process (TP) of the Theory of Constraints (TOC) is a method based on logical thinking. The method offers tools to answer 3 questions; What to change, what to change to and how to implement the change. The goal of the TP is to analyse and find the main constraints of a business process, to come up with a working solution and to give advice how the solution should be implemented.

In order to achieve the goal, TP offers a toolkit with 6 different techniques. A Current Reality Tree (CRT) is used to analyse the business process and to give the relationships between constraints. An Evaporating Cloud (EC) can be used to analyse the core problem further and gives a direction what to change to. A Future Reality Tree (FRT) shows that the injections (solutions) found will actually solve the constraints and achieve positive change. In order to analyse negative consequences of the injection, a Negative Branch Analysis (NBA) can be executed. After this, a Prerequisite Tree (PR) and a Transition Tree (TT) can be used to give organisations advice how the process can move from the current reality towards the more ideal situation.

In appendix C, a more elaborated explanation of this abstract about the techniques and their methodology is given together with the references. This theory is very usable for this research, because there is no statistical or analytical data available of the process. There are methods of TP which have the same goal as methods available in "Fundamentals of business process management".

Taxonomy

In this paragraph theory about taxonomies is discussed, based on the article "Ontologically correct taxonomies by construction" by Batista et al. (2022). The method of taxonomy is used to present information in a structured an logical way and is used in different areas. For instance, taxonomies are useful in conceptual domain modelling. Taxonomies use subtyping to structure the information based on the relationship of properties between type and subtypes. A type consists out of all of the subtypes and all of the subtype's instances are instances of the type. So, a type is characterized by its subtypes. There are different sorts of types. The most important types are kinds and subkinds. A kind is "a type capturing essential properties of the things it classifies" (Batista et al., 2022,p.3). Like a motorbike, a person and the University. These kinds have all subkinds, which are the subtypes of a kind. The university can be divided into the subkind departments etc.. Kinds and subkinds are rigid types, because they "represent essential properties of objects" (Batista et al., 2022,p.3). There are also anti-rigid and non-rigid types, these are types which are not necessarily all instances of the kind it classifies. Like "being a TA" can be a potential property of a student.

Taxonomies are used in this report to give a visual representation of the types and subtypes concerning consumables and customers. This is done in order to get an overview of the available information. Nex to this, it gives insights into the relationships and possible decisions with regard to the composition list.

4. As-is discovery

The organisational structure behind the RTS delivery

In figure 3 an overview of the departments which are (in)directly related to the organisational structure are mapped. The main goal is to get more information about who engages in the process and what the responsibilities of different departments are.

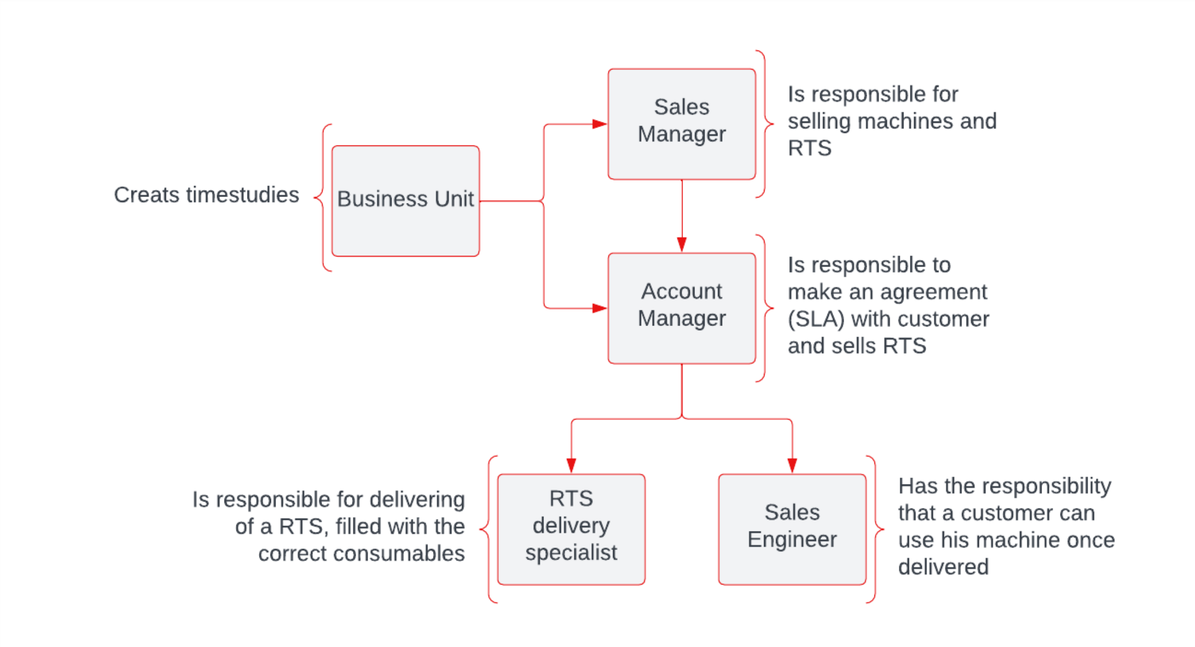


Figure 3 Roles and responsibilities with regard to RTS

When a customer wants to buy a new machine, the sales manager is the first contact within the company. The sales manager is responsible for selling the RTS concept. Some customers want to get an analysis of a new production line for varied reasons. One of the main reasons to ask for time-studies is to see if their business case of buying a new production machine holds.

The time-studies are executed by the business unit department. A customer gives data of their production on which an analysis can be performed, to get an estimation how long the production time of their products is. This data is often in the form of nesting's, a technical drawing of a steel plate with all the small plates which will be cut or drilled out, or technical (TECLA, a widely used drawing program in the steel fabrication) drawings of the products a customer produces. This gives information of the number of, for instance, saw cuts, drill holes, milling meters and cuts. The analysis of nesting's also gives an estimate of what and how much consumables a customer needs. Time studies are not created often but are only made if a customer wants to get one.

The account manager is the person responsible for making the Service Label Agreement (SLA) with a new or existing customer. An existing customer can buy an RTS directly in cooperation with the account manager. There are different service levels. If a customer chooses the Red label, part of the arrangement can be an R(ed)T(ooling)S(ystem). The relevant agreements, settled in an SLA, regarding an RTS are:

1. The initial filling is in consultation with the customer,
2. Voortman will periodically execute analysis and give advice on the storage.

For this research, only the first agreement is relevant. However, the second agreement can be considered throughout the research.

Once the SLA is signed, the RTS delivery specialist is responsible to deliver a filled RTS towards the customer. As agreed in the SLA, filling the RTS is done in consultation with the customer. Part of a correct delivery of an RTS is to set up the software of the cabinet and training of the machine operators who are going to work with the system. Besides the delivery of the cabinet, the delivery specialist is responsible for monitoring the RTS via dashboarding.

Sales engineering does not have a direct responsibility regarding the RTS. When a machine is sold, the account manager and sales engineer have contact with the customer to arrange the consumables which are needed to start production with the machine. The sales engineer is responsible for selecting relevant consumable. Once the machine is used, sales engineer checks whether the customer is still buying consumables at Voortman (ten Brinke,2024).

Lastly, not every department is always in charge when an RTS is sold. When an RTS is sold together with a Voortman machine, then all the 4 departments might be involved. If only a RTS is sold to an existing customer, an account manager may arrange the sale and the RTS delivery specialist is included to organise the initial filling and the delivery.

To conclude, this analysis gives valuable insights into the organisational structure of the completion of the RTS delivery towards a customer. Although the business unit has no responsibility regarding the RTS, their role can be considered in a potential to-be process design. The same case holds for the sales engineers since their activities have some overlap with the responsibilities of the RTS delivery specialist. Also, the commitments made with the customer are good to consider for a potential to-be process.

A BPMN model of the current composition process

To analyse the current composition process at Voortman, a BPMN model is developed with help of feedback sessions together with the process owner. In this section, the main process and its sub-process are discussed.

Before this discussion, a remark should be made. The current process has not a well-thought structure. There is not a fixed standard way of working and there are deviations within the process. However, a general model is extracted from the gathered information and observations. In this paragraph, the processes will be discussed and, where applicable, the deviations within the process will be mentioned.

Main process

In figure 4, the BPMN model is shown. There are two pools and three lanes included in the process. The customer is included in the analysis, since the process needs input from the participant and the process is also oriented towards a customer specific outcome. Within Voortman, two departments are included. The account manager and the RTS delivery specialist. In the discussion of the organisational structure more information on the different departments are given.

The process starts when a customer buys an RTS from the account manager. The account manager will send an email towards the delivery specialist. This mail contains information about the customer and the arrangement made between the account manager and the customer.

The delivery specialist will have an RTS introduction with the customer, e.g. via Teams, to get to know each other and to explain the procedure which is followed to deliver a filled cabinet. In this conversation, ordinary questions are asked to get to know what consumables the customer wants. After this meeting, a mail is sent with more information about consumables and with a question sheet. If applicable, an earlier composed composition list is attached. This can be the case when the customer has the same machine and processes as an earlier customer.

When the customer responded, the information delivered by the customer is checked. The information received is different per customer. Some will have already listed the consumables needed, included with the desired amount of stock. Others will have no clue what specific consumables are needed. When this information is not detailed enough, the loop of the process will be entered where the delivery specialist will ask for additional consumable information. If the information of the customer contains enough information so that the delivery specialist can create an initial list, the sub-process “create initial list” is entered.

It is important to highlight the fact that when the customer can use an existing initial composition list of consumables, which is created during an earlier process, the described loop to ask for mor information and the sub-process of creating an initial list can be skipped.

Once the sub-process, which will be discussed later, is finished, an Excel sheet with the list is sent to the customer. The feedback of the customer on the list is reviewed. When the list is not accepted, the list should be altered on the customer wishes and the list is again sent to the customer. This is a loop until the customer accepts the list. Actually, that is also the end of the process.

Sub-process

In figure 5, the BPMN model of the process of creating the initial list is shown. If a customer does not know what specific consumables should be on storage, the delivery specialist first checks which machines the customer has. The Voortman machines owned by the customer is stored in an SAP list. However, this is also general information the customer can give at the first information request. It is also possible that the machine is not produced by Voortman. After this, the process which the customer will perform on the machine is selected. Based on these, specific consumables can be choses. Then the alternative paths come together.

The chosen consumables, by the customer or the delivery specialist, are put in an Excel list and the output of the machine is determined, this to give some input for deciding the level of stock. More information on output is given later on in the report. Per consumable, a maximum and minimum stock level is set. These levels are based on the demand of the customer or are more or less guessed.

The consumable relationships should be checked once the list is almost complete. The taxonomies of consumables gives more information on these relationships. Next to this, constraints given by the customer should also be checked. For example, a financial constraint is very often present. During the sub-process, the relationships and the constraints are taken into account, however the checks are modelled in this way to show that there are external factors with influence. Once the checks are performed and are correct, the initial list is finished.

As already mentioned, the customer is modelled as well to show the steps which the customer needs to take to cooperate within the current composition process. Al the time between sending and receiving information for the customer, is time that the instance of the process is on hold for the delivery specialist. Within the process, the customer is asked to give information and for acceptation of the initial composition list. The information available and shared by a customer, has a considerable influence on what steps of the process should be taken.

To conclude, the BPMN model gives a representation of how the process looks like. Although there are deviations and the process is not according to a certain procedure, the general structure containing the activities give an overview of the process analysed in this thesis.

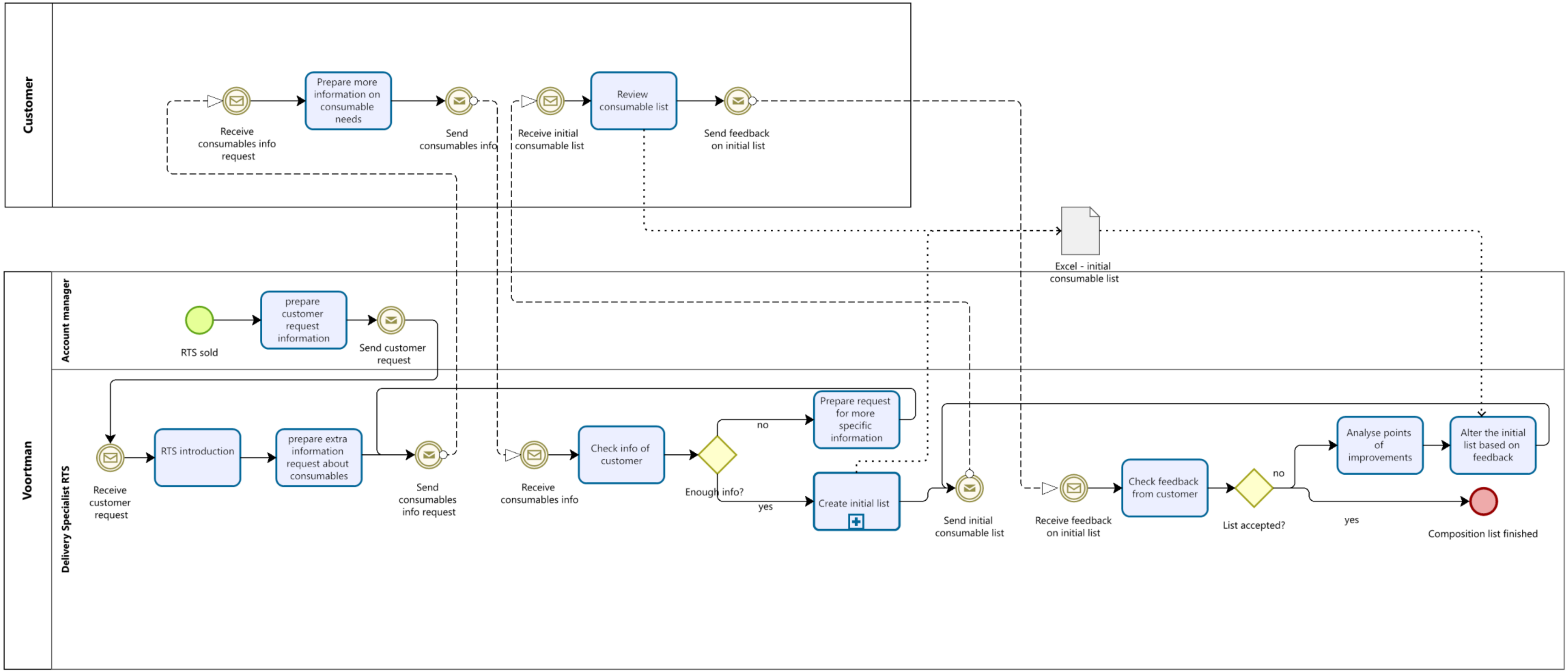


Figure 4 BPMN model of composition as-is process model

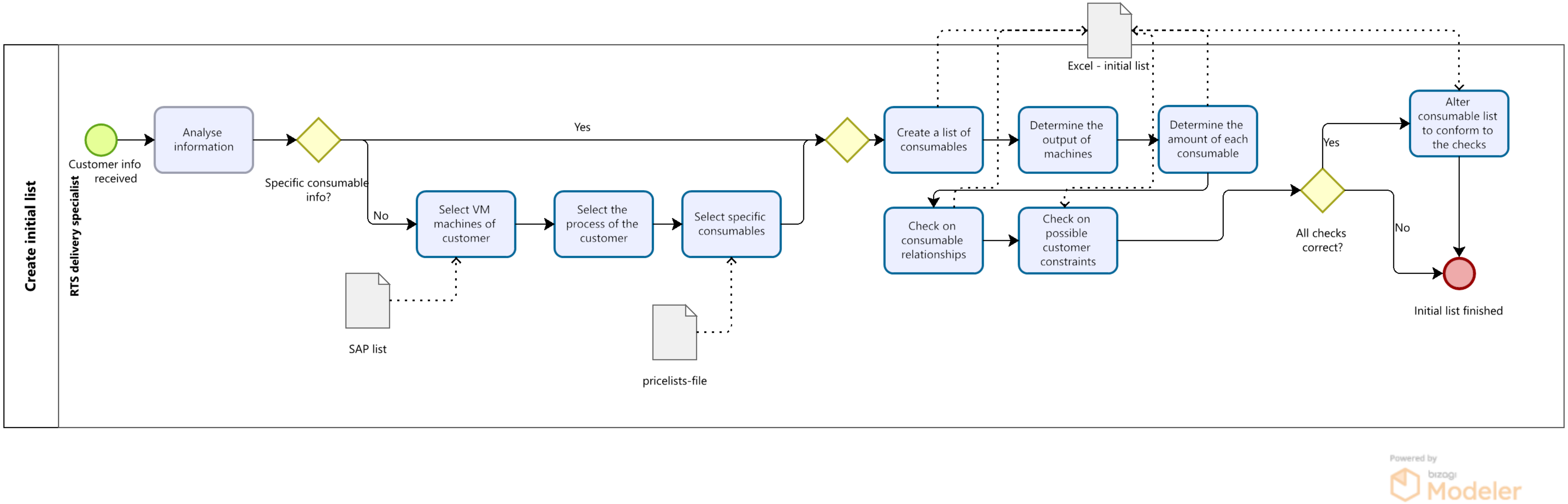


Figure 5 BMPN model of create initial list as-is model

5. Process analysis

An analysis of the quality of the process

Part of the analysis of the current composition process is to check the quality of the outcome of the process. This to investigate how good the performance of the process itself is and to validate the outcome of the process. To check the quality, the next Key Performance Indicators (KPI's) are introduced:

1. The number of unique articles initially filled,
2. The number of unique articles delivered to a customer by an automatic generated RTS order,
3. The number of unique articles which are ordered (manually),
4. The number of unique articles returned.

The first KPI is about the number of articles included by the initial filling. This makes it possible to compare different cases. The second KPI gives the number of unique articles ordered automatically by the RTS software. This gives insights into how much different articles a customer actually uses, because these articles are taken out of the cabinet. The third and forth KPI are most interesting to know, because these give information about how correct the initial filling has been for that customer. If there are many articles ordered extra and many are returned, the quality of the initial filling might be low. A case study can give more insights in what went wrong during the process.

The available data within Voortman is the constraint in defining these specific KPI's. These KPI's are also evaluated by Voortman as valuable information.

Analysis

There are a few limitations and assumptions with respect to the handling of data:

a. Part of the analysis of customer data is the first half year after the delivery of the RTS. It is possible that customers have some storage themselves, which is not visible in the ERP system of Voortman. It can be argued that these consumables need replenishment within half a year. If these articles are not included in the RTS, a traceable manual order must be created in SAP. A longer period might mean that changing workorders of the customer influence the need of different consumables. This is not in the scope of this research. RTS's which have not yet information of half a year are excluded of the analysis.
b. The storage of the orders in SAP was not according to a strict protocol and the current protocol is not always followed. This makes that for some ordering data automatic and manual orders must be separated based on the information available in SAP. Throughout the analysis, the same method of reasoning was used in order to get comparative data.
c. Since customers are not contractually obliged to order all their consumables by Voortman, it is possible that missing articles are ordered at third parties. The assumption is that customers are only ordering missing articles by Voortman.

d. In general, the data used in this analysis is taken from SAP. So, anything else is excluded from the analysis. For example, the initial filling can exist of more articles which the customer has already on stock.

In table 1, the findings of the research are summarised. To keep the customers of Voortman confidential, the companies are labelled with a letter. In internal documents the letter and the company are linked. The columns correspond to their respective KPI's. The percentage of the number of extra orders compared to the number of articles ordered by the RTS are added and the percentage of the returns compared to the initial filling. Next to this, the industry type and the year in which the RTS is delivered are given.

Company	Initial filling # articles	#articles by RTS	# articles extra	% extra	# articles returned	% returned	Industry	Delivered in
A	64	38	20	53%	0	0%	Steel fabrication	2021
B	95	69	24	35%	3	3%	Steel processing	2021
C	Not traceble	106	1	1%	8	Not traceble	Steel fabrication	2021
D	31	29	5	17%	0	0%	Steel fabrication	2021
E	50	33	11	33%	0	0%	Steel fabrication	2022
F	58	81	4	5%	33	57%	Steel distribution	2022
G	160	76	11	14%	13	8%	Steel fabrication	2022
H	22	64	1	2%	8	36%	Steel fabrication	2022
I	54	30	4	13%	0	0%	Steel fabrication	2022
J	64	16	8	50%	0	0%	Steel fabrication	2023
K	126	55	1	2%	77	61%	Steel fabrication	2023
L	50	16	6	38%	1	2%	Steel fabrication	2023
M	66	7	3	43%	37	56%	Steel fabrication	2023
N	99	39	66	169%	14	14%	Steel processing	2023
Average	**72**	**47**	**12**	**25%**	**14**	**19%**		

Table 1 SAP data analysis RTS

First of all, this analysis cannot be used to make statistical claims about the outcome of the process. One of the major reasons for this is that the current sample is too small and there are significant differences between the cases. For instance, the initial filling lists are constructed by different (former) employees of Voortman. Next to this, every company can have different limitations or constraints themselves which influence the initial filling. However, general and case specific case analysis can give insights into the quality of the process. The most important findings will be discussed, there is no need to exhaustively analyse the findings further.

A general note is that on average the number of articles of the initial filling is larger than the automatically ordered articles by the RTS. On average there are 35% more articles initially filled than are used. This hints towards the existence of dead stock which is not touched in half a year. At least, the company did not use enough articles to reach the minimum quantity to order the article. The current approach by the process owner is to put more in the RTS to be on the safe side. Returning articles is considered more desirable than that a customer misses' articles. What this dead stock exactly is, is not part of the research. The proposed analysis tool in chapter 6 can be used to analyse the dead stock. There are articles which are stock items, these articles will not wear in the process. However, these articles can become unusable and need immediate replacement in that case.

According to table 1, the number of unique articles which are ordered extra is 25% of the unique number of articles ordered by the RTS. That seems a significant percentage, although company N has a large influence on the average. The absolute numbers are in most cases not so large and explainable. For instance, if a customer wants to drill another diameter, there are already at least 2 unique articles extra needed. Both the steel processing companies, B and N, have a larger percentage of extra orders. Company N is investigated further, in order to get some insights why these extra orders are 169% more.

For the returns it is important to notice that only the unique articles are taken into account, not how many of these articles. It can be that the article returned, stays on storage with a lower stock. The percentage of returns is lower than the extra articles ordered. However, dead stock might be send back later than half a year, so that does not give much information. For the returns, company F and K are investigated further in order to get insights.

Case studies

Company N has the largest percentage and absolute number of articles ordered extra. Within the first half year 66 more unique articles were ordered. One of the reasons for this is that the company started producing with a new machine, so the customer probably did not know what to expect to use. There has been an organised extra filling after the delivery of the RTS. Ordering extra articles is also not a problem, according to the process owner. It is actually something that is expected once the RTS is installed. However, it is interesting that in the first half year (and according SAP data, until 21-5) only a few articles are returned by the customer. It is not the case that the process of composing the initial list went differently than normal.

Company K also has an suitable explanation. The start package for a machine, which is created by a sales engineer, is used to fill a RTS. However, the number of articles is differently for a start package of a machine than the initial filling of the machine. So that is something that went wrong during the process.

To conclude, this analysis shows that the outcome of the process is at an acceptable level. There are no standards within Voortman with regard to the quality, therefore the qualification of the process cannot be concise. The articles which are stored in the RTS do change after delivery. This is not considered as a problem but is supported by Voortman. However, an analysis of the ordering data of the RTS can give valuable insights on what articles are never ordered or are ordered frequently. Trends about consumable consumption is not used in the current process, that might be valuable to improve the quality. This is also mentioned by Jan Mark Haase (2024).

A flow analysis of the BPMN models

The BPMN models developed in chapter 4 are used for further quantitative analysis. A flow analysis is executed as part of the process analysis of the as-is model. This analysis gives insights into the time the different activities take and how often the feedback loops are used in the model.

The flow analysis is often used to calculate the performance of a complete process by assigning cycle and processing times to activities. The cycle time is the average time it takes between the start and finish of an activity or task. Processing time is the time that participants actually do work on the activity or task. There are several KPI's which can be calculated with help of flow analysis. For instance, the average cycle time or the efficiency of the cycle time can be calculated. (Dumas et al., 2018) In this analysis, the main goal is to examine how long the activities take and what the most time consuming tasks are. These tasks will be analysed further to find the root causes.

Cycle time analysis
The cycle time of the main process can be found in figure 6 at the end of this section. The cycle times are based on the input of the process owner and of observations. There are no track records available and deviations of the instances of the process hinder an exact timing. Therefore the cycle and processing times are estimations though based on reality.

In the cycle time analysis, the time it takes from the moment the activity is started until it is finished is estimated. As default, the cycle time is in days, this is because most of the tasks take on average a day or more to be finished. One day in the cycle time is considered to be eight working hours and the days are expressed in working days.

At a first glance, no particular activities or tasks stands out when figure 6 is analysed. All the tasks which should be performed by the RTS delivery specialist are dealt with within a day. Therefore, these activities should be analysed further with the processing times in order to define time-consuming tasks. Since there are some loops involved in the process, a total cycle time calculation is executed per activity or event to give more insights. In table 2 the cycle times are analysed further and the total process cycle time is given.

In table 2 the cycle times are those from figure 6 and the rework probability is how often a specific task or activity is executed within the process. The total cycle time is the consequence of both of the given numbers. For example, for the send and receive consumable information the cycle time is 3 days and since there is a probability that 50% of the instances enter that event again, the total cycle time is 4 ½ days. In this way all the activities are calculated. These calculations are performed as discussed by Dumas et al (2018) in chapter 7.

Activity or Event	Cycle time	Rework probability	Total cycle time
RTS introduction	½ day	100	½ day
Prepare extra info request	½ day	100	½ day
Sent and Receive consumable info	3 days	150	4½ day
Check info of customer	1 day	150	1 ½ day
Prepare request specific info	1 day	50	½ day
Create initial list	1 day	100	1 day
Send and Receive feedback initial list	1 day	300	3 days
Check feedback from customer	1 day	300	3 days
Analyse points of improvements	½ day	200	1 day
Alter the initial list based on feedback	½ day	200	1 day
Total process cycle time	**10 days**		**15 1/2 days**

Table 2 Cycle time analysis

Although there are no obvious outliers when comparing the cycle times in figure 7, the analysis of the cycle times in table 2 gives more valuable insights. The waiting time between the events 'consumable information request' and the 'receive consumable information' is on average three days. In half of the cases, the feedback loop is entered and therefore the total cycle time increases to 4 ½ days. The second waiting block, between the message events 'sent initial consumable list' and 'receive feedback on initial list' takes on average one day, since one instance will go multiple times through this event, the total cycle time is three days. The two waiting times together are responsible for almost 50% of the cycle time. Besides the events causing waiting time, the activity 'Check feedback from customer' takes the most time. This activity has a total cycle time of three days, this is also mainly due to the number of repetitions within one instance of the process. Without repetition the total process cycle time would be 10 days, now it is 15 ½ days.

The sub-process 'create initial list' is not analysed with help of a cycle time analysis, this is because this process is, in most cases, executed directly as one task. The 'create initial list' cycle time of one day is already included in the cycle time analysis of the main process.

The conclusion of the cycle time analysis is that the waiting times take up the biggest chunk of the total cycle time. According to the analysis, this is because these events, which cause waiting time, are repeated several times. This is also the case for the task which takes the most time. Specific reasons why that takes so much time is discussed in another section.

Processing time analysis

The processing times are put in hours. This is because the processing times can be estimated more precise and the tasks do not need days to work on. In the processing time analysis both the main process and the sub-process will be analysed. The processing time is the time the employee at Voortman is actually working on a task.

Main process

A first look at figure 6, shows that the processing time of the sub-process 'create initial list' is the activity which takes the most time. That is not perse an indication that this task is time consuming. To get more valuable insights a further analysis of the processing times, like the cycle time, is executed in table 3. Instead of the cycle time, the processing time is used. Furthermore, the analysis is the same.

Activity or Event	Processing time	Rework probability	Total processing time
RTS introduction	1 hour	100	1 hour
Prepare extra info request	1 hour	100	1 hour
Sent and Receive consumable info	-		
Check info of customer	½ hour	150	¾ hour
Prepare request specific info	1 hour	50	½ hour
Create initial list	6 hours	100	6 hours
Send and Receive feedback initial list	-		
Check feedback from customer	1 hour	300	3 hours
Analyse points of improvements	½ hour	200	1 hour
Alter the initial list based on feedback	½ hour	200	1 hour
Total process processing time	**11 ½ hours**		**14 ¼ hour**

Table 3 Processing time analysis main process

Besides 'create initial list' no activities do take a considerable amount of time. When taking into account the rework probability, the activity 'check feedback from customer' is also a time consuming activity. The difference between the total process processing time with and without the rework probability, is three hours.

The efficiency of the process, which is the processing time divided by the cycle time is 8.7%. This shows that the process can be improved by decreasing the cycle times.

Sub–process

The processing times of the sub-process is given in figure 6. When the process is analysed from the beginning till the end, the next observations are made. First, when a customer has no specific consumables preferences the process takes 1½ hours extra. This is most of the time the case. There are no specific tasks which processing time stands out, 'create a list of tooling' takes the most time. Next to this, 'select specific consumables' and 'determine amount of each consumable' are the most time expensive. The task 'alter consumable list to conform to the checks' takes one hour as well. However, this task merely takes place. During an observation, the 'create a list of consumables' together with 'check for consumable relationships' were perceived to be the most time consuming tasks and least value added time.

Although the tasks 'select specific consumables' and 'determine the amount of each consumable' are not perceived to be time-consuming tasks by the process owner and according to the flow analysis, these tasks can be more time efficient as well.

To conclude, there are a few important findings as a result of the flow analysis. Both the total process cycle time and the total process processing time are influenced by the repetition of tasks. The cycle time is also influenced largely by a long waiting time. The total processing time is also influenced by the sub-process. Within the process of 'create initial list' two tasks are considered to be time consuming. These are 'create a list of consumables' and 'check for consumable relationships'. These findings are discussed in the next section in further detail.

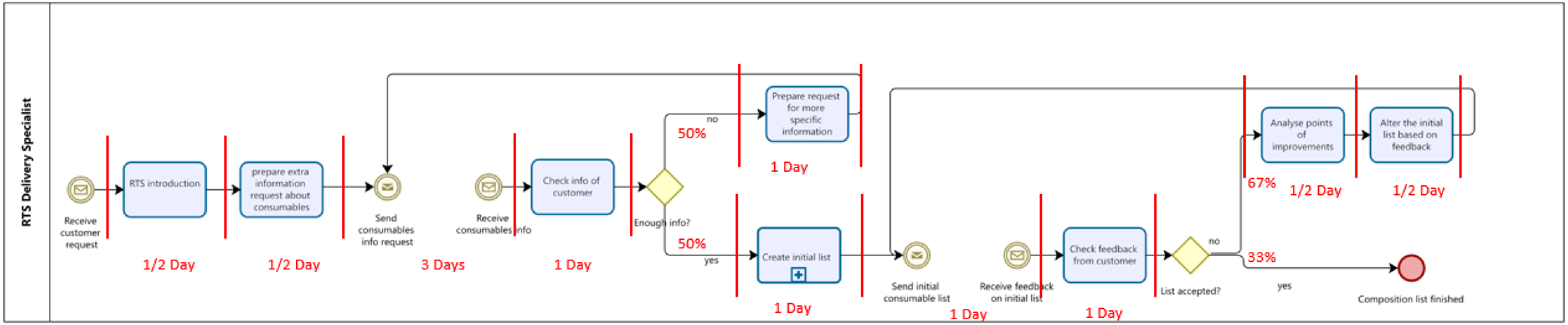


Figure 7 Flow analysis 'cycle times' main process

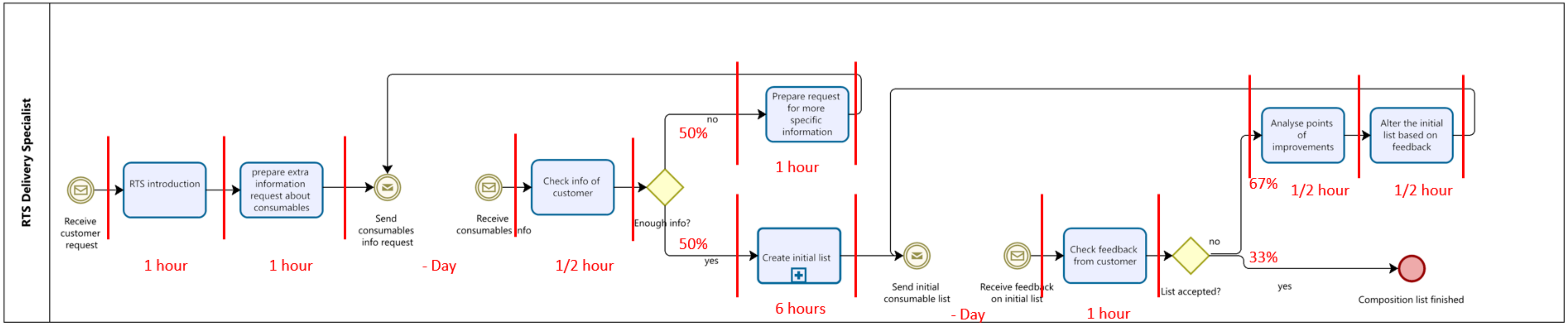


Figure 6 Flow analysis 'processing times' main process

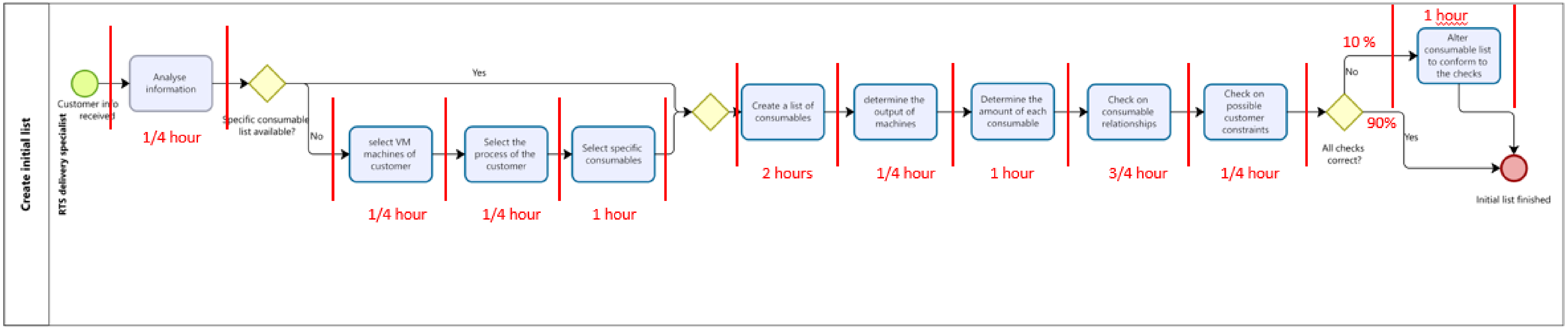


Figure 8 Flow analysis 'processing times' sub-process

Analysis of causal factors for time consuming tasks

In this section, the time-consuming tasks found with help of the flow analysis are discussed. First, there is some more background information given about the process in order to understand the problem context. Next to this, a fishbone analysis is executed on the main findings.

There are three main findings, as stated in the conclusion of previous chapter:

1. The first waiting time block takes a lot of time
2. The activity 'create initial list' is time-consuming
3. The activity 'check on consumables relationship' is time consuming

The findings are discussed after each other and a small discussion on two other activities are given.

A fishbone structure is a brainstorm measure to help finding cause and effect relationships. In this report the standard categorisations as discussed by Dumas et al. (2018) in chapter 6.4 is used. In this chapter, the 6 M's are discussed and the goal of the fishbone structure. The fishbone structure should not be used as a strict protocol, but should guide and help the brainstorm phase.

Waiting time

The first waiting time block is 4 ½ days, when taking into account the loop of the process. When the RTS delivery specialist has had contact with a new customer, he will send an email. In this mail, general questions about what consumables have to be in the RTS are asked. Next to this, a pricelist is send to the customer with an example how the consumables can be added to this list. The idea behind this is that a customer adds all the article number of consumables needed on the list. In chapter 4 the notion is made that when a customer gets a initial list during the first mail contact, this waiting block can be skipped completely. This is relevant to repeat during the analysis of the waiting block, since this hints towards a potential solution which is discussed later.

The waiting time of the second loop is much smaller, according to the process owner this is mainly because there is something concrete (namely, the initial list) which gives the customer an incentive to work on.

In the fishbone of the waiting time, see appendix H for more information, causes are explored why the waiting time is time consuming. Both the causes for the long waiting time and the reason why there is a second information request. The summarisation or conclusion of the analysis is that Voortman expects too much, based on the support customers get. Currently, a customer gets a mail with a pricelist per process and the question to choose which articles should be on the list. At the customer, more reasons might play a role. However, this conclusion is made in only considering the responsibilities of Voortman, since influencing the process at the customer is not in scope of this thesis.

Create initial list
This activity is part of the sub-process. Earlier steps of this process is the selection of specific consumables, the conclusion of the analysis of the quality of the process is that maybe for this phase more available data can be used. Once the consumables which should be included in the RTS is determined, a complete consumable list is build. In appendix G an example of an initial list is given. There is an Excel format which is filled in with article numbers of the selected consumables. A VLOOKUP-function is used to find the corresponding article description. So, from every article which should be included in the RTS, an article number is copied and pasted into the first column. According to table 1, an average of 72 unique articles are included in an RTS.

The fishbone analysis of this activity, again: see appendix H for more information, gives a good overview of the problems concerning this process. The fact that the list is composed completely manually relates back to most of the problems.

Check on consumable relationships
This activity is to check if all relevant consumables are included in the list. This has to do with relationships between consumables, which is explained in greater detail in a later section. This activity thus exists of checking whether every article is included. For instance, if a drill holder 18 mm is included, a drill bit 18 mm should also be included. When a certain amperage of cutting is included, 4 different items have to be checked for inclusion. Checking this takes a considerable amount of time since it is manual work.

As discussed in appendix H, the causes of the previous discussed task has a lot in common with this task. If the task 'Create initial list' is completed correctly, this activity can be removed from the process. The main cause for the time inefficiency is that this task is completely manually.

Select specific consumables
Although this activity is not perceived as time consuming, it still can become more efficient and thus improved. There is no fishbone analysis of this task. In this phase of the process, the delivery specialist decides what consumables a customer needs per process. The specific steps taken depend on how much information the customer can give. If a customer has ordering history by Voortman, an analysis of this will give exact information of their needs. When there is no information and no ordering history, it is an educated guess what to advice to customers.

Determine amount of consumables
This activity is currently mostly based on assumptions of the process owner. Since this is also a repetitive task, further development of this task might reduce the number of time needed.

To conclude, there are two main causal factors found in the analysed activities. The current process is too much based on the customer, who is not able to perform as Voortman expects. And the composition of the initial list is completely manual work, this is sensitive to errors. Therefore a check has to be executed if everything is included.

6. To-be process

Recommendations to improve the composition process

In this section, findings of the previous chapters are shortly discussed. Combining all found problems and information in the research leads towards a to-be recommendation for Voortman.

In this assessment of the information gathered, the Thinking Process of the Theory Of Constraints is taken as a method to determine what to change and what a good direction to change to would be. The tools given by TP are not particular used in this part, since the problem context is not particular difficult to understand.

What to change?
In table 4 all the different activities of both the process and the sub-process are given, together with the conclusions drawn throughout the research. Also a direction of how the process could be improved are given.

Activity	Observation/conclusion	Assumed changes
Process		
RTS introduction	Necessary	
Prepare extra info request	In this mail, the customer customers are asked to make a list of consumables; customers don't do this	Give the customer a better incentive to give more specific information, lower the burden to create a list.
Check info of customer	Necessary	
Prepare request specific info	If the customer did give better responses, this is not necessary	
Create initial list	If a customer creates a list themselves, Voortman can skip this phase.	Lower the effort for the customer to compose a list themselves
Check feedback from customer	Most of the times there are small changes, this task is needed and cannot be skipped.	
Analyse points of improvements	Necessary	
Alter the initial list based on feedback	Inserting and deleting articles takes manual steps	
Sub-process		
Analyse information	Necessary	
Select VM machines of customers	Necessary	
Select processes of the customer	Necessary	

Select specific consumables	Available data is not used which can help make it more effective and efficient	Create (analysis) tools to use available data. (Buer et al., 2018)
Create a list of consumables	This asks a lot of manual steps in Excel and checking the relationships requires a lot of attention	Make use of a software tool to select the proper consumables which directly adds all the consumables based on the selection. (Dumas et al. 2018)
Determine output of machines	In reality, this step is not really giving information for the rest of the process.	This step can be skipped in the process.
Determine the amount of each consumable	This steps are taken for every customer again, however there is not a well-thought approach where to base the numbers on	Define a clear protocol, using available data (Buer et al., 2018) .
Check on consumables relationships	This asks a lot of manual steps in Excel and checking the relationships requires a lot of attention. Is not necessary when earlier steps are taken correctly	This step can be skipped in the process.
Check on constraints	Necessary	

Table 4 Conclusion and recommendation of the process analysis

Summarising the assumed changes of table 4 shows that there are two main steps which could be taken in order to improve the process. First of all, the use of available data is low. During some tasks there is available data, which is not used at all or not optimal. Using data might give a better direction in decision making, since choices for one customer can be based on a likewise company. Also an analysis tool of already available customer information about the history of consumable orders might make the selection of consumables more time efficient.

Secondly, the use of Excel has a lot of limitations. As recommendations show, a better method of composing lists should be implemented. Customers might be able to create a list themselves if they are more supported in this task. So, two main causal factors can be tackled by one. Namely, make the composition of the list more easy with help of another approach. Then Voortman has a more efficient business process and customers might give better responses.

What to change to?

The second question of the TOC states the question what the process should look like. More research into the specific tasks should be performed to give a better understanding of how to change the process. Therefore, the next sections discuss what the different tasks in the process entail and how these can best be optimized. Also, the implementation of the recommendations is discussed.

Consumable overview of Voortman

In order to be able to propose changes to the current process, it is necessary to understand in more detail what the process entails. The consumables have an high impact on the process, therefore this is part of the research. In this section, an overview of the available consumables and other tools which are often included in an RTS are given. Next to this, some more information about consumables and tooling is included. Most of this information is retrieved from the internal pricelists.

Taxonomies

An overview of the consumables can be found in appendix E. Figure 15 shows the different sub-categories of consumables. These can be defined in processes and tools. All the main processes which can be performed on a Voortman machine are part of this taxonomy. Almost all of the machines can perform multiple processes, thus customers need also consumables of different processes. All processes, besides sawing, have their own taxonomy to enhance readability. Next to the processes, consumables can also be categorised under tools. These differ per machine type. Part of the category tools are lubricants, these are also articles which are often included in an RTS.

Drilling, milling and tapping have a comparable taxonomy. The difference in the sub-kinds of drilling and milling are the material of which the tools are made of. For both materials, different consumables are available. From the 2nd generation sub-kinds, by tapping the 1st generation, at least one of every kind is needed. This is because different parts are needed to be able to perform the process with the machine. Of these 2nd generation sub-kinds, different kinds; mainly diameter and length differences, are available. These relationships which are not obvious of the taxonomy are explained in the text box of the taxonomies.

Cutting has a different form of taxonomy. This because the available consumables can be ordered in a different, logical way. There are two different processes within cutting. Oxy cutting, which is cutting with help of gasses and plasma cutting, which is cutting with an electrical source. A machine can cut with only one of the two available gasses. The consumables of the two types of gas are likewise, though the diameters differ. For plasma cutting, consumables can be filtered by brand, material to cut and amperage needed to cut. Based on these decisions the sub-parts can be chosen. There are rules of thumb what the consummation ratio of the sub-parts are within Voortman. Consumables of punching can be categorized in sub-parts and the shape of these parts.

Tool life

Tool life is a characteristic of how long tooling and consumables last. This is a specific duration per unique consumable. The tool life is also expressed differently per process. For instance, drills and mills are expressed in meters. Sawing is expressed in the number of saw cuts and cutting is measured in meters cut and the number of starts of cutting. For the plasma cutting, concrete and exact data about the tool life is available. However, this is not the case for the other processes.

The actual tool life is subject to different parameters. One of these is the setting of the machine itself. To give a feeling about the range difference, the demonstrator of Voortman gave the next example; There are 2 customer with the same machine with comparable production. One uses a saw band for 2 weeks, the other uses a saw band for just 2 days. This is due to different choices the machine operators make. The machine has also a large influence on the tool life. The same tool can last on the V310, which is a cutting machine with a drilling head for plates, 4/5 times shorter than on a V630, which is a machine specific for drilling.

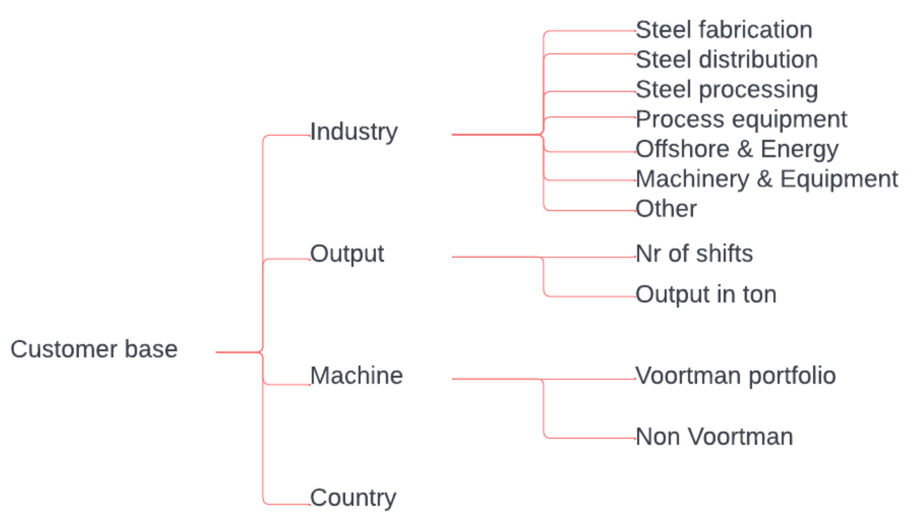
To conclude, taxonomies are used to visualize the relevant consumables and tooling per process with regard to the RTS. Not every process has as much different consumables as other processes. The tool life of consumables is difficult to measure and the relationship with the parameters of customers is complex.

The customer base of Voortman

In this section, the customer base of Voortman is discussed. Customers have a large influence on the process and therefore more insights on the customer base is valuable. A categorisation is made to show the possible difference between customers. The industry type is investigated further, because more data is available to execute an analysis.

Categorisation of customer base

Voortman has a large customer base who use their Voortman machine in different production processes. This has as a consequence that there is a large deviation in what tooling and consumables a specific customer needs. In some way, it is possible to classify customers based on their characteristics. The sub kinds which are chosen in this research are based on their relevancy in regard with the RTS.



Within Voortman there is already a common classification of customers based on the type of industry they belong to. The six main industries are given and are not further specified within Voortman. A further classification would be out of scope of this research. However, there are 3 additional characteristics of customers.

Output gives additional information of a customer. There is a relationship between the output of the customer and the amount of consumables which should be replenished. This relationship has to do with the tool life of the consumables. As discussed in the previous section, this tool life can have large variations. However, it is difficult to have a more correct benchmark for measuring output. Using the number of shifts a customer works does imply that a machine is used for a certain amount of time, although that does not necessary say something about how much the machine performed. This is the same for tonnage. Knowing the tonnage of a customer does not tell necessarily something about the number of drilled holes or milling and cutting meters. Tonnage is widely used in the steel industry as an indicator. Even with the limitations of it, using tonnage or the number of shifts indicate something about the intensity a machine is used and compared to the same industry gives an understanding of how much consumables are needed.

The type of machine is a very important sub kind of the customer. Since the machine will have the largest influence on the consumable need of a customer. When a customer has only a V310, which can cut and drill, a band saw will never be needed. The industry type already gives a hint on the machine(s) that a customer will most certainly have. However, deviations in machine portfolio are possible. The type of machine can be the complete portfolio of Voortman and competitor machines. The precise types are not included in the taxonomy because of readability issues. In appendix F the number of machines which are linked to an RTS is given per type.

The country where a customer is situated is relevant for the lead time towards the customer but has no consequence for the technical or operational situation of the customer.

Industries
Figure 10 gives the percentage of machines sold per industry type. The main purpose of this figure is to show how the business of Voortman shifted throughout the years and what the main focus industries are. This figure does purposely not tell anything about the growth of Voortman. Throughout the years, the most machines are sold to the steel fabrication industry. The steel fabrication industry is mainly focussed on manufacturing steel for building real estate. Although the steel fabrication decreases in market share, it still remains the most important industry. This is because existing customers buy RTS as well and steel fabrication has been the biggest market throughout the years.

When the sales of the RTS and machines are compared, the same conclusion is taken as already discussed. At this moment, the steel fabrication is responsible for the largest share of RTS sales. It is logical to assume that the industry type has a large influence on the use of consumables. However, since there is only a significant amount of data on steel fabrication customers this statement cannot be supported with evidence. As a consequence of this finding, the conclusions which are drawn in this report are more focussed on the steel fabrication industry.

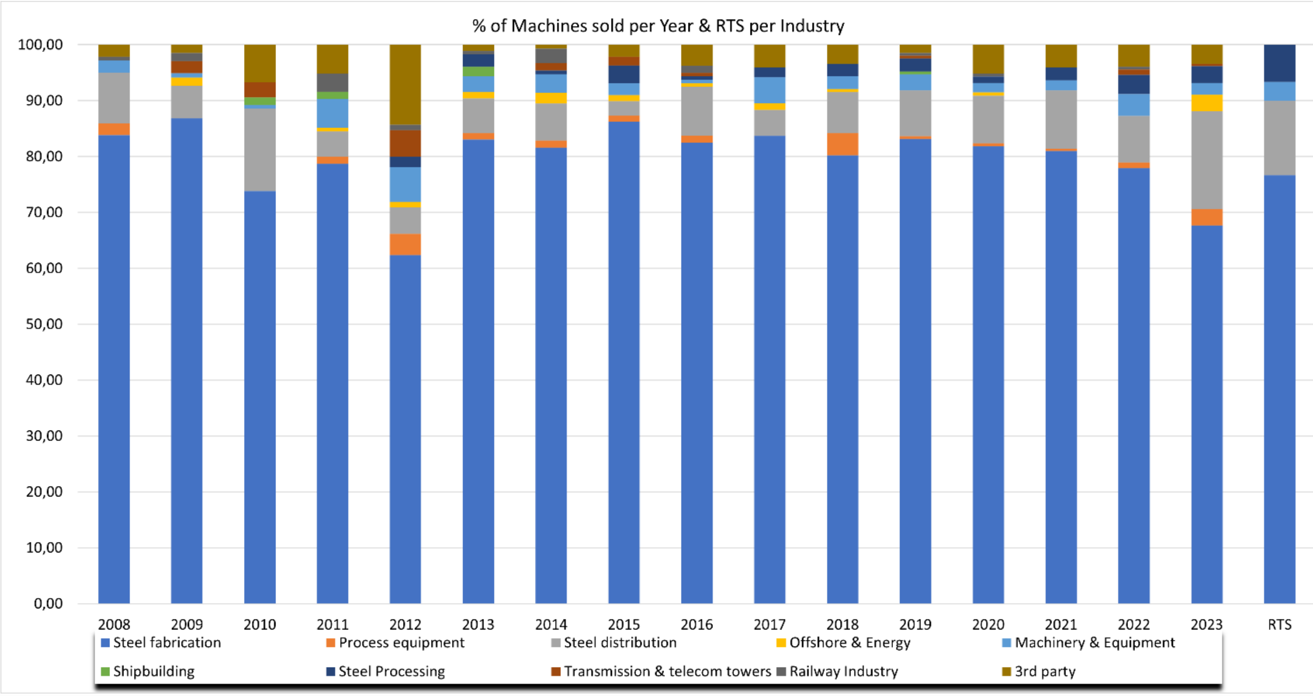


Figure 10 Percentage of machines per year and RTS sold per industry

To conclude, the customer base of Voortman can be categorised with help of the taxonomy given. Currently, data about one industry type is available. Therefore the relevancy of categorising customers in relation to the RTS is currently not very apparent. However, when the deviation of customers becomes larger in the future of the RTS and more data is available, then this categorisation is a helpful method to determine the type of customer.

The selection of consumables

In this section, the selection of consumables is discussed and how that can be improved to be more efficient. The selection is made on what the delivery specialist in cooperation with the customer think what is needed. A more data driven approach might make the process more efficient, therefore this is investigated further. In the literature, for example (Buer et al., 2018), the use of data and ICT solutions are seen as potential factors to improve business processes.

Available data

There are roughly three different cases with regard to the availability of data about the consumable needs of a customer:

1. A customer has bought (all) consumables at Voortman,
2. A customer has experience with production and knows to a certain extent what is needed,
3. A customer has no experience at all and is completely dependent on the advice of Voortman.

At this moment, the SAP data about the orders made by a customer are checked visually to see what different consumables are bought. When a customer has some idea about what consumables are needed, a draft list is sent by the customer to Voortman. Most of the times not according the prescribed way. When a customer has no experience at all and there is no data, the delivery specialist gives advice based on other customers and experience.

There is also some data gathered by all the initial lists which are already composed. Analysing these might also give some general insights into the consumables which are most relevant. Especially since almost all of the customers are part of the same industry, as discussed during the customer base discussion of Voortman.

Recommendation
In order to use data of historical orders, an analysis tool should be created. A suggestion is to use Excel, since it is widely used within the company. In SAP it is possible to create an export to an XLXS file, this datasheet can be put in a sheet of the Excel analysis tool. In different sheets the different consumables per process can be added and with help of a Excel worksheet formula the amount of sales per consumable can be counted.

If the data of a specific customer is uploaded to this tool, a structured and exact overview of the used consumables by this customer will be given. This gives customer specific information to determine what to include in the RTS. This is more efficient than scrolling trough the SAP list and determine the articles sold by visual inspection of the raw data. When the complete RTS sales history is uploaded to this tool, an overview of the consumables used by more customers in the same industry can help giving other customers advice or to make an educated guess what a customer potentially needs. Especially when more data of RTS orders is recorded, a better conclusion of the relevancy of specific consumables can be made.

During the execution of this research, a draft version of an analysis tool has been developed in Excel. In a first test run, for a customer who has already bought all consumables at Voortman, this analysis tool proved to be helpful and make selecting the right consumables with less effort and therefore more efficient. In appendix J more information about this tool is given.

A useful addition to the draft of the tool could be to include the use of consumables per machine, so that predicting the right selection is even more specific. When a machine operator takes a consumable out of the RTS, a machine is selected for which the item is needed. This data is available and gives insights into what specific consumables are used on what machine.

Another possibility with such an analysis tool is to show the difference between the initial filling and the actual orders by the RTS. This gives insights into the consumables which are likely to be dead stock. And thus gives an answer to the question posed to research the dead stock in the conclusion of the analysis of the quality of the process.

There are no negative consequences with implementing an analysis tool discovered. There is an investment which should be made in order to create a working analysis sheet. Since the delivery specialist is able to make one, an IT specialist is not needed. Therefore the investment costs are not high.

To conclude, there is a low key measure to get more easily valuable insights from available data with help of an Excel spreadsheet. The ordering data can be used to help in all three of the cases and in answering the proposed question of dead stock.

The creation of the initial list of consumables

In this section, two possible measures are discussed to make the creation of the initial list more time efficient. Based on an earlier observation that existing lists could be used in specific cases again for a new customer, standardisation might be a measure. As another solution for deleting the manual steps in Excel a selection tool might be a solution.

Standardisation
The proposed Excel analysis tool in the previous section is used to analyse the existing data of the ordering history of the RTS. This analysis gives the exact number of sales per consumable, which enables to select frequently used consumables. When per process the most used articles are selected, a standard list per process can be created. This can be used to create a format of an initial list by adding the processes executed by the customer.

There are a few negative consequences to this proposal. Using the logic of the Negative Branch Analysis of the TP TOC, the next problems are encountered. A standard proposal needs adjustments to the specific wishes of the customer. For some processes this would entail more changes than others, but altering a standard list gives exactly the same problems as discussed in the problem analysis phase. Currently, only steel fabrication customers are part of the analysis and these are assumed to use standard consumables since there are standard diameters of holes used in the real estate. In other industries a larger deviation of the consumable need is expected.

Although there are negative consequences, a format might be a solution for the short term with a considerable reduction of time. Especially for processes other than drilling and punching since these have a lot of different articles which can be relevant. Adding more drills than a customer needs in the initial list is also not a problem. During the process the customer can delete the consumables which are not relevant.

Selection tool
A selection tool can be used to automatically create a list, so that all the manual steps are not necessary anymore. The concept of the tool is that the delivery specialist can select the consumables and that the tool creates the list based on the selection and the relationships. As discussed in chapter 4, sales engineers do create starter packages as well. Potentially a tool has additional value for that department within Voortman.

The idea of using software is also discussed in the book of Dumas et al. (2018). In chapter 9.2 the advantages of a Business Process Management System (BPMS) are discussed. One of the key advantages is the workload reduction. A BPMS is an automation software for (administrative) processes in a company. Since the development of the composition list is a repetitive task, a software tool will reduce the workload for the RTS composition process as well.

During the research a selection tool has been developed to test the concept. The concept has been tested during the creation of one composition list. During this test run the concept proved to be working and the delivery specialist is convinced that it would increase the efficiency. In appendix K more information is given.

The designing process of a tool is an higher investment at frond than the development of process formats of consumables. Voortman has experience in designing tools and further research should give recommendations if it is possible to use this expertise of the company. In that situation the initial investment can be reduced.

To conclude, both options would be a valuable improvement of the process by reducing the time spent in creating initial lists. Although a selection tool is preferred because of the arguments given. When that reduction of time is reached and a forecast for a customer can be made, as discussed in the previous section, than a customer can receive earlier in the process a concrete list. That would reduce the necessary number of contacts, resulting in a reduction of waiting time.

Inventory stock levels of consumables

The amount of consumables that are put in an RTS has not been part of the analysis thus far. This is because the determination of the right amount of stock is not explicitly part of the composition process. The strategy behind the RTS is that with help of a dashboard analysis the stock should be corrected, according the agreement that 'Voortman will periodically execute analysis and give advice on the storage'. In this section, a better approach to determine the stock values during the composition process with use of available data is discussed.

As already discussed in 'The selection of the consumables', data can be used to improve business processes and models (Buer et al., 2018).

Available data
There are a few companies of who information about the stock levels are visible on a Power BI dashboard. This is a dashboard, which is also accessible for customers, to monitor the amount and number of articles on stock. Per month the information of the stock levels of the RTS is visualised. In appendix I visuals of the dashboard are given. The problem with the dashboards is that it are datasets per customer, so these datasets should be bundled but also the visualisation is not structured. So a different Power BI dashboard should be developed in order to gain insights into the consumable usage over time and per machine.

However, the Excel analysis tool which is recommended can also be used to analyse the amount of consumables which is sold. The only addition to the tool would be to include the number of unique customers, so that the average usage over a certain period per customer is known. An easier method to determine how often an article is ordered does also give valuable insights. Because than the frequency and the average amount per order can be calculated, showing the demand of the article.

The use of the datasets created by the RTS and used in the dashboard is preferred over the ordering data in SAP, since SAP contains the orders but not the use of consumables. So it can be the case that a customer uses plasma consumables, but after half a year a replenishment is needed. Than SAP will only give information that a customer ordered 25 articles at once, but not over what period of time it is used. So the SAP data will reflect the choices which are made in the past for the stock level of the RTS, but not give straightforward information how to change the inventory policy.

Recommendations
Using data, a standard approach to determine the stock values of the RTS for a single customer can be used. For example, when the stock levels of a few customers are visually checked in Power BI, the conclusion is that drill holders are not taken more than once per month out of the RTS. Only a few exceptional cases were found. Using this information could result in a conclusion that the default value of the minimum and maximum stock value of a drill holder is one article. This makes determining the amount of stock much easier, since the characteristics of a customer are not taken into account for making this decision.

When there is a good representation of the available data, more information on different consumables can be used to determine an approach to determine stock values based on data. Further recommendations on how data should be visualised will not be discussed, since this report is mainly about process improvement and not on dashboarding.

To conclude, using data can improve the composition process. Because a general approach of determining stock values or the use of default values reduces the time needed instead of deciding again per customer. To be able to define a general approach, available data should be better visualised so that conclusions can be drawn out of consumable usage.

Customer support

In the analysis of the process the role of the customers proved to be inefficient as well. To summarise the main problems: the communication takes too much time and the answers of the customers are not according the expectations.

One of the solutions is to send earlier in the process an initial list of consumables, so that customers have a better understanding of what is expected. If the list contains already relevant consumables for the customer, only small changes have to be made. This is more concrete than sending all pricelists to a customer and expecting a filled in list to return. And less information is needed at first from the customer.

A possibility is to reserve time in the first meeting to discuss what processes a customer is going to perform and what specific consumables a customer needs. When a selection tool has been developed, an initial list can be created with help of these questions during the first meeting. This would increase the speed of the process. When a customer needs more time to discover the information within the company, another approach should be used. But having a brainstorm session together might be the most direct way and is also in line with the agreements in the SLA that a customer together with Voortman decide what should be included.

Instead of sending pricelists per process to a customer, one file should be send containing all consumables per process. The main difference is that the customer should select consumables instead of copying and pasting the article numbers to the consumable list. This task has less steps and might lower the burden for the customer.

To conclude, there are changes possible to the process which will result in a better customer participation. Especially the first meeting with the customer can be used more effectively. The strategy of how the customer is informed and participated in the process can be changed, so that a customer is more actively involved and knows better what to do. This does not perse ask a change of the process but a different execution of the process.

Available software at Voortman to create a selection tool

Within Voortman there is a Configure To Order (CTO) department which has experience with developing tools for different automation projects. CTO is responsible for the development and maintenance of the tools. In a small demonstration of one of the tools, the programming structure of the software has been explained by the team leader of CTO.

CTO uses a standard Excel VBA programming structure. This structure makes use of data tables in the workbook sheet, where all the information is stored. The information gives input for the relationships between different items. For example, a V631 drilling machine has 4 drill heads. Than the table would have the relationship of value 4 between the V631 and the specific drill head. Based on the drill head another table has the relationship between the drill head and the hours of service. The output in this case would be information to put in a service agreement. Using the relationships in tables has as a major advantage that the information can change and that the VBA code does not need to change. The VBA code is not very hard since the same trick, checking relationships, is executed every time.

The development of a consumable selection tool can be performed by the same department. A challenging part of the development of a tool in this format is defining good relationship tables. For the relationship tables of the consumables the created taxonomies can be used to check the relationships. The relationships between a type of customer and the need of consumables per process is also information that can be put in tables. The default values of the stock values can also be put in a table. The advantage of this structure is the flexibility to change and add other relationships and data. Especially since the data which will be gathered throughout the improvement process of the composition process can be applied directly.

The flexibility of this kind of software can also deal with the different available data of customers. If a customer has no idea about what consumables are needed, relationship tables between the type of customer and the advised consumables can give a standard composition list in a few seconds. When the specific consumables for a customer are known, consumables can be selected and a composition list can be created in a few seconds. So there is software available within Voortman to build a selection tool.

Recommendation
In order to implement the selection tool a basic start might be the best option. This means to translate the taxonomies into relationship tables and use a manual selection sheet where the articles to include are selected manually. Than the tool is the same as the test tool in for this research as discussed in appendix K. The reason to start more basic is because the software is flexible to extensions. And when a more data driven approach to the selection of consumables and determining stock values is ready, this can be added later.

The software parts which are needed can be used from other tools, since the same tricks are used. Someone with some programming skills is able to build the tool, when relationships tables are developed.

A new structure of the composition process

In this section, the findings of the to-be chapter are summarised into BPMN models and table. The table contains information about the different activities of the process and recommendations which are relevant for that activity. The BPMN model is given in figure 11 and gives a new structure, based on the recommendations.

Activity	Explanation	Recommendation(s)
RTS introduction	In this meeting the customer is informed about the RTS and how the process until delivery is going.	- Explain the initial filling, so that a customer and Voortman have the same expectation. - When a customer knows what is needed, the list can be composed with the selection tool during the meeting.
Check info	In this task the information gathered from the customer in the meeting is checked and potential ordering data in SAP.	- For checking the information of a customer the analysis tool can be used. This gives a quick overview. - If there is enough data, but no specific consumables, data of similar customers can be used.

Prepare request for more specific information	If there is not enough information, than more information should be asked.	- Giving an incentive for customers to actually provide specific data should be taken into account. - Sent a list of consumables where the customer only has to select specific ones. - Explain what is expected in detail
Create initial list	In this sub process the initial list is created with help of a selection tool.	
Create initial list – Analyse information	In this task of the sub process the available information of the customer is analysed on specific consumables	- For this the analysis tool can be used - It is not perse necessary to have specific information, based on other customers specific consumables can be selected
Create initial list - Select VM machines	In this task the Voortman machines are selected.	- This information is in SAP, but new machines are not booked. Therefore the SLA with the customer could also be used.
Create initial list – Select processes of the machine	The correct processes which will be executed on the machines have to be selected.	
Create initial list – Create list using the selection tool	In this task the tool to be developed is used to select the correct consumables.	- There are several possible ways to select the correct consumables: - Specific consumables are selected, - Relationships between processes and customer type gives a advice of most relevant consumables.
Create initial list – Check stock proposal	The selection tool can be extended with relationship tables for stock values, automatically assigning values to the selected consumables	- For this a protocol should be defined, this can be done when the existing RTS data is easily accessible on consumable level or process level.
Create initial list – Check on possible customer constraints	In this task the initial list is checked if the constraints of the customer are met. If not, the list should be altered. Otherwise the list if finished	- Most of the times the constraint is financially. This can be taken into account for the first filling of the RTS.
Send and receive initial consumable list	The next step is executed by the customer where the list is reviewed.	
Check feedback from customer	When feedback of the customer is gathered, it should be checked. When the list is accepted the process is finished. Otherwise a feedback loop is performed	

Table 5 Conclusion and recommendations of the to-be process

The to-be process is largely based on the as-is process model, however executing activities in a different order and in another manner will improve the current process.

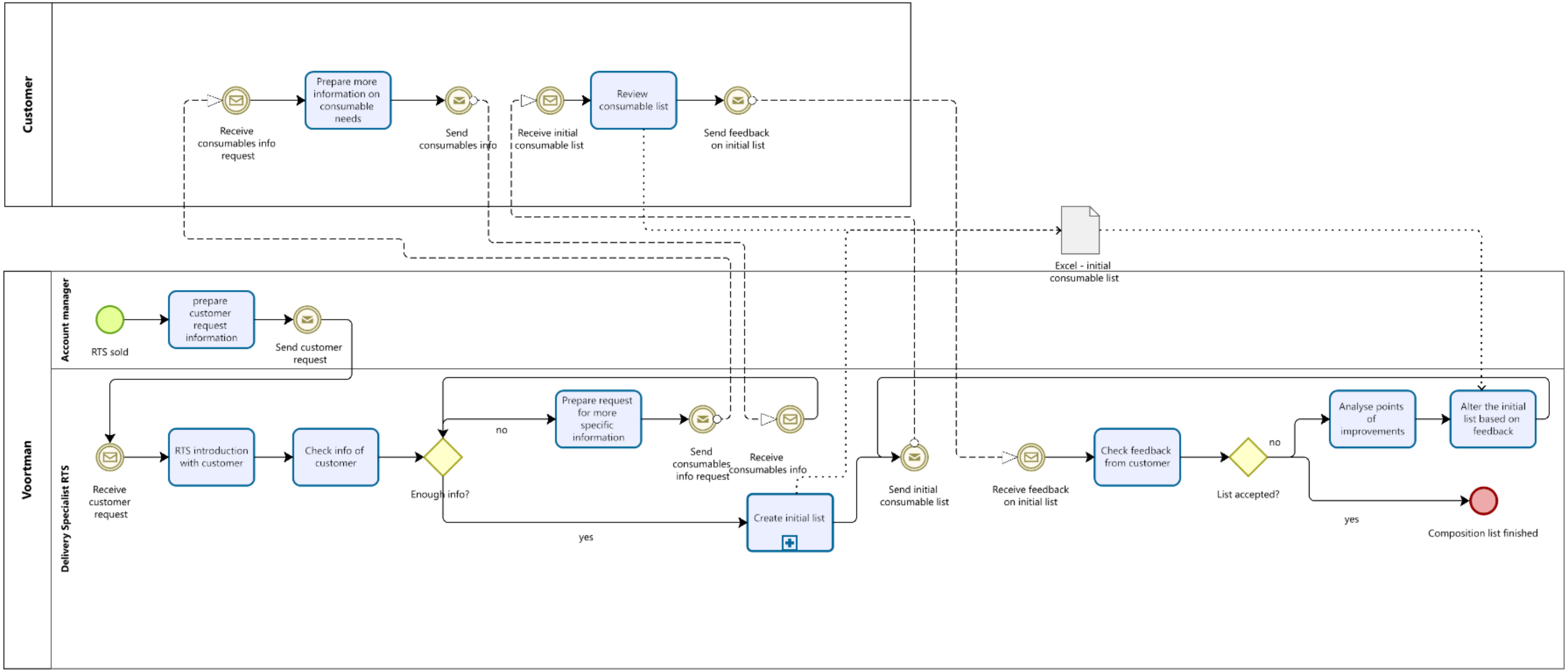


Figure 11 BPMN model of the composition to-be process

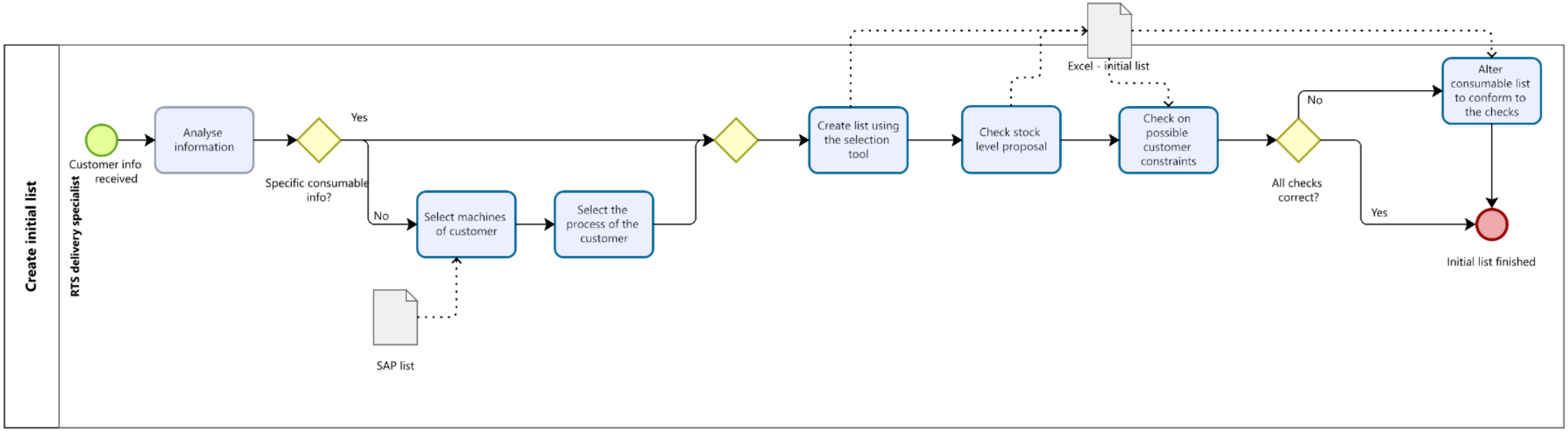


Figure 12 BPMN model of the create initial list to-be process

7. Implementation

The implementation of the recommendations

In this chapter the third question of the TOC, how to implement the change, is explored. For this a Transition Tree (TT), which is one of the tools from the Thinking Process, is used to answer to the question.

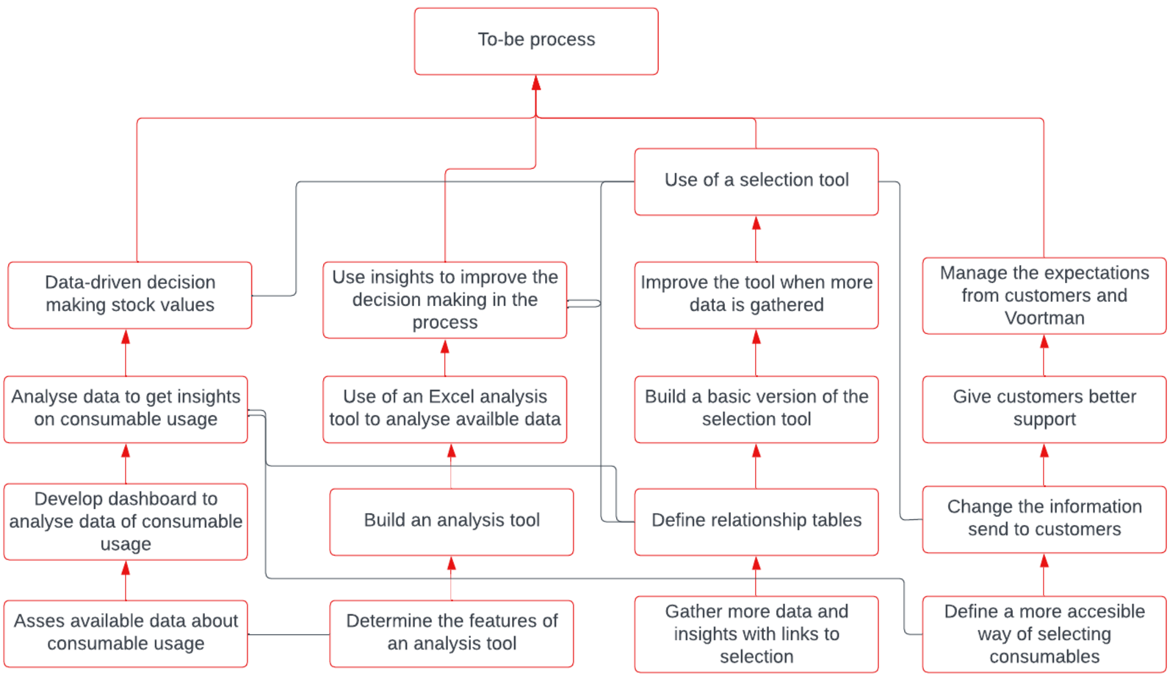


Figure 13 Transition Tree of the implementation phase

In figure 13 an implementation tree is given. To goal of all the steps is to reach to the to-be process. The top row of every column are the recommendations which are made in table 5, because these will alter the process. In the lower rows the steps which have to be executed to reach to the next step are given.

The grey lines are included to show that the implementation of a data driven decision of stock values has consequences for the development of a selection tool. Several logical relationships are portrayed by the grey lines. These are meant to show that the implementation is not one solution, but a number of changes will improve the process. The transition tree is not a very detailed step by step explanation of how to implement the changes but it gives the direction of how the recommendations can be used.

8. Validation

Validity "refers to the appropriateness of the measures used, accuracy of the analysis of the results and generalisability of the findings" (Saunders et al. p.214). In order to have a valid research design; appropriate methods should be used, the way how the analysis of the results are performed should be valid and findings should be generalisable. This validation section is about determining how valid the findings are as perceived by Voortman.

Validation form

In appendix L, all the Likert-scale statements are given which are used to validate the outcomes of this research. The main focus of the statements are on the quality of the as-is and to-be models and on findings of the analysis and measures. Some statements are based on literature, then a reference is added to the statement. A Google Forms questionnaire is developed to ask the level of agreement.

Validation outcome

In appendix M, the answers of three employees are given. Per subject the statements are discussed. For the numbered statements, see appendix L.

Statement 1 is about the organizational structure. According to the answers all the relevant departments are included.

Statement 2 and 3 are about the quality of the as-is model. According to the answers the model does contain all relevant activities. For the representation of the model, one participant disagrees with the statement if the model represents the reality. Since this participant does agree that all activities are included, it is assumed that the participant did not recognize that the statement was negatively stated.

Statement 4 and 5 are about the quality of the current composition list. The chosen KPI's to determine the quality give the right information to determine the quality according the participants. About the quality of the process there is a large spread if the quality is assumed to be high or low.

Statement 6 and 7 are about the flow analysis. The estimations of the time spend per activity in the flow analysis are considered to be close to the reality. In the agreeability if the analysis does discover the main problematic activities is a spread. On average the participants agree.

Statement 8 is about the causal factors found in the fishbone analysis. The found causal factors, as discussed in this thesis, are recognized as being potential causes.

Statement 9 and 10 are about table 4. According to the employees the observations about the activities of the as-is process are correct and complete. The assumed changes are seen as potential measures or solutions for a structured process.

Statements 11, 12, 14 and 15 are on the analysis and selection tool which are proposed in the recommendations. The insights given by the analysis tool are valuable for Voortman. Both tools are considered to be functional. Voortman should use their capacity to build a selection tool, which shows that the employees are convinced of the value of the proposed selection tool.

Statement 13 is about using a format of a composition list, the reactions on this statement show that the employees think that this measure would improve the composition process less than a selection tool.

Statements 16, 17 and 18 are about the quality of the to-be model. On average, the respondents agree that the process contains all relevant activities and that the activities included are correct. However, the participants differ in their level of agreeability. The respondents do unanimously agree that the process is executable. The executability of the process does also give some information about how the participants look to the correctness and completeness of the process. So the reactions on the statements are in line with the expectations based on the individual answers of the statements.

Statement 19 is about the transition tree. Two respondents disagree with the statement that the transition tree does not represent a roadmap to implement the new process, while 1 respondent agrees that this transition tree does not represent a roadmap to implement the new process. This reaction is not contrary to this thesis, because the goal of the transition tree in this thesis is not a strict transition protocol.

Conclusive discussion

Overall, the employees of Voortman do agree on the findings in this report. The quality of the BPMN as-is model is considered to be good. Since the as-is model has been developed with feedback sessions, this was already expected. The to-be BPMN model is considered to be of a good quality, however the agreeability is less unanimous as for the as-is model. Specific reasons are not researched, assumptions can be made that managers expect another model than an operational employee.

The different analyses executed in this research finding the causal effects and the quality of the process did result in findings which are related to the real-world. This shows that the used methods and a correct interpretation of the results gave findings which describe actual matters.

A small negative notion is that in the conclusion of the quality the statement is made that Voortman does perceive the quality of the composition list as good or high enough. While the responses in the Google Forms are more mixed if the quality was high enough.

9. Conclusion

In this section, a conclusion and a critical reflection on the research question of this thesis is given. In order to get a structured conclusion, every sub-question is answered and discussed and then an overall conclusion is given. At last limitations of this research and possible research topics are given.

Sub-question 1*: How does the current RTS composition process look like?*

In picture 3 an overview of the departments included in the RTS are given. This gives a background information for the context of the composition process. The RTS composition process has been modelled in BPMN models (see figure 4 and 5), which gives an overview of the activities undertaken in the process. In modelling, choices have been made in order to get an average model. However, as discussed in the validation section, the BPMN quality is good and thus represents the reality.

Sub-question 2: *What are points of improvement according the analysis of the as-is process?*

Based on the process discovered in sub-question 1, a flow analysis has been executed to quantitatively analyze the process. In this analysis several time consuming activities are determined which are analyzed qualitatively with help of a fishbone analysis. Based on this, the observation is made that the process is dependable on the customer and that the composition list is created manually. This is recognized by Voortman as potential points of improvement.

A critical note of this quantitative and qualitative analysis methods is that different estimations of time and another way of reasoning might give different answers. However, the methods lead to activities and causes which are actual problems. Or better to state, Voortman recognizes the problems found in this analysis as discussed in the validation section. More problems which are not found can still exist.

Sub-question 3: *How can customer service improve specific activities of the RTS composition process?*

Based on the flow analysis, several activities of the process are considered to be time-consuming or could be made more time efficient. The waiting times and the tasks 'create initial list', 'check on consumable relationships', 'select specific consumables' and 'determine amount of consumables' are discussed to make improvements in how these tasks are managed. For this, some existing literature for supporting decision making is used. Some improvements lack a suitable scientific underpinning, this is discussed later.

The improvements are mainly about using tools and data to process the different activities faster. The proposed tools, of which a test version has been developed, do show that the composition of the initial list is more time efficient. There are also recommendations how customers can be supported better, so that the expectations between Voortman and the customer are on the same level. A change in the overall process should reduce the waiting times. In table 5, all the exact recommendations are mentioned.

Sub-question 4: *How should the structured to-be RTS composition process look like?*

In table 5, all the activities are discussed together with recommendations how to make them time efficient. As a result of the as-is process discovery and the recommendations a to-be BPMN model of the composition process has been developed (see figure 11 and 12). Once the as-is BPMN model was created, a general structure and all the activities which are part of the process were defined. For the to-be process model the next step was to give an improved version of a structured process, based on the analysis and recommendations.

Research question: *What is a suitable plan for customer service to introduce a structured RTS composition process?*

In this thesis, the research question has been answered. An as-is BPMN model, quantitative and qualitative analysis, recommendations, a to-be BPMN model and a implementation tree have been developed or performed in order to answer this question. In the validation part and in the conclusion is shown that the deliverables give Voortman a structured business model of the composition process which can be incorporated.

Further research

There are a few limitations with regard to this thesis. There has been no discussion if the RTS delivery specialist should actually be in the current department, or that a better department would be Sales engineer based on the departments analysis. This could be part of a further study. This thesis also does assume that a better support of customers will increase in a better customer participation. Incentivising customers is a large research area, this should be researched further in order to get a better understanding of how the customer can be supported best in order to live up to the expectations of Voortman. And lastly, this study has been about developing a complete process design, therefore the research has been broad. A specific research into relevant activities might give more information leading to an even better improvement.

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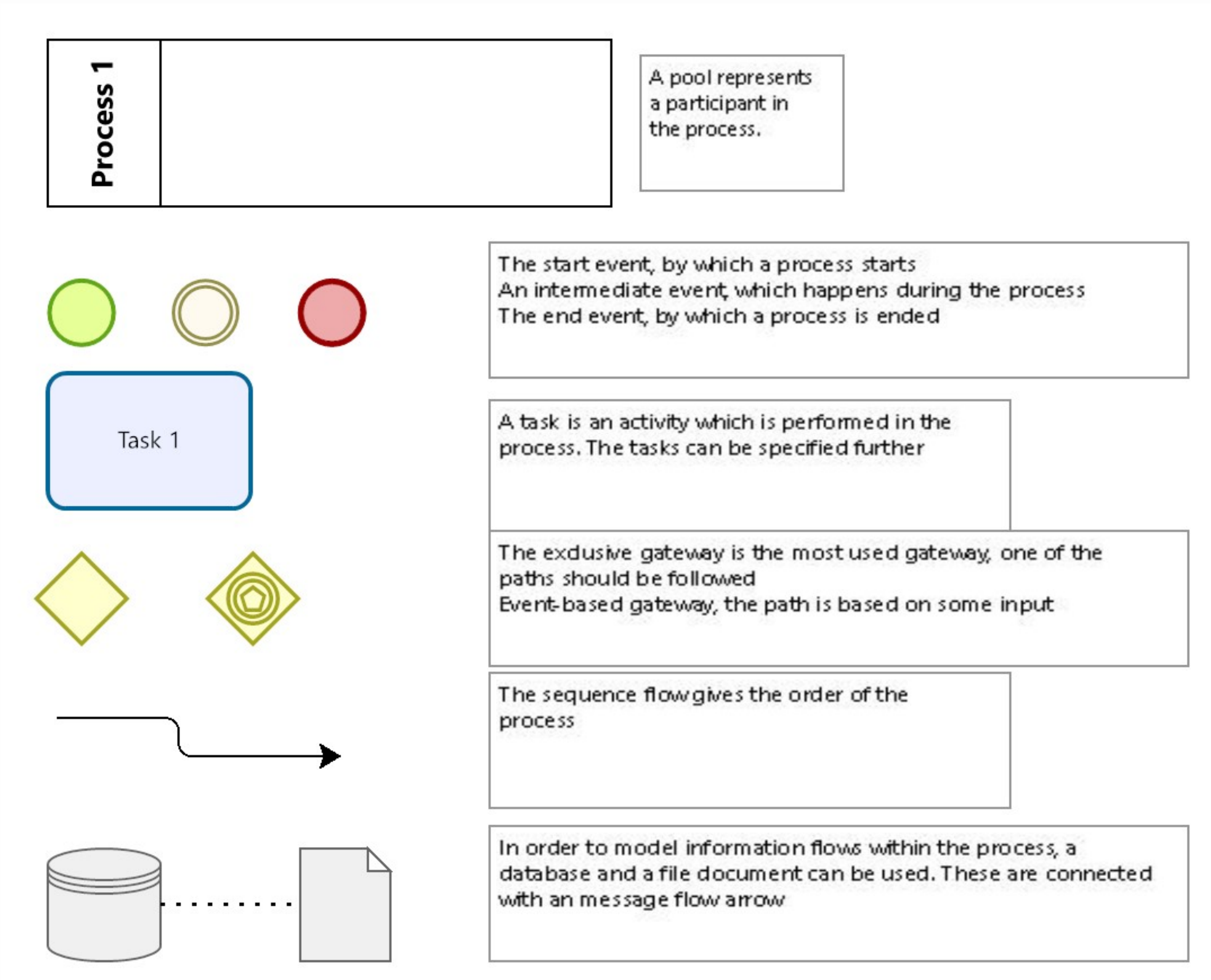
Appendixes

Appendix A: Research design

RQ	Data gathering method	Theory	Deliverable
Sub question 1			
RQ 1: *What is the organisational structure of Voortman with regard to the RTS?*	Interviews and observation	BPM	A scheme of the organisational structure
RQ 2: *How does the current composition process look like?*	Observations and brainstorm sessions	Business Process Modelling Notation	BPMN models of the process and sub-process
RQ 3: *What is the quality of the process?*	Data objects in SAP	KPI's	Analysis of the quality
RQ 4: *What are time consuming tasks within the composition process?*	Observations and brainstorm sessions	Flow analysis of BPM	Flow analysis scheme and tables
RQ 5: *Why are the activities time consuming?*	Observations and interviews	Fishbone analysis	Fishbone analysis of the root causes
RQ 6: *How can customer service improve their composition process?*		TOC TP	Summarising of previous findings
RQ 7: *What consumables are stored in an RTS?*	Available data within Voortman and interviews	Taxonomies	Taxonomies of the consumables
RQ 8: *What is the customer base of Voortman?*	Available data within Voortman and interviews	Taxonomies	Taxonomy of the customer base
RQ 9: *How can the selection of consumables be improved?* RQ 10: *How can the creation of the initial list be improved?* RQ 11: *How can the amount of stock of consumables be determined?* RQ 12: *How can customers be supported to give more specific information?*	Available data within Voortman		recommendations
RQ 13: *What software is available at Voortman to create a selection tool?*	Observation of available software		
RQ 14: *How should the structured composition process look like?*		BPMN	BPMN models of the to-be process
RQ 15: *How should Voortman implement the recommendations to change to the to-be process?*	Combining findings in the report	TOC TP – Transition Tree	Transition Tree

Table 6 Research design: method, theory and deliverables

Appendix B: BPMN Language



Appendix C: Thinking Process of the Theory Of Constraints

In order to improve a specific business process the Thinking Process (TP) posses 3 different questions; What to change, to what to change to, how to implement the change? TP is one of the methodologies based on the theory of constraints (TOC). Other methodologies are the operations strategy tools and performance systems. The general idea of the TOC is that there are constraints which hinder a process to achieve its goal (e.g. Kim et al., 2008) In order to make the process more effective in reaching its goal, these constraints have to be resolved.

The TP methodology consists of different tools to examine the 3 questions. According to Scoggin these are: Evaporating Clouds (EC), Current Reality Tree (CRT), Future Reality Tree (FRT), Negative Branch Analysis (NBA), Prerequisite Tree (PT) and Transition Tree (TT). The other articles that give an overview of the TP theory give the same techniques, with a small note that Kim et al. (2008) give some refinements on these techniques.

The EC is a method which gives a structured template to examine the current process by examining a core problem. In appendix D, the template of the EC is showed together with a small explanation of Kuruvilla (2017). Not only is the EC a method to get better insights into the core problem, but the EC also gives a hint what to change (Kim et al., 2008). According to (Taylor & Thomas, 2008), the EC is used when there is no clear answer or the answers are in conflict to the core problem. In contrast to Scoggin et al. (2003), (Taylor & Thomas, 2008) put the EC technique after the CRT. This seems to be more logical, since the core problems will be find with help of a CRT.

The CRT is a "logic-based tool for using cause-and-effect relationships to determine core problems that cause the undesirable effects of the system" (Walker & Cox, 2006, p.139). A step-by-step approach for the traditional approach of constructing a CRT is shown in appendix C. The objective of the CRT is to explore the core problems and to find the constraints which are the most pressing to solve (Kuruvilla, 2017). When the tree is constructed, the logic of the tree can be checked. This can be done by using if-then statements while reading the tree bottom-up (Taylor & Thomas, 2008).

The objective of a FRT is to visualize that the changes of the process will take away the constraints found in the CRT and EC (Kim et al., 2008). A small explanation of the logic which should be followed will be discussed based on the FTR example by Taylor & Thomas (2008). The tree is built with help of cause and effect relationships. The FTR starts with a injection, a possible solution to resolve the constraint, at the bottom. It is possible to have more injections throughout the tree. The rest of the tree is than build with if-then statements and these statements are linked by logic. When the injections lead at the end towards a desired effect, the injections show to resolve the constraint.

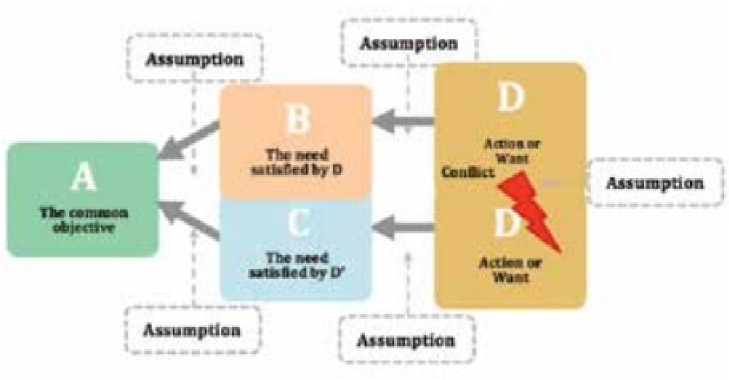
However, it is possible that the injection has negative consequences. For this the tool NBR/NBA can be used to analyse negative outcomes and based on this insights possible injections can be included to prevent these(Scoggin et al., 2003). A precise method to use the NBR is not mentioned, although using cause and effect relationships to form a diagram, or a subtree of the FTR, are suggestions to explore the negative results (Scoggin et al., 2003) and (Kuruvilla,2017). Scoggin et al. (2003) uses a tree-like diagram with the negative effect on top and a logic analysis of negative statements downwards.

For the implementation of the injections, 2 tools can be used. A PRT is executed by exploring all possible obstacles in the process of implementing the injections and how these are overcome (Kuruvilla, 2017). Taylor & Thomas (2008) use a table to show what the obstacles are and how these will be resolved. A TT is a "detailed step-by-step set of actions that need to be completed in order to implement change within an organization"(Scoggin et al., 2003, p.789). For this a diagram with layers of actions which should be taken can be constructed, with on top the injection (Kuruvilla, 2017).

The use of the techniques mentioned, are part of a toolkit which can be used in any problem (Taylor & Thomas, 2008). The Indian case study of Lowalekar and Ravi (2017) shows with help of a simulation that the use of TP TOC to find desirable effects can result in a more effective and efficient business process. It is also possible to use only one or a few of the tools, as already noticed in the literature. According to Kim et al. (2008), the selection of tools can be done based on the specific situation and needs of the users.

The theory discussed does answer the question "how can the theory of constraints be used to analyse inefficient business processes?". With help of a SLR a specific methodology within the theory of constraints is found, the Thinking Process. TP consists of techniques to logically analyse the current problem situation, to come up with possible injections and how to implement these. Applying these techniques in the process redesign phase of the research will give solutions, by logic these can be proven to be successful, to improve the business process at Voortman. These reason to use this theory instead of different methods is that there is no analytical data of the process at Voortman. Therefore a method which guides logical thinking is the best suitable method.

Appendix D: SLR Appendix



The cloud is about the necessity logic. This diagram can be read as
"In order A we (I/they/etc) must B
In order B we (I/they/etc) must D
In order A we (I/they/etc) must C
In order C we (I/they/etc) must D'
D and D' are in direct conflict
D puts in danger the need C
D' puts in danger the need B"

Figure 14 The format of an EC, obtained from (Kuruvilla, 2017, p. 12)

Step 1	List between five and ten problems (called undesirable effects – UDE's) related to the situation
Step 2	Test each UDE for clarity – is the UDE a clear and concise statement. This test is called the *clarity reservation*
Step 3	Search for a causal relationship between two of the UDEs
Step 4	Determine which UDE is the cause and which is the effect. Read as "IF cause THEN effect." This test is called the *causality reservation*
Step 5	Continue the process of connecting the UDEs using the If-Then logic
Step 6	Many times the causality is strong to the person feeling the problem but doesn't seem to exist to others. In these instances, "clarity" is the problem. Use the *clarity reservation*. Generally, entities between the cause and the effect are missing
Step 7	Sometimes the cause by itself is not enough to create the effect. These cases are tested with the *cause insufficiency reservation* and are improved by reading "*if* cause *and* ___________ *then* effect"
Step 8	Sometimes the effect is caused by many *independent* causes. The causal relationships are strengthened by the *additional cause reservation*. These cause-effect relationships are called a "*magnitudinal and*" for each cause increases the magnitude of the effect. Each of the causes must be addressed individually to eliminate most of the effect
Step 9	Sometimes an if-then relationship seems logical but the causality is not appropriate in its wording. In these instances words like "some", "few", "many", "frequently", "sometimes" and other adjectives can make the causality stronger
Step 10	Numbering of UDEs on the CRT is for ease of locating entities only. An asterisk by a UDE indicates that UDE was provided in the original list of UDEs

Figure 15 The procedure to construct a CRT, obtained from (Walker & Cox, 2006, p. 140)

Appendix E: Tooling taxonomies

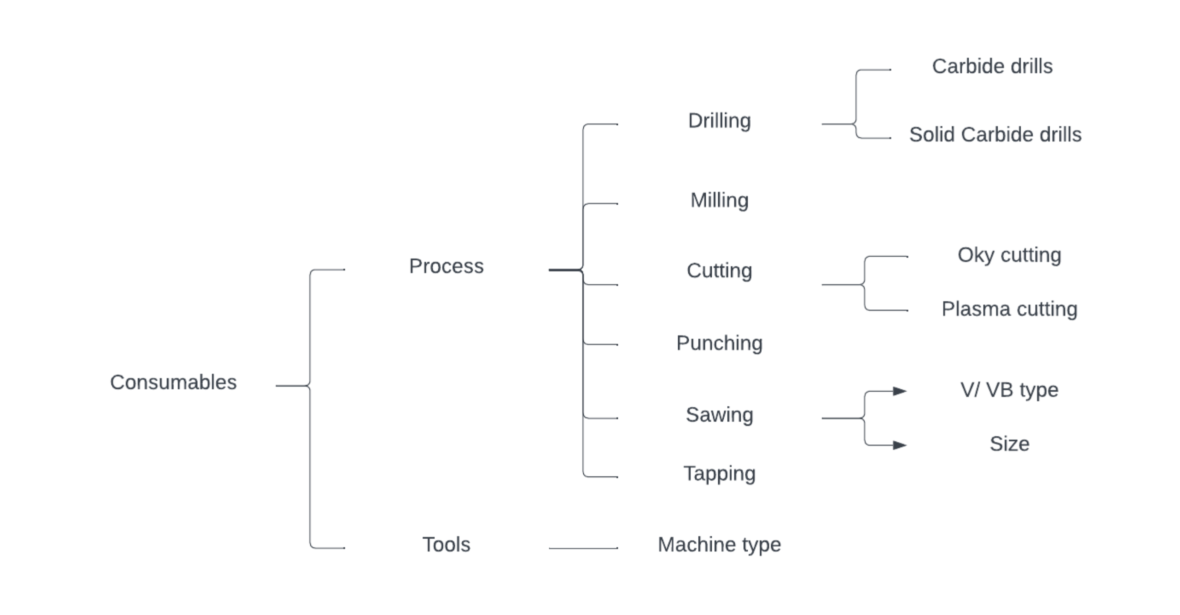


Figure 16 Taxonomy of consumables

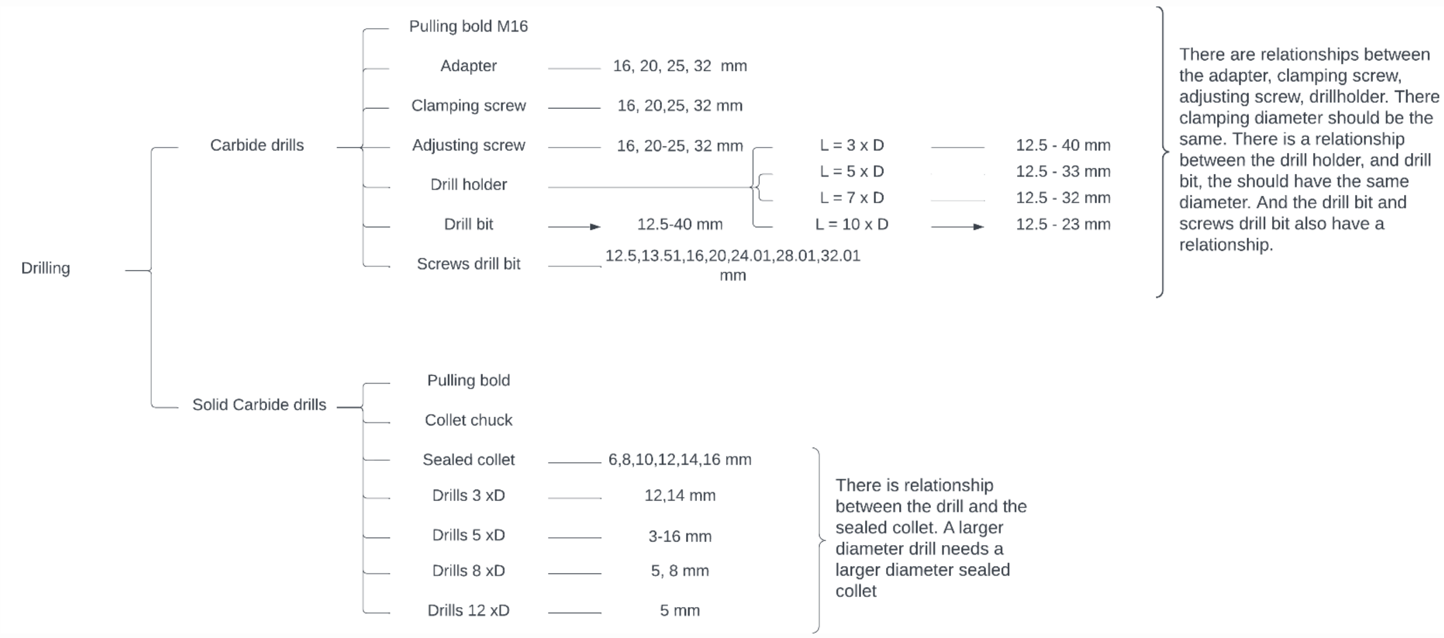


Figure 17 Taxonomy of consumables - Drilling

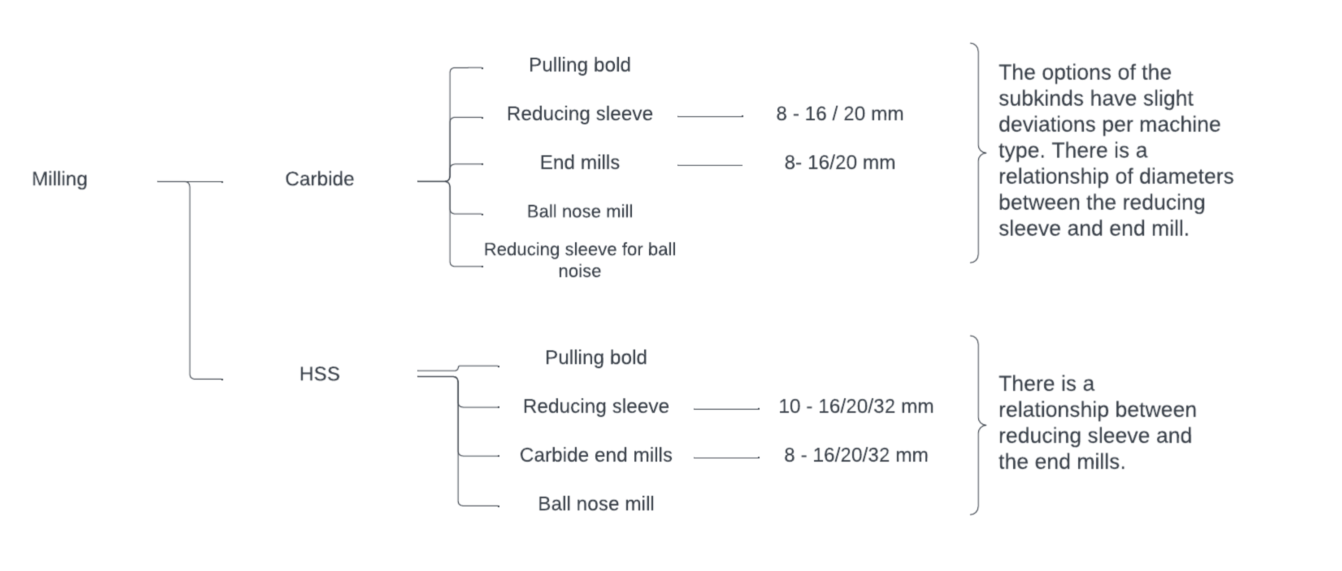


Figure 19 Taxonomy of consumables - Milling

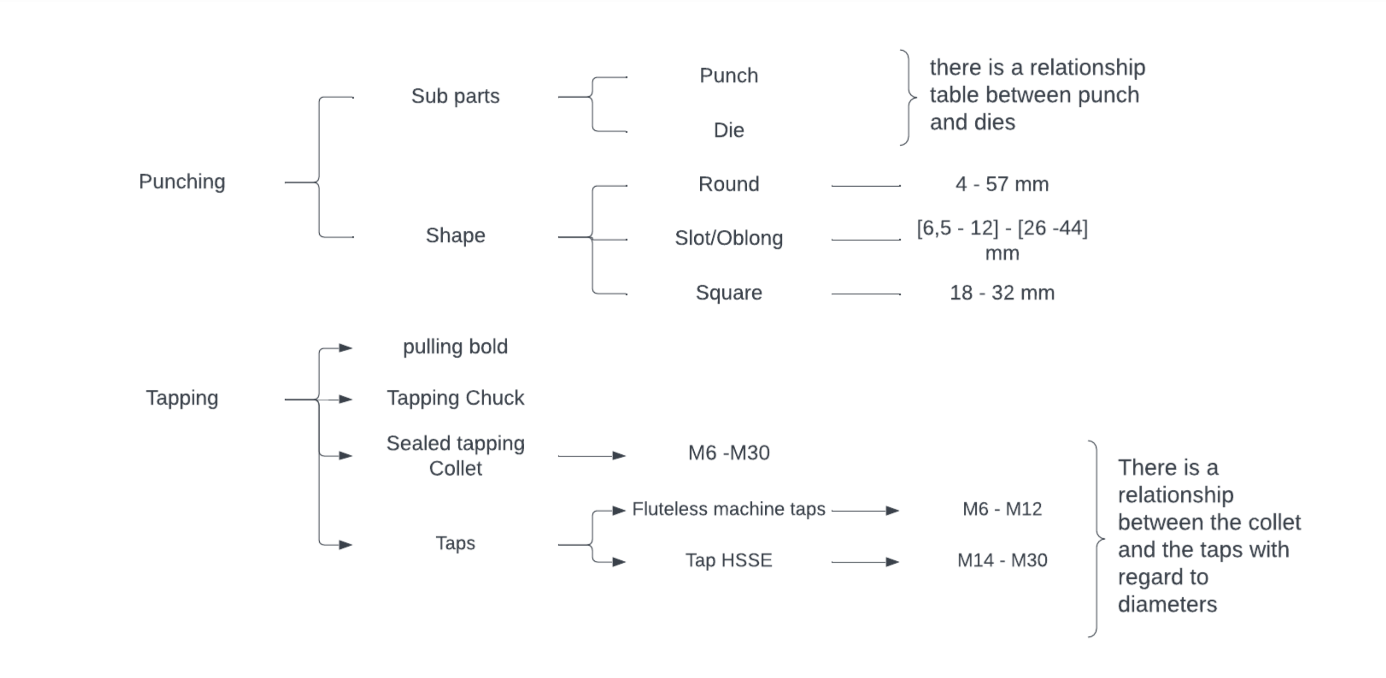


Figure 18 Toxonomy of consumables - Punching and Tapping

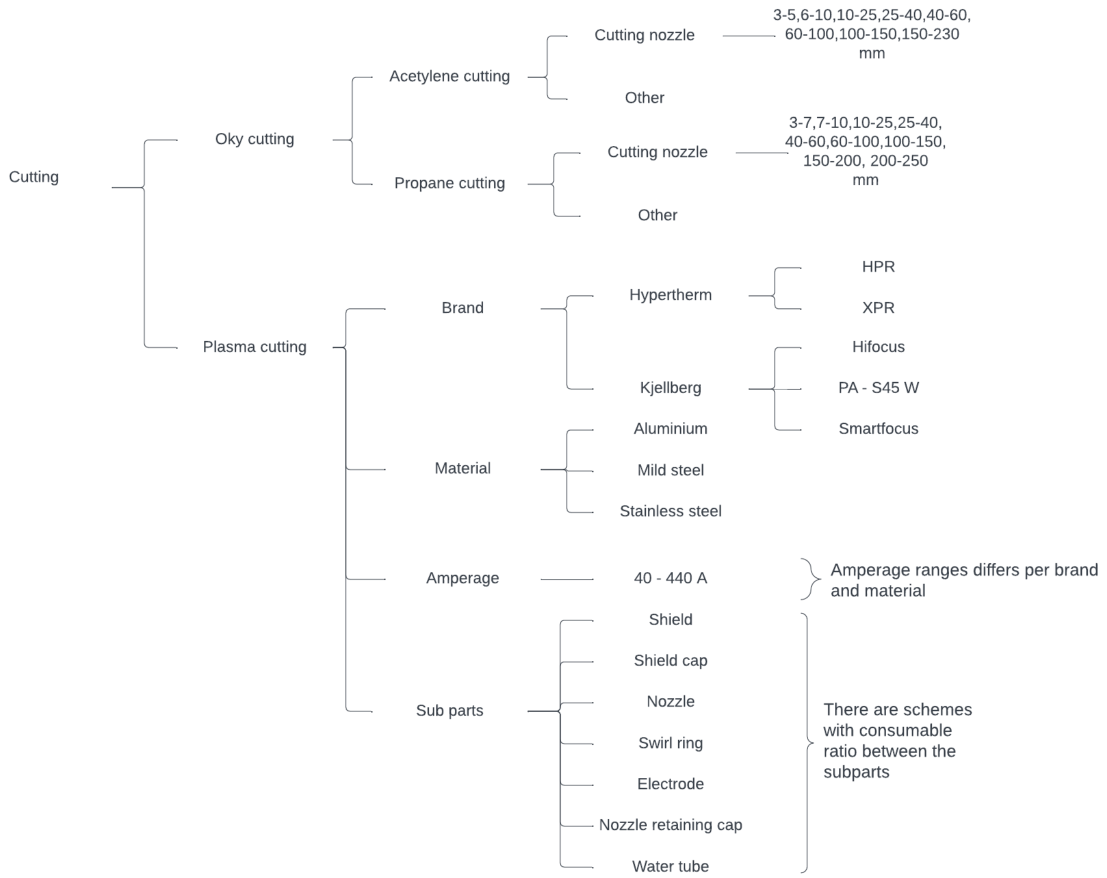


Figure 20 Taxonomy of consumables - Cutting

Appendix F: Current machine portfolio in relation to RTS

In this figure an overview of the combinations of machines in relationship to an RTS is given. For the research it does not have direct relevancy. However, this might give Voortman some insights which are interesting to have. In order to draw any conclusions on this data more information on the sales of machine should be taken into account.

Machines	#
V200	3
V304	7
V310	14
V320	8
V325	1
V808	3
V807	11
V505	2
V550	10
V600	1
V603	1
V630	9
V613	1
V623	1
V631	14
V633	3
V704	3
VSB	12
VHP	1
V2000	2
V70	4
V71	2
VP	1
FABR. IX	1
VB	17

Figure 21 Machines in combination with the RTS

Appendix G– Example of an initial list

The consumable list in this figure is part of a real consumable proposal towards a customer. This list is currently composed manually.

Voortman Red Tooling System						
Inventory proposal						
Customer						
Machines	V302 + V550-7 + V320 + V633 + VB1250 + V807 + V630					
Material number	**Description**	**Add**	**Yearly usage**	**Monthly usage**	**Minimum value**	**Maxiumum value**
	Mild Steel cut consumables					
005-7843	XPR Shield 30A MS 420228	30 AMP			6	8
005-7857	XPR Nozzle Retaining Cap 30-300A 420365	30 AMP			11	15
005-7858	XPR Nozzle 30A MS 420225	30 AMP			1	2
005-7872	XPR Swirl Ring 30A MS CW 420407	30 AMP			1	2
005-7884	XPR Electrode 220-300A MS 420276	220-300 AMP			5	10
005-7842	XPR Shield Cap 30-300A 420200	30-300 AMP			5	10
005-7889	XPR Water Tube 30-300A 420368	30-300 AMP			5	10
	Mild Steel Bevel consumables					
001-0133	HPR XD Shield 130A 220183	130 AMP			5	10
001-0128	HPR XD Nozzle 130A 220182	130 AMP			5	10
002-2430	HPR XD Electrode 130A Silverplus 220665	130 AMP			5	10
001-0129	HPR XD Nozzle 260A 220439	260 AMP			15	30
002-2431	HPR XD Electrode 260A Silverplus 220668	260 AMP			15	30
001-0126	HPR XD Water Tube 30-260A 220340	30-260 AMP			1	2
	Plasma maintenance					
001-5940	O-ring silicone 0,208x0,070 026009				2	3
001-0122	Torch Coolant 028872 Hypertherm				2	4
005-9231	XPR Quick Disconnect Torch 420221				0	1
	Drilling					
000-1216	Pulling bolt SK40 DIN69872A M16				2	3
002-5337	Adapter SK40-WN16-130 D=36 DIN69871				0	1
002-5338	Adapter SK40-WN20-130 D=40 DIN69871				0	1
002-5339	Adapter SK40-WN25-130 D=46 DIN69871				0	1
002-5340	Adapter SK40-WN32-130 D=52 DIN69871				0	1
006-6897	Clamping screw M12x10				0	1
005-1712	Clamping bolt M16x1x10mm				0	1
007-0763	Drillholder ø16mm L=3xD WN20				1	2
002-4165	Drillholder ø18mm L=3xD wn20				1	2
002-5536	Drillholder ø20mm L=3xD wn25				1	2
000-1282	Drillholder ø21mm L=5xD wn25				1	2
002-4166	Drillholder ø22mm L=3xD wn25				1	2
000-6596	Drillholder ø26mm L=3xD wn32				1	2
000-6598	Drillholder ø28mm L=3xD wn32				1	2

Figure 22 Example of an initial list of consumables

Appendix H – Fishbone analysis

In this section, the fishbones of the three findings of the analysis of causal factors for time consuming tasks are given. Together with a small explanation.

Waiting time

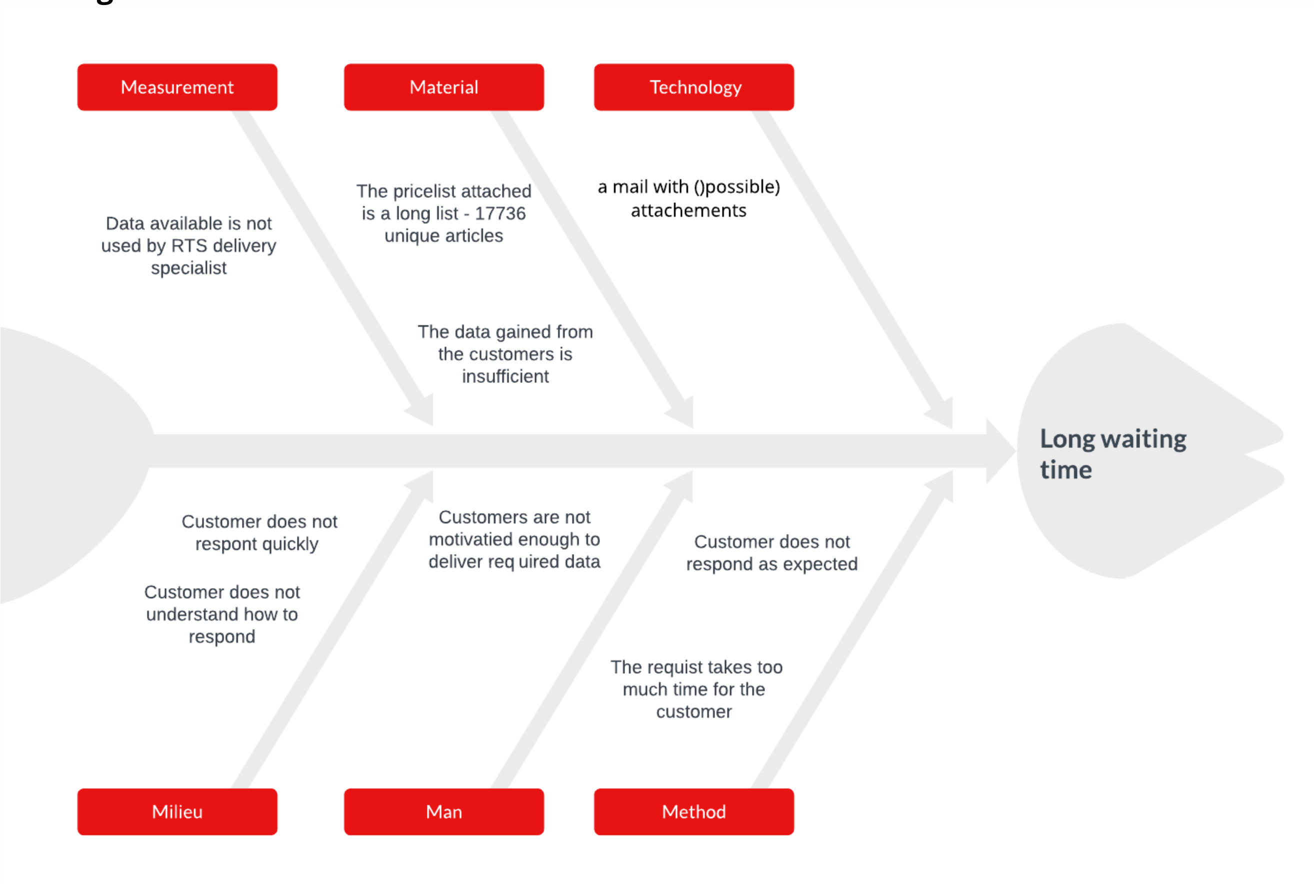


Figure 23 Fishbone analysis waiting time

In the 6 categories, problems are inserted related to them. Of course, there is some discussion possible if a certain problem can be under a different category. Though more important is that the problem is included.

The problem 'a mail with (possible) attachments' might not be seen as a problem. Although the observation is that this way of communication and use of technology might hinder a good incentive for the customer to put effort in this project. No customers deliver a (fully)created list themselves. That is also something that comes across as the root cause in other problems stated.

Another cause for the long waiting times is that available data to make a list of consumables based on data of other customers is currently not part of the structure. When Voortman can give a proposal towards a customer in the first mail or contact moment, the process might directly be in the second phase.

'Create initial list'

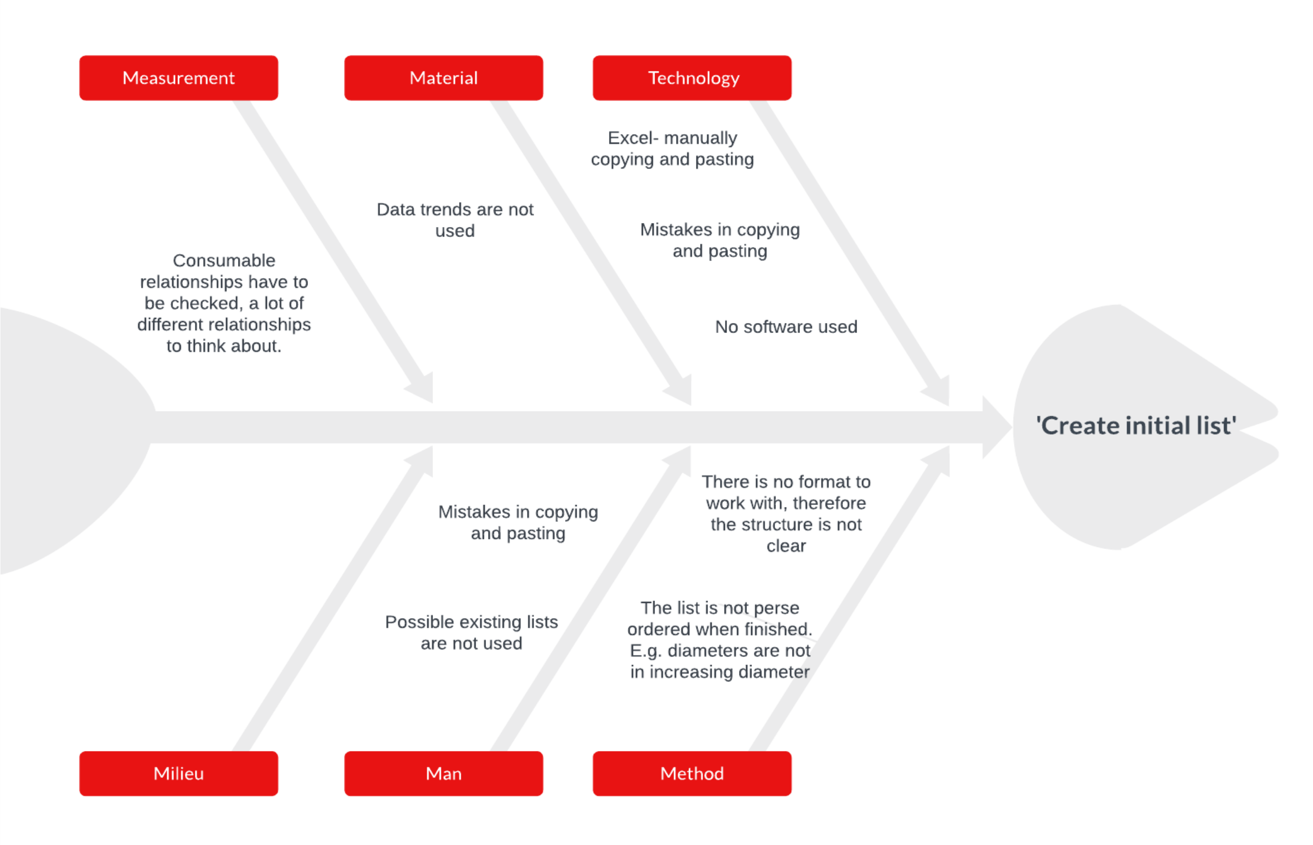


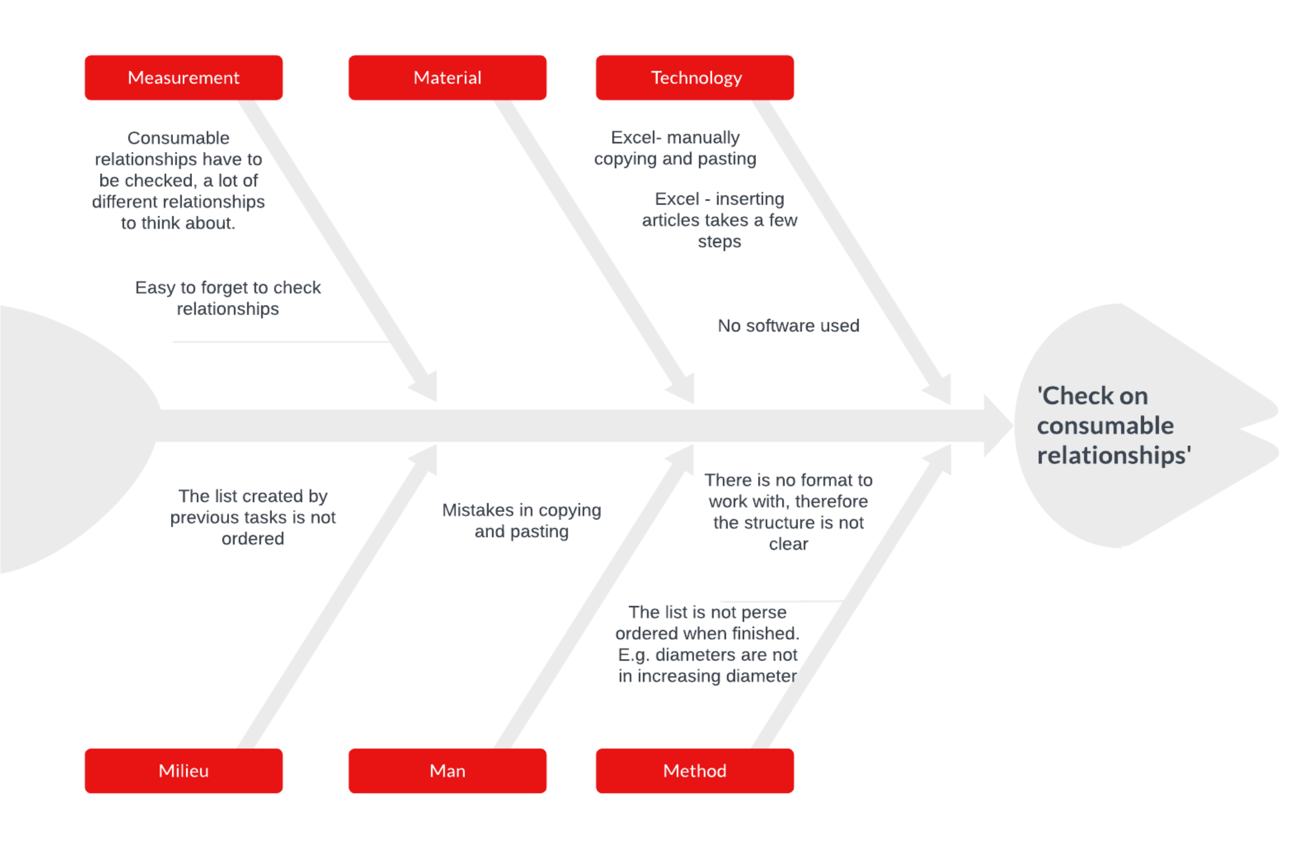
Figure 24 Fishbone analysis 'Create initial list'

Most of the problems or causes for an inefficient activity are related to the fact that the current task is manually and not executed according a set workplan. Therefore every necessary step of the process should not be forgotten and tooling relationships should be checked when including an article. This asks a lot of thinking and checking, which is time consuming but also sensitive to errors. Also the outcome of this process reflects the unstructured workplan. The list is potentially unordered and should be restructured manually. This has consequences for the next tasks in the process.

Since every article has to be copied and pasted from the pricelists per process, a lot of articles have to be copied and manually put at the correct place in the list. This is sensitive to mistakes and is repetitive work, which is not value adding in the end.

Another cause is that a list has to be created from scratch, there is only a format of the headers and layout. Data trends are not used in composing proposals, this is actually also a problem in the 'select specific consumables' task which is closely related to this. This will be taken into account during the recommendation phase.

‘Check for consumable relationships’

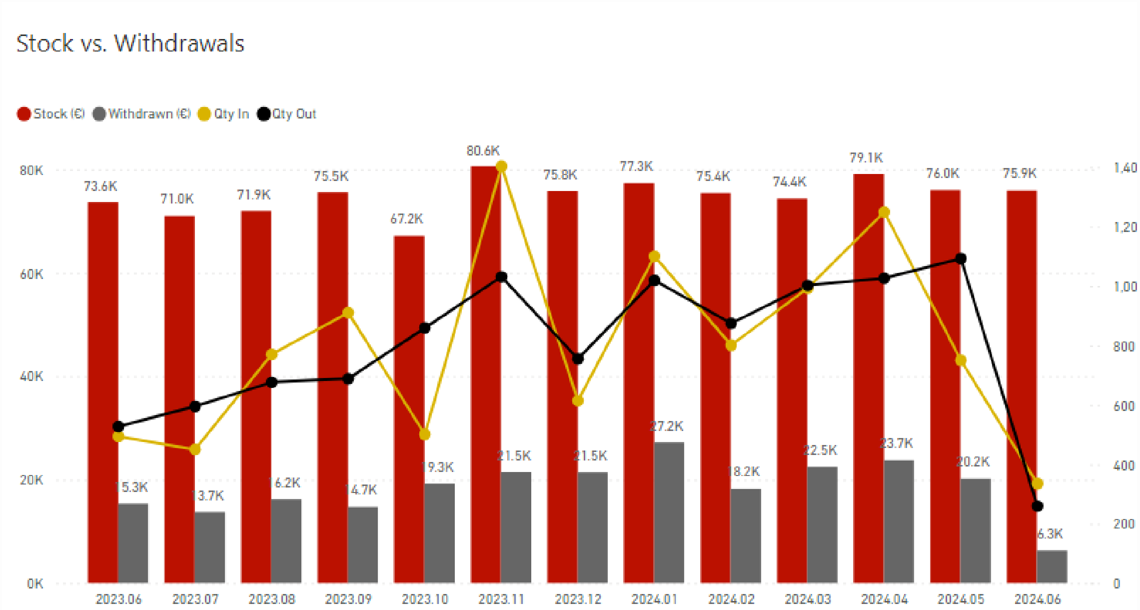


Most of the causes discussed in the previous paragraphs relate to this activity as well. This is simply because the initial list created in Excel is also altered in Excel, meaning that the same problems occur. Specific for this task is that for every consumable, the relationships has to be checked. Which asks a lot of thinking and to be analytical strong. An unordered list makes this even more work. When a new article should be included, inserting an item takes a lot of steps due to the used Excel form.

If the task ‘create initial list’ is executed correctly, this task can be completely removed from the process.

Appendix I – RTS Dashboard

Because of confidentiality, not the complete dashboard can be shared. Though the tables are representative for the information gathered and visualised by the dashboard. In the first figure a complete overview of all the consumables is given. If a specific consumable is selected in the dashboard, for example in the table of the second figure, the bar graph shows the stock values in the last year of that specific item. For an analysis for the stock values this is valuable data, however the format in which the data is presented makes it difficult to make conclusions.



Items | Details

Item	Description	Stock Qty	Stock Value	Withdr. Qty	Min.	Lowest Qty
000-1204	Sleeve (2, 4) V550/V250 (44x45m	4	262	3	2.00	2
000-1216	Pulling bolt SK40 DIN69872A M16	8	50	6	4.00	4
000-1318	Carbide Tip Ø14mm KSEM HPGM KCP	5	347	6	4.00	3
000-1336	Carbide Tip Ø16mm KSEM HPGM KCP	4	338	4	4.00	4
000-1347	Carbide Tip Ø18mm KSEM HPGM KCP	5	437	6	4.00	3
000-1357	Carbide Tip Ø20mm KSEM HPGM KCP	6	612	2	4.00	0
000-1365	Carbide Tip Ø22mm KSEM HPGM KCP	5	493	6	4.00	5
000-1380	Carbide Tip Ø26mm KSEM HPGM KCP	7	822	1	4.00	7
000-1395	Carbide Tip Ø30mm KSEM HPGM KCP	5	647	1	4.00	5

Appendix J: The ordering history analysis tool

As discussed in the selection of consumables a analysis tool to get an overview of the consumables a customer has bought at Voortman is a helpful support to the process. During the process, a blueprint for such a tool has been created to test the functionality and the value for such a tool. In this appendix, this tool is showed in the functionality. This tool is also handed over to Voortman.

milling		#RTS	#Initial lists	#Customer	# of orders
010-0916	SK40 WD16 Cool Bores L=130	1			1
Pulling bolt					
ARTICLE#	Description				
000-6659	Pulling bolt SK50 DIN69872A+B M24	2			1
Reducing sleeve SK50					
ARTICLE#	Description				
008-4472	SK50 WD8 Cool Bores L=130				
008-4473	SK50 WD10 Cool Bores L=130				
008-4474	SK50 WD12 Cool Bores L=130				
008-4475	SK50 WD16 Cool Bores L=130				
007-4030	SK50 WD20 Cool Bores L=100				
Reducing sleeve SK50 High Performance					
ARTICLE#	Description				
009-7654	SK50 WD8 Cool Bores HP B+ L=134				
009-7653	SK50 WD10 Cool Bores HP B+ L=129				
009-7652	SK50 WD12 Cool Bores HP B+ L=123				
009-7651	SK50 WD16 Cool Bores HP B+ L=117				
009-7650	SK50 WD20 Cool Bores HP B+ L=107				
Carbide end mills V310					
ARTICLE#	Description				
006-9591	Harvi Carbide Mill ø8mm WD8 necked		28		
007-0205	Harvi Carbide Mill ø10mm WD10 necked	7	25		3
006-9592	Harvi Carbide Mill ø12mm WD12 necked	50	43		14
006-9593	Harvi Carbide Mill ø16mm WD16 necked	64	37		15
006-9594	Harvi Carbide Mill ø20mm WD20 necked	47	31		11
ARTICLE#	Description				
004-2604	HSS rough end mill 8mm (WD10)		3		
004-2605	HSS rough end mill 10mm				
004-4038	HSS rough end mill 12mm	21	9		7
004-2606	HSS rough end mill 16mm	20	9		6
004-2607	HSS rough end mill 20mm l=54mm	8	3		3
007-5041	HSS Rough End Mill 20mm DIN 844 91mm	16			5
007-1538	Harvi Carbide Mill ø20mm Cylin. necked				
HSS Ball Nose Mill*					
ARTICLE#	Description				
006-9588	SK40 WD20 Cool Bores L=63	6	7		5
010-2511	HSS Ball Nose Mill ø20mm WD20				

ZRTS | Initial lists | Customer | milling | drilling | Countersinking | Tapping | Marking | Cutting-plasm

Figure 25 Example of an analysis sheet of the ordering data

In figure – an example is given of the analysis sheet. The sheets are not very difficult. The available consumable lists are put in one Excel file. These are the green tabs and contain the information of the taxonomies. In the grey tabs ordering data can be put. ZRTS contains all the ordering history of the RTS, which is also the first column of the analysis tool. This gives insights in what other customers bought and thus needed. In the Initial list, the data about the initial filling is put, to compare the ZRTS orders with the initial filling. The Customer tab can be used to put SAP data of customers. Than the third column will show per article how much is bought during the period of time of the SAP data. In figure 24, immediately is recognised that the customer does not do milling. If the customer does not have a new machine which can mill, this process should not be filled in the RTS.

		#RTS	#Initial lists	#Customer
008-9898	Adapter SK40-WD25-35 DIN69871 D=45			
009-5954	Adapter SK40-WD32-65 D=50 DIN69871			
008-1415	Synch. Tapping Chuck M6-M30 ER32 SK40	7	3	3
Spanner for Nut				
ARTICLE#	SIZE			
008-0130	Spanner For Nut Collet Chuck ER32	1	2	1
Sealed Tapping Collet ER32				
ARTICLE#	DIAMETER AND SIZE			
009-0944	Sealed Tapping Collet ER32 Ø6mm M6			
009-0945	Sealed Tapping Collet ER32 Ø8mm M8			
009-0946	Sealed Tapping Collet ER32 Ø10mm M10		2	
009-0947	Sealed Tapping Collet ER32 Ø9mm M12	1	2	
009-0948	Sealed Tapping Collet ER32 Ø11mm M14		1	
009-0949	Sealed Tapping Collet ER32 Ø12mm M16	2	6	
009-0950	Sealed Tapping Collet ER32 Ø14mm M18		3	
009-0951	Sealed Tapping Collet ER32 Ø16mm M20	2	3	
008-0128	Sealed Tap Collet ER32 Ø18mm M24/M27/M30	3	5	
Fluteless machine taps with internal cooling				
ARTICLE#	SIZE			
008-0140	M6		3	
008-0141	M8	5	3	2
008-0142	M10		3	2
008-0143	M12	8	8	
Tap HSSE with internal cooling				
ARTICLE#	SIZE			
007-6591	M14		2	
001-2077	M16	2	24	2
007-8301	M18	4	2	
001-2078	M20	10	18	2
001-2079	M24	1	22	
006-2183	M27	2	5	
006-2184	M30	3	5	

ZRTS | Initial lists | Customer | milling | drilling | Countersinking | Tapping

Figure 26 Example of analysis tool for tapping

In figure - the additional value for an analysis tool is visually proven. Instead of selecting 11 different tapping diameters, a selection of 4 diameters is enough based on ordering history. So data can be used to make more precise decisions in consumable selection.

Appendix K: Draft version of a selection tool

In this appendix the selection tool which has been developed in the VBA surrounding of MS Excel is explained. This to show how the use of a basic selection tool makes the composition process faster.

Step 1

Step 1 is to select al the consumables which should be included in the composition list. Especially in relation with the analysis tool large efficiency steps can be made. Because then the exact consumables to select are known.

Material number	Description	Controle	Add
	Drilling		
000-1216	Pulling bolt SK40 DIN69872A M16		
002-5337	Adapter SK40-WN16-130 D=36 DIN69871		x
002-5338	Adapter SK40-WN20-130 D=40 DIN69871		x
002-5339	Adapter SK40-WN25-130 D=46 DIN69871		x
002-5340	Adapter SK40-WN32-130 D=52 DIN69871		x
006-6897	Clamping screw M12x10		
005-1712	Clamping bolt M16x1x10mm		
008-2515	Adjustment Screw M12x20 IC		
008-2516	Adjustment Screw M16x25 IC		
008-2517	Adjustment Screw M20x25 IC		
Drillholder 3xD	Drillholder		
007-0756	Drillholder ø12,5mm L=3xD WN16	12,5 mm	
007-0757	Drillholder ø13mm L=3xD WN16	13 mm	
007-0758	Drillholder ø13,5mm L=3xD WN16	13,5 mm	
007-0759	Drillholder ø14mm L=3xD WN16	14 mm	x
007-0760	Drillholder ø14,5mm L=3xD WN20	14,5 mm	
007-0761	Drillholder ø15mm L=3xD WN20	15 mm	
007-0762	Drillholder ø15,5mm L=3xD WN20	15,5 mm	
007-0763	Drillholder ø16mm L=3xD WN20	16 mm	x
007-0764	Drillholder ø16,5mm L=3xD WN20	16,5 mm	

Figure 28 The selection field of the VBA selection tool

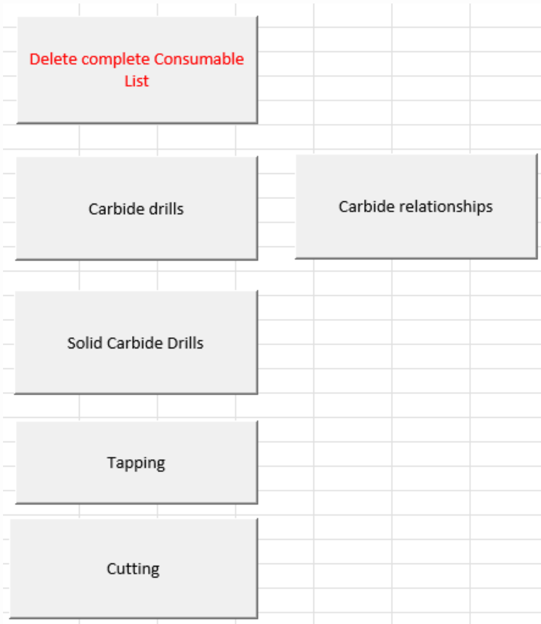


Figure 27 Buttons of the VBA selection tool

Step 2

When for all processes the correct consumables are selected, the script can be runed. The buttons for the specific processes can be pressed in order to get the initial list as result.

Step 3

After pressing the buttons, a complete list is automatically generated. The relationships of consumables is used to find the correct additional articles to include in the list. Some articles still have to be added manually, this is because programming this takes a lot of time. However, as can be seen in figure -, there is a warning included which articles should still be included.

Step 4

For plasma cutting another interface is used, which can be seen in figure -. Using this means that only the correct amperage should be selected and then all the right parts are automatically included as is shown in figure -.

Article Number	Description	Minimum value	Maxiumum value
	Carbide Drills		
002-5337	Adapter SK40-WN16-130 D=36 DIN69871		
002-5338	Adapter SK40-WN20-130 D=40 DIN69871		
002-5339	Adapter SK40-WN25-130 D=46 DIN69871		
002-5340	Adapter SK40-WN32-130 D=52 DIN69871		
007-0759	Drillholder ø14mm L=3xD WN16		
007-0763	Drillholder ø16mm L=3xD WN20		
002-4165	Drillholder ø18mm L=3xD wn20		
000-1271	Drillholder ø16mm L=5xD wn20		
000-1275	Drillholder ø18mm L=5xD wn20		
000-1280	Drillholder ø20mm L=5xD wn25		
007-0816	Drillholder ø30mm L=7xD WN32		
	Carbide Tip		
000-1318	Carbide Tip Ø14mm KSEM HPGM KCPM45		
000-1336	Carbide Tip Ø16mm KSEM HPGM KCPM45		
000-1347	Carbide Tip Ø18mm KSEM HPGM KCPM45		
000-1357	Carbide Tip Ø20mm KSEM HPGM KCPM45		
000-1395	Carbide Tip Ø30mm KSEM HPGM KCPM45		
	Socket Screw		
000-6618	Socket screw ø13,51 - ø15,99mm 364.016		
000-6619	Socket screw ø16,00 - ø19,99mm 364.010		
000-6620	Socket screw ø20,00 - ø24,00mm 364.011		
	Solid Carbide Drills		
000-6623	Socket screw ø32,01 - ø40,00mm 364.015		
	manual include correct adapters!		
	Tapping		
008-9898	Adapter SK40-WD25-35 DIN69871 D=45		
008-1415	Synch. Tapping Chuck M6-M30 ER32 SK40		
008-0141	Fluteless Machine Tap M8 Int. Cooling		
008-0142	Fluteless Machine Tap M10 Int. Cooling		
007-8301	Tap M18 HSSE with internal cooling		
001-2079	Tap M24 HSSE with internal cooling		
008-0130	Spanner For Nut Collet Chuck ER32		
009-0945	Sealed Tapping Collet ER32 Ø8mm M8		
009-0946	Sealed Tapping Collet ER32 Ø10mm M10		
009-0950	Sealed Tapping Collet ER32 Ø14mm M18		
008-0128	Sealed Tap Collet ER32 Ø18mm M24/M27/M30		
	Add predrill diameter: 9,3 mm		
	Add predrill diameter: 15,5 mm		
	Add predrill diameter: 21 mm		

Figure 31 An automatically created composition list

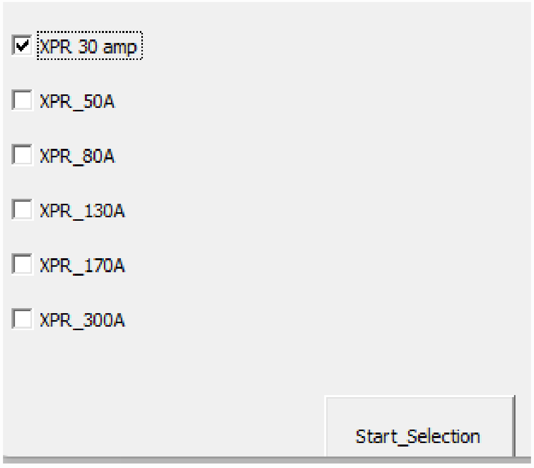


Figure 30 Interface for plasma cutting

Article Number	Description	Minimum value	Maxiumum value
	Cutting Mild Steel -Bevel		
005-7843	XPR Shield 30A MS 420228		
005-7858	XPR Nozzle 30A MS 420225		
005-7872	XPR Swirl Ring 30A MS CW 420407		
005-7880	XPR Electrode 30A MS 420222		

Figure 29 Overview of the plasma composition list

Conclusion, the list of consumables which is composed to explain the selection tool is created in a few minutes. Of course, the lay-out is not yet correct and must be changed manually. However, this is also something that can be programmed. But this shows that there is a large potential in using a selection tool to decrease the amount of time spent on creating an initial list.

Appendix L: Validation form

This form is used to check the validity of the research and outcome of the research by employees of Voortman. The questions and statements of this form should be answered with help of a Likert scale. A Likert scale is a rating technique to measure the level of agreement of a respondent.

1. In the organisational structure behind the RTS, no important departments are excluded
2. The BPMN model of the as-is process does entail all significant activities included in the process (source)
3. The BPMN model of the as-is process does not represent the reality(source)
4. The four KPI's used in chapter 5 give the right information to analyse the quality of the process
5. Based on the analysis of the quality in chapter 5, the quality of the current composition process is not high enough.
6. The estimations used in the flow analysis of the current process is in line with the values in reality (source)
7. The flow analysis does not discover the main problems of the current process
8. The causal factors given are recognized by Voortman as possible causes for a time inefficient process.
9. The table (table 4 in this report) given shows correct and complete observations about the activities of the as-is process
10. The assumed changes of the activities are no potential measures/solutions for a structured process
11. The proposed analysis tool gives the insights Voortman is interested in
12. The proposed analysis tool is functional in practice
13. A format of a composition list, based on several parameters, would not improve the composition process
14. The proposed selection tool is functional to use in order to create composition lists
15. Voortman should use their capacity in order to build a selection tool
16. The BPMN model of the to-be process does not contain all relevant activities (source)
17. The BPMN model of the to-be process does contain only correct activities (source)
18. The BPMN model of the to-be process represents an executable process in the real-world (source)
19. The transition tree of the implementation does not present a roadmap to implement the new process.

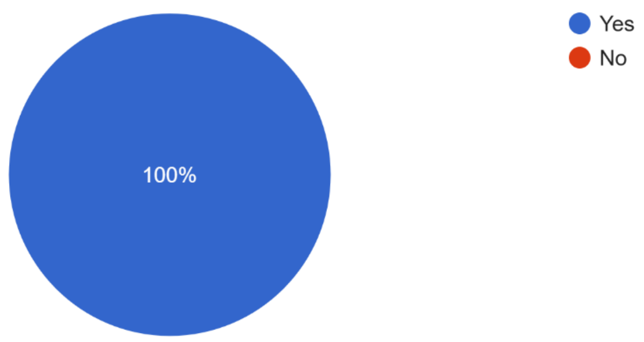
Appendix M: Validation answers

The validation form has been answered by:

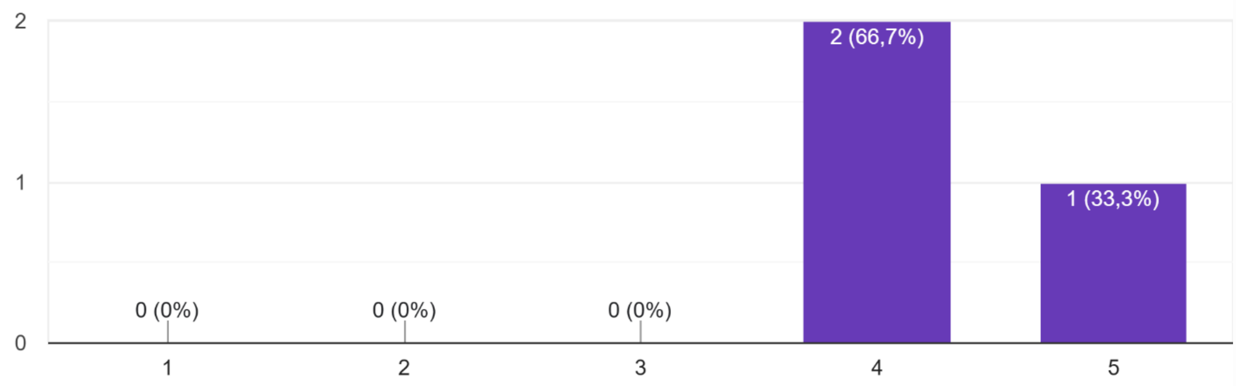
1. Sander Jansen, who is the Service Operations Manager and thus the manager of customer service and delivery
2. Daan Ensink, who is Customer Service Manager
3. Michel Averesch, who is Delivery Engineer. Due to internal circumstances he is responsible for the RTS delivery at this moment.

For every statement the outcomes are given. The Likert-scale had a spread of 1 (totally disagree) till 5 (totally agree).

Do you give consent for using the data to collect in the thesis?
3 antwoorden

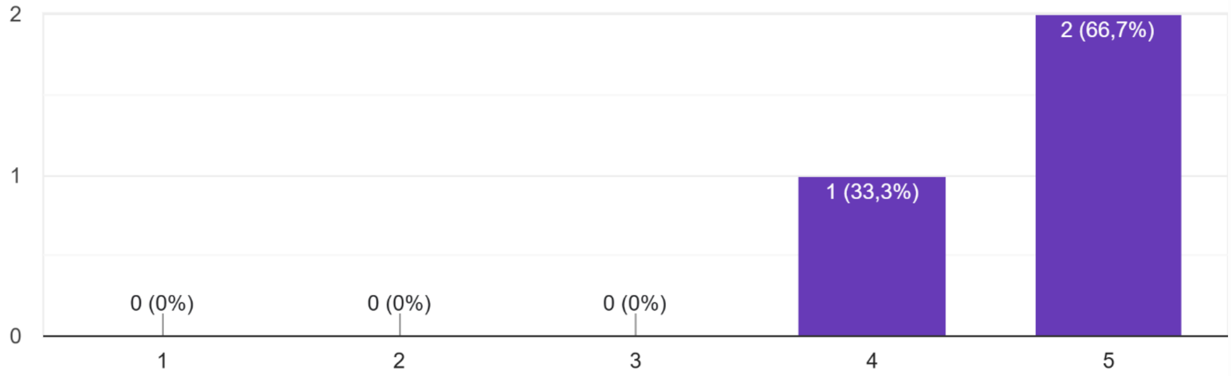


The organisational structure behind the RTS, includes all relevant departments of Voortman
3 antwoorden



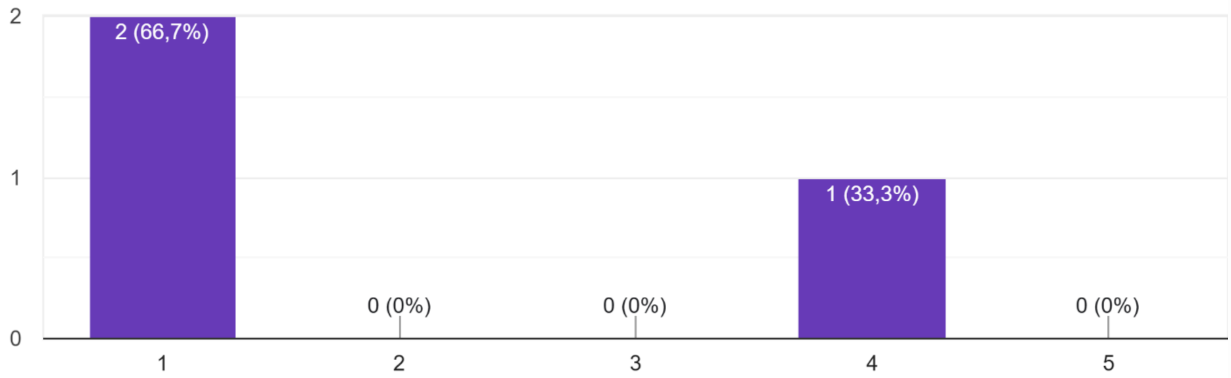
The BPMN model of the as-is process does entail all significant activities included in the process (Nelson et al., 2011) (Information is given in the pictures above this question)

3 antwoorden



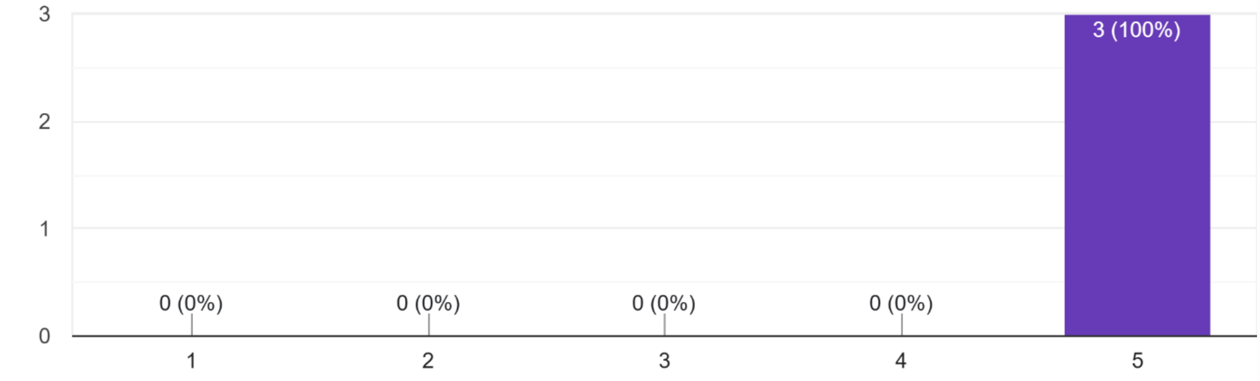
The BPMN model of the as-is process does not represent the reality (Nelson et al., 2011) (Information is given in the pictures above this question)

3 antwoorden



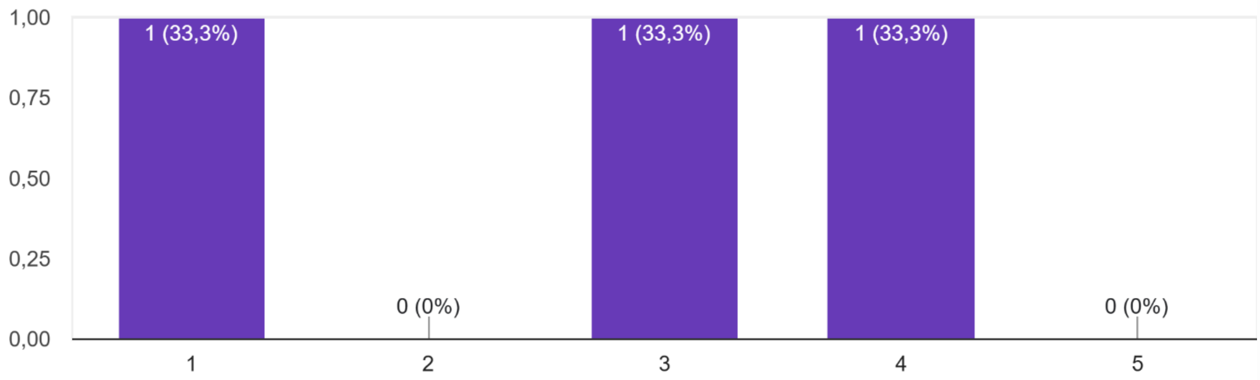
The four KPI's used give the right information to analyse the quality of the process

3 antwoorden



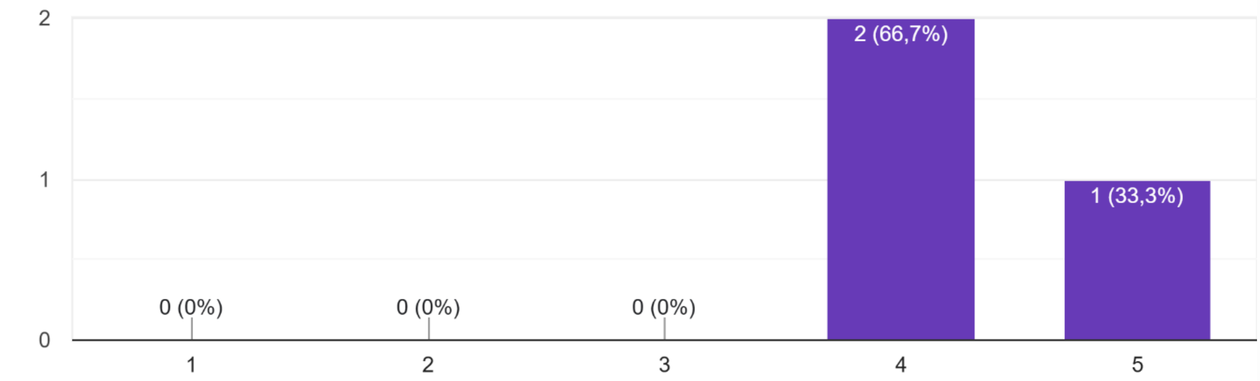
Based on the analysis of the quality, the quality of the current composition process is not high enough.

3 antwoorden



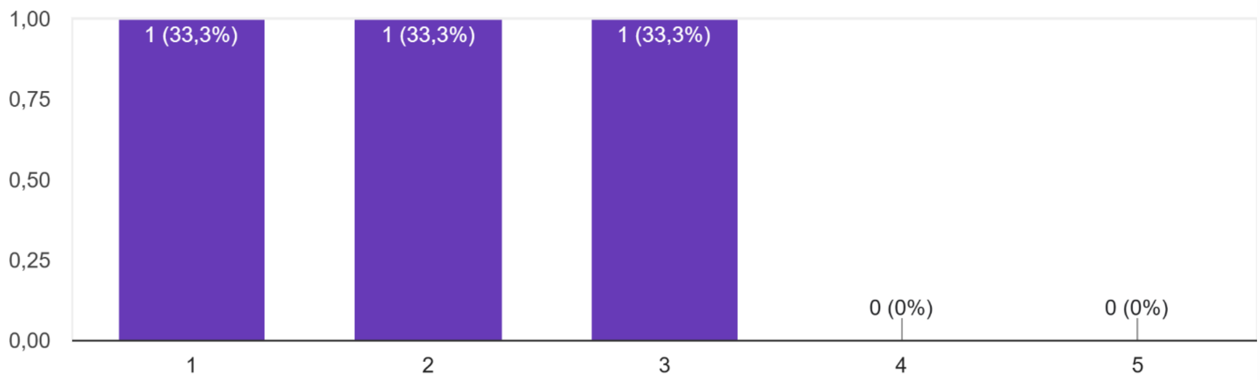
The estimations used in the flow analysis of the current process is in line with the values in reality (Nelson et al., 2011)

3 antwoorden



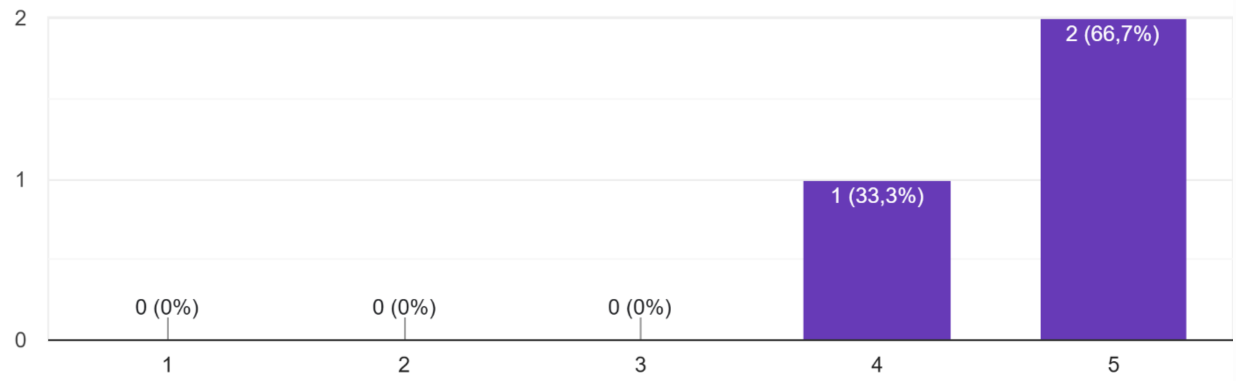
The flow analysis does not discover the main problematic activities of the current process

3 antwoorden



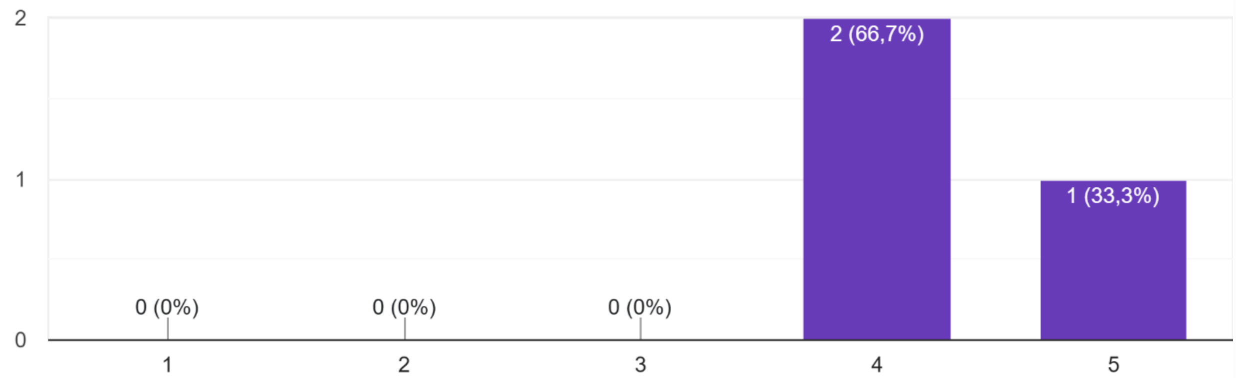
The causal factors given are recognized by Voortman as possible causes for a time inefficient process

3 antwoorden



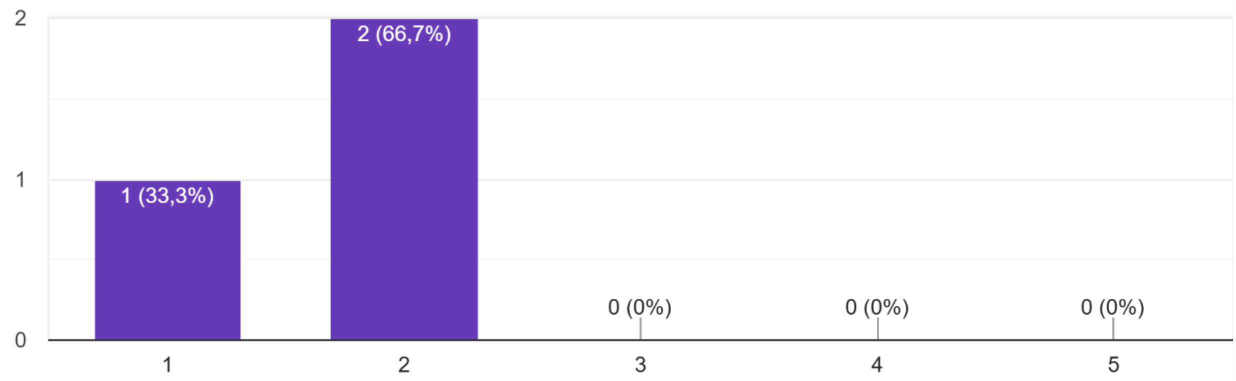
The table given shows correct and complete observations about the activities of the as-is process

3 antwoorden



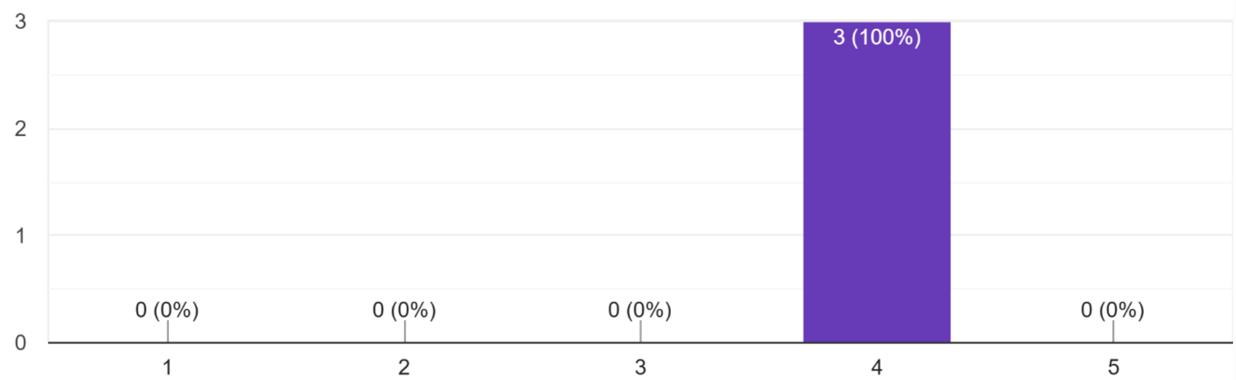
The assumed changes of the activities are no potential measures/solutions for a structured process

3 antwoorden



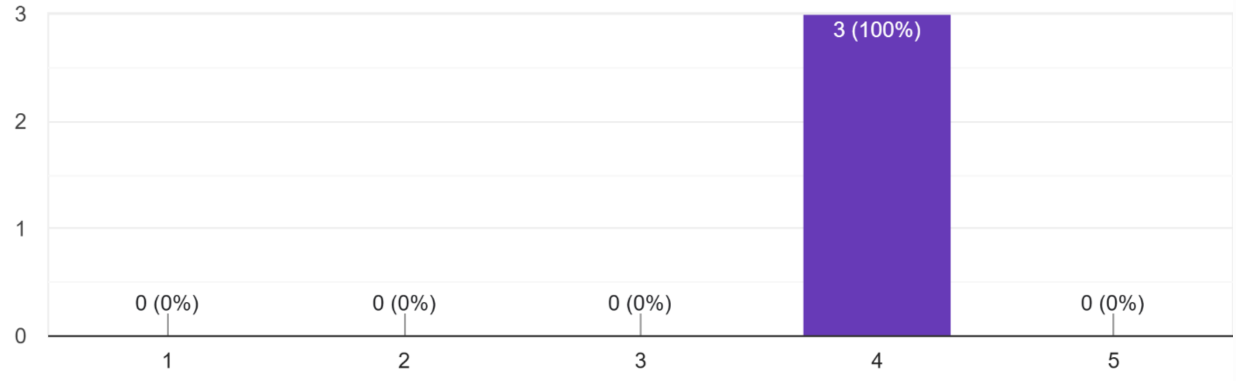
The proposed analysis tool gives the insights Voortman is interested in

3 antwoorden



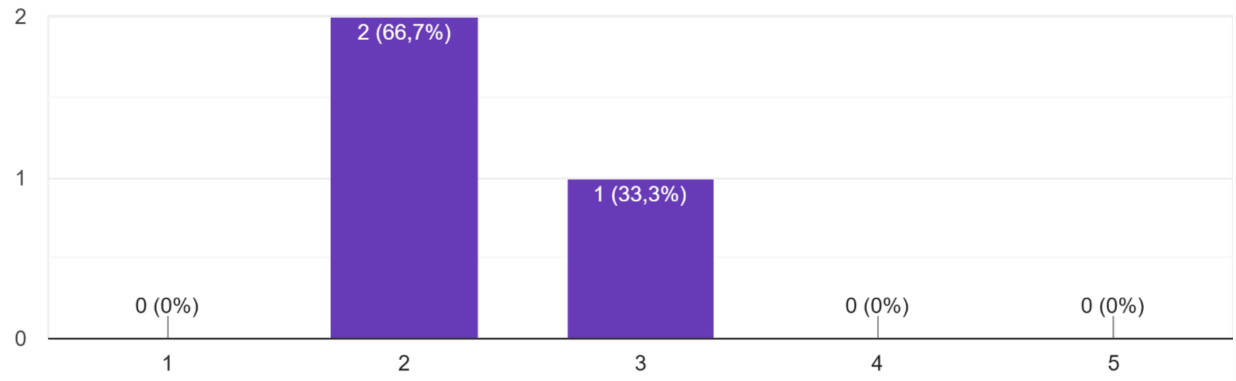
The proposed analysis tool is functional in practice

3 antwoorden



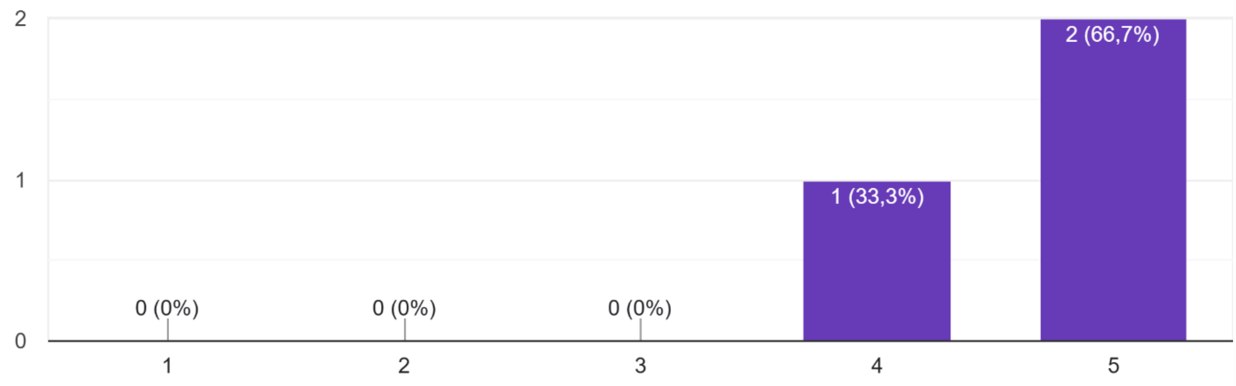
A format of a composition list, based on several parameters, would not improve the composition process

3 antwoorden



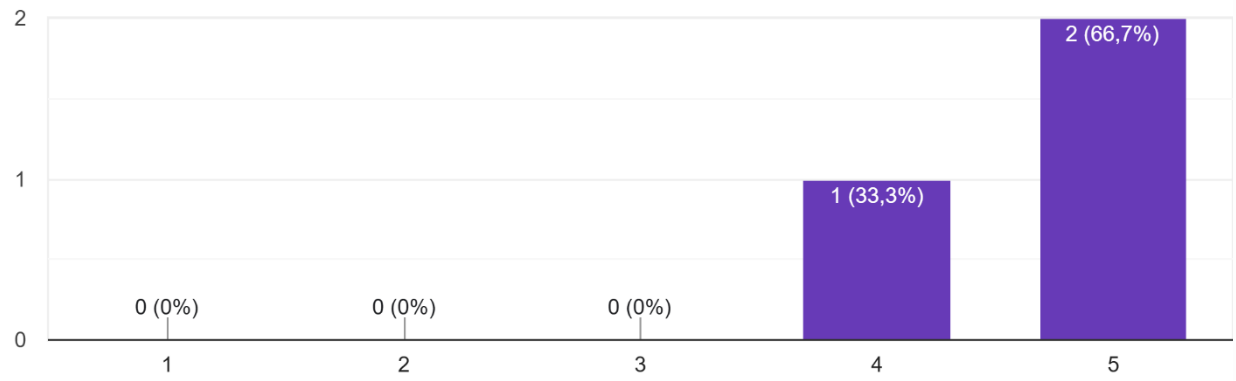
The proposed selection tool is functional to use in order to create composition lists.

3 antwoorden



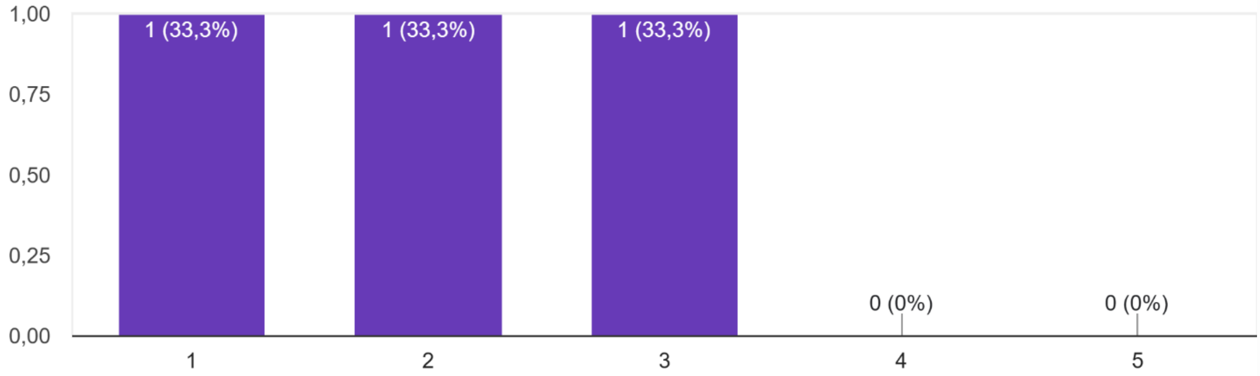
Voortman should use their capacity in order to build a selection tool

3 antwoorden



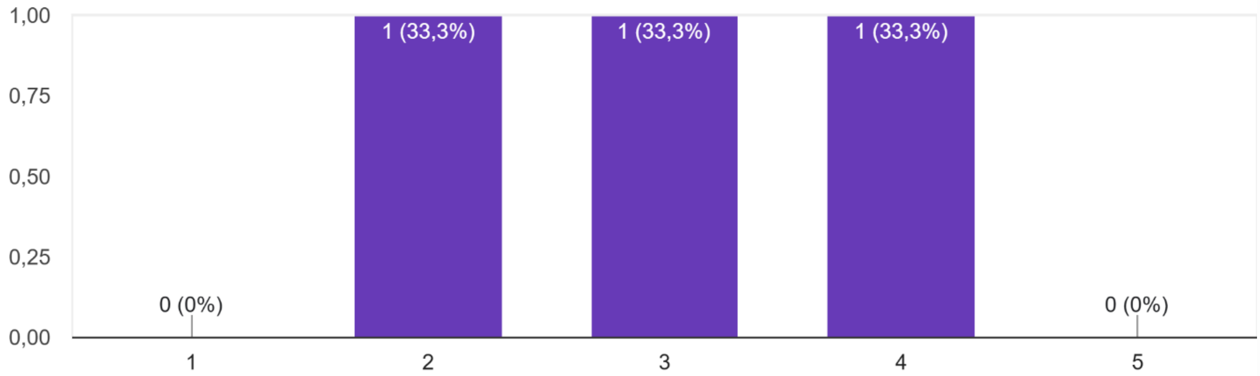
The BPMN model of the to-be process does not contain all relevant activities (Nelson et al., 2011)

3 antwoorden

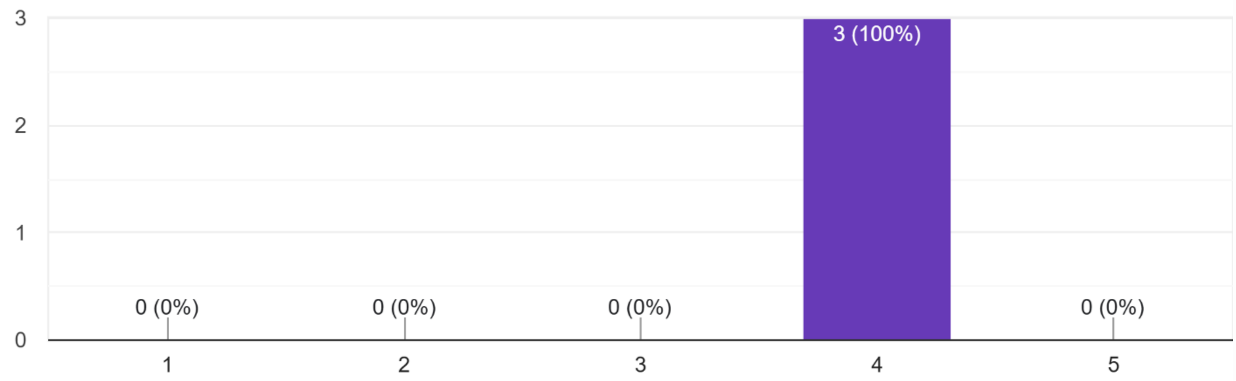


The BPMN model of the to-be process does contain only correct activities (Nelson et al., 2011)

3 antwoorden



Implementing the BPMN model of the to-be process will result in an executable process by Voortman (Nelson et al., 2011)
3 antwoorden



The transition tree of the implementation does not present a roadmap to implement the new process
3 antwoorden