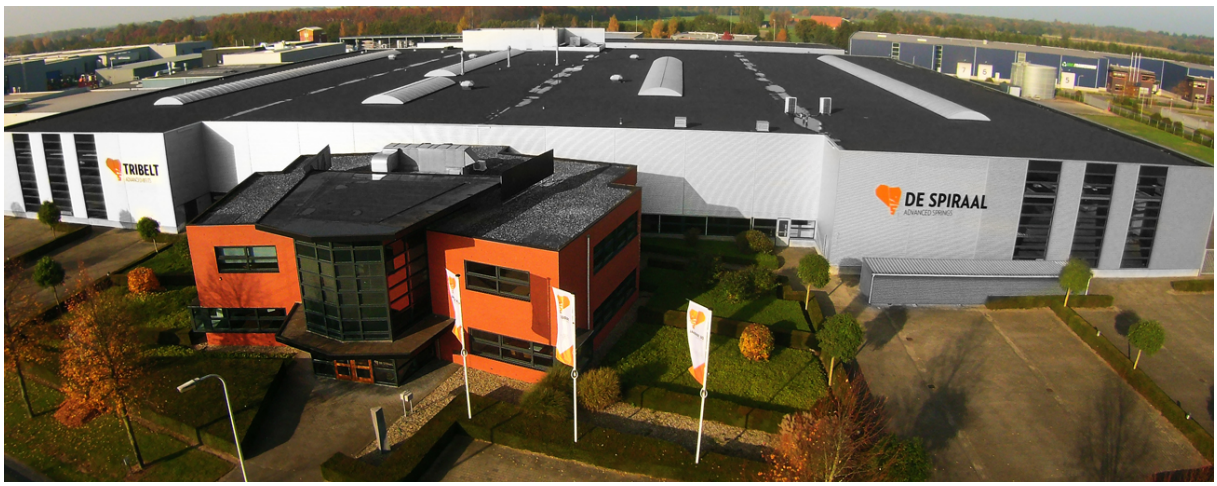
UNIVERSITY OF TWENTE.

DE SPIRAAL
ADVANCED SPRINGS

TRIBELT
ADVANCED BELTS

“Research into a fitting purchasing volume determination tool”



Student: Rick Peters
Student No.: 1766465
Company supervisor: Msc. H. Veldhuis
University supervisor: dr. P.C. Schuur
Date: 1-3-2019

UNIVERSITY OF TWENTE.

DE SPIRAAL
ADVANCED SPRINGS

TRIBELT
ADVANCED BELTS

“Research into a fitting purchasing volume determination tool”

“Adequately determine the right purchasing volume for raw material ”

R.N. Peters

Haaksbergen 1-3-2019

Verenfabriek De Spiraal B.V. and Tribelt B.V.

Student: Rick Peters

First supervisors: dr. P.C. Schuur

Second supervisor: dr. ir. B. Roorda

External expert: ir. H. Kroon

Company supervisor: Msc. H. Veldhuis

Glossary

Aftermarket	The market in which customers demand for components which are used to replace existing components
Assembly	The action of fitting together the component parts of a machine or other object
Breakdown	The event of a machine or installation being inoperative
Colloquium	An oral presentation and a Questions and Answers section in which the student has to defend his work
Factor	A variable that can influence a situation
Item	An unique product
Lead-time	The amount of time it takes to complete one cycle of a (sub-)process
Model	An existing theoretical formula
Prototype	First version of the purchasing volume determination tool
Purchasing volume	The amount of material the purchasing department needs to purchase in order to fulfil the demand
Raw material	Material purchased by the company that is processed in order to make a finished goods
Stock-out	The event of having an inventory level that is insufficient to fulfil the demand
Valuation	The extent in which a factor is influencing a situation
Volume determination tool	A tool that is used in order to determine the purchasing volume

Acknowledgement

The thesis you are currently reading is the last step in concluding my study Master of Business Administration at the University of Twente. This is a one-year study of which 20 weeks consist of writing a master thesis. I performed my research within De Spiraal Advanced Springs and Tribelt Advanced Belts (further called: the company). I already was familiar in this company which made it easier to conduct a complete and accurate research. Despite the fact that i was already employed at Tribelt, I'm thankful for the opportunity I was given by the company.
I would like to thank the purchasing department of De Spiraal and Tribelt for their time and effort with regards to my research. Without their input, the results of this research would not by as useful as it is right now. Next to the employees of the purchasing department, I would like to thank Henri Veldhuis for being my mentor during this process.
Also, I would like to thank DR. P.C. Schuur for his guidance as examiner. He has spent a lot of time in our almost weekly meetings.

Management summary

Motivation

De Spiraal Advanced Springs B.V. and Tribelt Advanced Belts B.V. (further called: the company) manufacture their products out of metal wire and strip metal. De Spiraal produces technical springs while Tribelt produces metal conveyor belts. The competitive advantage of the company is to achieve short lead-times for their customers. Because of the long lead-times of the supplier, the company is forced to keep a certain amount of inventory. This amount of inventory should be determined by the demand. However, the demand for raw materials within the company is fluctuating. That's why it is difficult to set the right inventory levels. Consequently, this leads to unnecessary high inventory as well as stock-outs. One of the probable reasons for these negative developments is the fact that the purchasing department does not have a clear dashboard to determine the purchasing volume.

Central research question

The aforementioned problems are converted into the research question: *"In which way can the purchasing department of the company use factors and associated valuation to adequately predict the purchasing volume for raw materials within the company to minimize stock-outs?*
In order to answer the research question, a methodology is designed.

Methodology

First of all, the current situation is analysed. After analysing the current situation, the performance of the department is tested. This is done by displaying 2 kinds of Key Performance Indicators (KPIs): the performance in terms of costs and in terms of lead-time. The performance in terms of costs is displayed by plotting the total value of inventory together with the costs of sales with regards to raw material. After analysing the problem, literature research is conducted in order to find solutions for the problem. The models found in the literature are scored based on their applicability on the situation of the company. After scoring the models, it is decided to combine these models into several prototypes since none of the models did fit the situation completely.
In order to find an applicable tool, some of the most suitable models were combined into prototypes. This has led to 3 prototypes: "regression analysis combined with moving average", "multiple-regression analysis with moving average" and "multiple-regression analysis with moving average and probabilistic demand". These prototypes needed to be scored based on their applicability to the situation of the company.
In order to determine the preferred prototype, the purchasers filled out an AHP-form that defines the importance of 6 different features of the prototype. After filling out these forms, the three prototypes are presented to the purchasing department. The purchasers were asked to fill out a form to score the three prototypes on the aforementioned 6 different features based on the Likert Scale.

Results

By considering all features and the importance per purchaser, the prototype was provided with a total score. Prototype 3: “Multiple-regression analysis combined with moving average and probabilistic demand” is considered as the best applicable tool for the company. The tool is applicable on all the items within the company that are characterized as items with a high demand frequency. In Table 0-1 Breakdown item categories. The different possible combinations of characteristics are broken down. Prototype 3 takes all 5 characteristics into account. By doing this, every category has its own strategy. For example, two extremes are:
High frequency-High demand-stable-inexpensive: for these items, it is advised to hold a large amount of stock. However, the purchaser also needs to consider a more frequent delivery because of the high inventory-costs.
High frequency-low demand-fluctuating-expensive: for these items, it is advice to hold a low amount of stock that will satisfy smaller demands. Higher demands have to be purchased since the costs of stock are higher than stock-out costs

Table 0-1 Breakdown item categories

Demand Frequency	High frequency																
	Average demand		High demand								Low demand						
Fluctuation in demand quantity	Fluctuating				Stable				Fluctuating				Stable				
Price per quantity	Expensive		Inexpensive		Expensive		Inexpensive		Expensive		Inexpensive		Expensive		Inexpensive		
Predictability	Predictable	Unpredictable	Predictable	Unpredictable	Predictable	Unpredictable	Predictable	Unpredictable	Predictable	Unpredictable	Predictable	Unpredictable	Predictable	Unpredictable	Predictable	Unpredictable	

This prototype provides a clear overview of the item characteristics. Also, it gives a purchasing proposal for the purchasing volume. In this way, the purchasers can understand the variables on which the purchasing proposal is based.

Recommendation

In order to implement the new tool, the company has to take a few steps. First of all, the tool needs to be tested with actual data of the company. In this way, the applicability is tested completely. The next step is to implement the tool into the ERP-system. This can be done by the software-supplier Ridder Data Systems. Of course, this investment needs to be approved by the directors of the company. After implementing the new tool, the purchasing department needs to be trained in how to use the tool. Since the company is operating in a rapidly changing environment, there is a possibility that the tool turns obsolete. In order to prevent obsolescence, the tool has to be reviewed on applicability. These steps are also shown in Table 0-2 Roadmap.

Table 0-2 Roadmap

Prio	Action	Actor
1	Test tool with actual data of the company	Researcher
2	Redevelop tool based on test results	Researcher
3	Make investment proposal for management	Purchasing manager
4	Approve investment	Managing director
5	Develop tool in Enterprise resource planning	Software-partner
6	Train purchasers in using the tool	Purchasing manager/researcher

The implementation of this tool can help the company to minimize inventory values without an increase of stock-outs. Also, the tool can give the purchasing department a better negotiation position because of all the available information about the demand. These advantages will lead to a lower cost price, as well as a decrease in stock-outs. All in all, this will keep the company competitive and therefore ready for the future.

Table of contents

1 Introduction

In the framework of completing the Master of Business Administration at the University of Twente, a research was conducted at De Spiraal Advanced Springs B.V. and Tribelt Advanced Belts B.V. (further called: the company) into forecasting the demand for raw materials.

1.1 Master of Business Administration: Purchase and Supply management

The Master of Business Administration (further called: MBA) is master at the University of Twente. This Master is internationally oriented which is the reason for the fact that is it taught entirely in English. The main curriculum of MBA focuses on the broad spectrum of business worldwide. Characterizing for the study is that a significant part of the curriculum consists of specialized courses.[1] In the case of Purchase and Supply management these specialized courses are focused on the purchasing department of a company. For this reason, the thesis is written commissioned by the purchasing department of the company.

1.2 The company: De Spiraal and Tribelt

De Spiraal Advanced Springs (further called: De Spiraal) is a manufacturer of technical springs and industrial wire products. Shortly after WOII the company was founded in Hengelo (OV) by two former employees of Stork. These employees were aware of the fact that there was a scarcity of parts made out of metal wire. For that reason, they founded De Spiraal. After a few relocations and investments, the company was known as a regional supplier of technical springs and industrial wire products.[2]
In 2002 sister company Tribelt Advanced Belts (further called: Tribelt) was founded. This company uses the same raw materials as De Spiraal for the production of conveyor belts. Tribelt is a more internationally oriented company. This is because of the fact that the density of conveyor belt manufacturers is lower than the density of spring manufacturers.
The company is settled in a 12,000 square meter building that is located in Haaksbergen. In 2015, the company has moved to this site because of logistic and financial reasons. First of all, the previous site consisted of 5 different buildings. This resulted into inefficient internal logistics. Next to that there was the fact that the buildings were rented from several different landlords. In 2017, the company reached the milestone of having 100 full time employees (further called: FTE).[3]
In order to distinguish from competitors, the company attempts to reach competitive advantage by short customer lead times and high-quality products. Next to that, the company pays a significant amount of attention to the aspect of advising customers.

[1] See (Academy Behavioural Management Social Sciences, 2018)
[2] See (H. Veldhuis, 2018) page1
[3] See (H. veldhuis, 2018) page 1

1.2.1 Product/market- combinations De Spiraal

Aviation: advanced springs are used in aviation. Narrow tolerances and extensive material specifications are applied. Next to that, certificates and reports can be generated to guarantee certain standards.

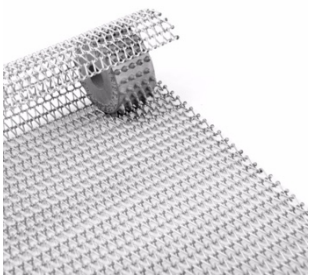
Agro Technique: the demand for products used in agro technical is mostly seasonal. The production process of the company is designed to act adequate on these fluctuations. The products used in agro technique mostly require a high strength and robust design. De Spiraal has machines and equipment that can provide for these requirements

Offshore: products in the offshore are exposed to extreme circumstances. High pressures and corrosive environment have to be considered. Compression springs which are used into valves are made of a specific material with a high durability.

1.2.2 Product/market- combinations Tribelt

Bakeries: The Tri-flex spiral tower belt is used to transport baked off bread rolls. After baking the bread rolls, a cooling down process takes place in a cooling tower. The fact that this belt can run straight as well as in a radius, makes this the perfect belt for these cooling towers.

Solar: solar weavers need to be tempered after the production. This is done under extremely high temperatures. In order to create the maximum transition of heat, standoffs are placed on the belt. The weavers rest on these standoffs when transported through the oven.



Washing and cleaning: this application requires a lot of flexibility in the openness of the belt. This causes a separation between the product and waste. The openness of the eye link belt is highly flexible. Also, there is the possibility to adjust carriers and cross flights

More information about the company and the product/market- combinations is to be found in **Fout! Verwijzingsbron niet gevonden.** and **Fout! Verwijzingsbron niet gevonden.**.

1.3 The problem

Customers in the market of the company ask for a lead time from around 2 weeks in the case of De Spiraal and 5 weeks in the case of Tribelt.[4] The difference in lead times is caused by the fact that the quantity of production hours is higher in the case of conveyor belts. Often, the belts are placed in large-scaled installations which often is inherent to a large belt. Next to that, there is the fact that the belts are hand-made while springs are mostly machine-made. Both of the products are mostly sold in the aftermarket. [5]

Aftermarket is the market in which customers demand for components which are used to replace existing components. Often this replacement is caused by parts wear. These parts are essential for the functioning of a machine or installation. In case of a (probable) breakdown, the essential parts need to be replaced as soon as possible. [6]

Next to the short lead time desired by the customers, there is the fact that the lead time of the production is around 1 week for De Spiraal and 3 weeks for Tribelt.[7] This means that there is between 1 and 2 weeks for the purchasing department to arrange for materials.

Because of the fact that the average delivery time for raw materials is over 4 weeks[8], there has to be a certain amount of stock in order to serve the customers within the arranged amount of time. This amount of stock should be determined by the demand. However, the demand for raw materials within the company is fluctuating. That's why it is difficult to set the right inventory levels. Consequently, this leads to unnecessary high as well as insufficient stock levels.

Momentarily the purchase department uses information from several dashboards in order to determine the purchasing volume for a certain item. These overviews provide limited historical information about material consumption. This information is interpreted by the purchaser and translated into assumed correct inventory levels. Often, there is some communication with the sales department in order to forecast a certain demand. However, the company often experience stock-outs as well as an increase in inventory value.

The purchasing manager would like to know how to make a more adequate demand forecast in order to prevent stock outs. This prevention of stock-outs may not be achieved by a higher total inventory value.

[4] (RiQ, 2018)
[5] (H. Veldhuis, 2018)
[6] (A.J. Muench, 1993)
[7] (RiQ, 2018)
[8] (RiQ, 2018)

2 Research approach

The research is guided by the research approach. This section contains all the information that is necessary for successfully completing the master thesis. During the research, small changes to the research approach can be made in order to get the preferred result.

2.1 Research design

In order to conduct a structured research, a research design has to be applied. In the case of this study, the gap-analysis model is chosen. This model structures a research with the goal to improve business processes. The gap analysis consists of 3 different stages that are displayed in Figure 2-1 Gap-analysis.

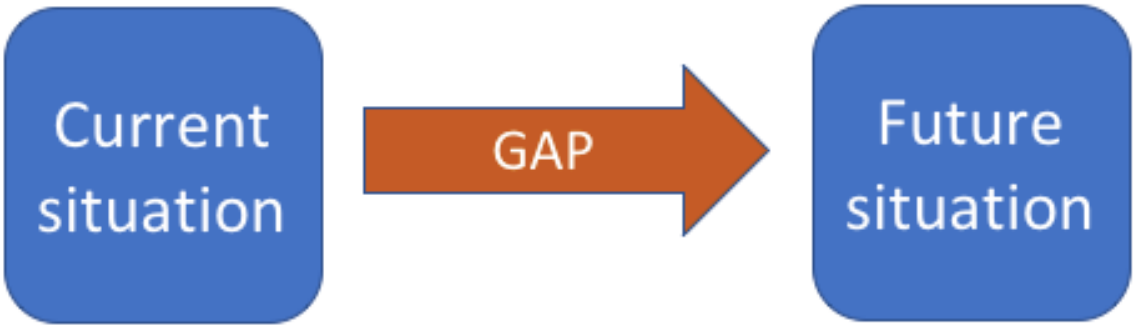


Figure 2-1 Gap-analysis

These steps result in a clear investigation of the causes of the problem. Therefor it helps to come to an appropriate solution. Also gap-analysis has a clear starting and ending point. This makes it an appropriate tool for writing a master thesis since there is limited time for finishing the master thesis.[9]

2.2 Research goal

In this section, the research goal is described. By setting up a set of clear objectives, the research goal focusses the research. This will prevent the researcher from deviating from the core purpose of the research. Also, the research goal motivates the researcher and the principal to achieve what the research was meant for. The research goal of this study is formulated as follows:
Give an overview of the different factors and the associated valuation that can forecast the demand for raw materials within the company in order to prevent high inventory costs as well as stock outs.

2.3 Research question

In order to reach the abovementioned research goal, a central research question has to be defined. The research has to be designed in a way that the research question can be answered. For this research the follow research question is formulated:
In which wa y can the purchasing department of the company use factors and associated valuation to adequately predict the purchasing volume for raw materials within the company to minimize stock-outs?

[9] See (M. Sokovic, D. Pavletic, & E. Krulcic, 2006)

2.4 Research sub-questions

Because of the fact that the research question is just one question meant to shape the whole research, sub-questions are defined in this chapter.

- Current situation: What does the current situation look like?
    - What does the current purchasing process look like? *In order to get a clear few on the processes that currently determine the purchasing volume, a flowchart is created. This flowchart is based on a process analysis and created in MS-Visio.*
    - Which variables are currently used in order to determine the correct purchasing volume? *The variables that are currently used to determine the purchasing volume, have to be written down in order to conclude the current situation. Based on a dashboard analysis, the dashboard of the purchase manager is analysed and the different variables are determined.*
    - What characteristics are applicable in order to distinguish item categories of raw materials? *It is likely that the company uses items with different characteristics. Probably these items need different strategies. By defining these different characteristics, it is possible to divide the items in different categories that can be used to define different strategies in the "future situation-phase". In a brainstorm session with the purchase manager, the characteristics that distinguish item categories of raw materials are defined.*
    - Which item categories are distinguishable in terms of purchasing volume of raw materials? *by using the defined characteristics, the raw materials are categorised by using a pinball model. By defining these different categories, it is possible to address different strategies in the "preferred situation-phase".*
    - What KPIs are currently in place in order to measure purchasing performance? *Based on a semi-structured interview with the purchasing department, the current set of KPIs is defined. These KPIs can be used to measure the actual problem in the "Gap-phase".*
- Gap: What issues are to be improved?
    - What is the performance in terms of costs? *By applying the aforementioned KPIs, the performance in terms of costs is measured. This indicator is used to measure the current problem, as well as to measure progress after the implementation of the new purchasing volume determination tool.*
    - What is the performance in terms of lead-times? *By applying the aforementioned KPIs, the performance in terms of performance is measured. This indicator is used to measure the current problem, as well as to measure progress after the implementation of the new purchasing volume determination tool.*

- Preferred situation: What would the preferred situation look like?
    - What tools are developed to determine the purchasing volume of raw materials? *literature research is executed to find theoretical information about how purchasing volume can be determined. These theoretical methods can be characterised in order to score them on applicability on the company.*
    - What are the criteria and valuation for models to determine the purchasing volume of raw materials? *The criteria for the models are defined by the purchasing department. By executing an analytic hierarchical process, these criteria can be scored in order to assign the correct valuation to the criteria.*
    - Which model is applicable for the situation of the company?
    - What would the applied tool for the company look like? *by prototyping a tool, the tool can be tested and the applicability towards the company can be tested*
    - What should the implementation process look like? *A planning is made in order to guide the implementation process*

2.5 Deliverables and phases

In the case of this research, the deliverables can be divided into two sections: deliverables towards the company and deliverables towards the university. In this paragraph, these two sections will be described.

2.5.1 Company deliverables

The goal of the company for this research is to improve the purchasing process. In this case the improvement is enriched by standardizing.
In the current situation, a set of variables is considered when making purchasing decisions. First of all, the company is interested in a distinction between different item groups. These are groups of raw materials with the same characteristics when it comes to the variables based on which the purchasing decisions are made. By doing this, it is possible for the company to make agreements with suppliers according to delivery time, prizing, packaging etcetera. The company wants to embed these variables into a tool that can be invoked when making purchasing decisions. Using this tool will lead to well considered purchasing decision.[10] Concluding, the deliverables for the company are:

- An item categorization in terms of purchasing characteristics;
- An overview of purchasing variables and their weights;
- A proposal for a tool that supports the purchasing department in the purchasing process.

[10] (W. Klumpers & H. Veldhuis, 2018)

2.5.2 University deliverables

As stated in the thesis manual of University of Twente (2017), the thesis consist of 4 phases. Below, the different phases are mentioned along with the deliverables.

Preparation, research design and theoretical background

These phases result in a research proposal for the master thesis. It consists of the following deliverables:

- Planning Part I and II: the overall planning of the graduation process;
- Methodology: The methodology describes which methods are used in order te collect the data that is needed for answering the research questions;
- Theory chapter: In consultation with the supervisor, the theory chapter is shifted to chapter 5.
- Final thesis version.[11]

Implementation

In this phase, the research proposal is applied to gather data that are needed for answering the research question. It is recommended to take notes throughout the implementation phase. These notes result in a deliverable that is used by reflecting on the graduation process. Next to the notes, a green light version of the thesis is delivered by the students. This is the version of the thesis that is approved by both supervisors.[12]

Completion

In this third phase, the student focuses on the analysis of the data that are gathered in the implementation phase. After completing the analysis, the student focusses on formulating an alternative solution in order to solve the problem. The last step is the conclusion and discussion regarding to the subject. After finishing these chapters, the student submits the thesis to the lead supervisor. After approval of the lead supervisor, the student makes an appointment for a "green light" meeting with both of the supervisors. If both supervisors agree on the fact that the thesis is sufficient, the student can prepare the colloquium by contacting the Educational Affairs Office. Deliverables for this phase are: definitive version of the thesis and a completed evaluation form.[13]

Colloquium

The last phase of the graduation process is the colloquium consist of an oral presentation and a Questions and Answers section in which the student has to defend his work. When passing the colloquium, the student will receive his degree which is the deliverable for this phase.[14]

2.6 Methodology

In order to give a clear overview of the methods that are used to answer the research questions, a methodology is displayed in **Fout! Verwijzingsbron niet gevonden.**(figure book). In the first column, the general research question is mentioned. The second and third column show which phase of the gap-analysis model is applied in which chapter. Column four and five represent the (sub-) sub-questions. The last column is used to show which research method is assigned to the different research questions.

[11] See (University of Twente, 2017) page 9
[12] See (University of Twente, 2017) page 10
[13] See (University of Twente, 2017) page 10-11
[14] See (University of Twente, 2017) page 11

2.7 Research scope

Because of the fact that the research has to be completed within 20 weeks, it is important to have a clear scope of the research. This scope will prevent the researcher from researching off-topic cases. The scope is defined by several clear agreements between the first supervisor and the company supervisor:

- The literature research will be executed in chapter 5. The reason for this decision is the fact that the current situation has to be analysed first. After doing this, a focused literature research can be done;
- The data from the ERP-system of the company are assumed to be reliable. The validity will be tested in this research;
- The new purchasing tool may not lead to higher total inventory value's;
- The research has to focus on the raw materials within the company;
- For time-related reasons, the tool is tested with fictional data instead of data from the company itself.

2.8 Planning

The planning for this master thesis is based on the tight deadline of completing the process before the end of 2018, see ***Fout! Verwijzingsbron niet gevonden.*** In the first column of the planning, the different chapters are displayed. In the first 2 rows, a timeline is displayed. The third row shows the milestones for the different deliverables.

By following the research approach, the outcomes from the research will be available for the company in the beginning of 2019. The implementation of the new way of demand forecasting will be implemented after the completion of the master thesis.

3 Current situation

In order to create a clear distinction between the current situation and the favourable situation, it is important to analyse and visualize the current situation. This chapter will describe the current situation by explaining the current purchasing process. Next to that, the variables that are currently considered for making purchasing decisions are described. In the third paragraph, the problem is quantified in terms of costs. The last paragraph gives insight in the problem by defining the lead-time of raw materials in the company.

3.1 Purchasing process

The purchasing process is described by having a session with the whole purchasing department. In this session, the possible flows of activities are described and captured in a Visio flow-chart which is displayed in **Fout! Verwijzingsbron niet gevonden.** (figure book). By doing so, a clear few on the purchasing process is realized.

Most of the purchasing activities are reported in an Enterprise Resource Planning-System (Further called: ERP-System). This system consists of several modules that represent the different departments within de company. All the office-processes are registered in this system. In that way, the information is available for everyone who is authorized, analysis can be performed and processes can be aligned.

Dashboard analysis

The next step of analysing the current situation is to investigate the tools that are momentarily used to determining the purchasing volume for a raw material. By doing this, a clear view is given on what information the purchasing department is using for determining the purchasing volume. The dashboard of the purchasing department basically consists of different panels that are mentioned and explained in the following paragraphs.

3.1.1 Inventory registration system

The company uses a separate system to register the location of raw materials. The stock level of the system is transferred to the ERP system by a flow of hardcopy documents that contain all the information of a stock change. This dashboard is shown in Figure 3-1 Inventory registration system.

Figure 3-1 Inventory registration system

3.1.2 Stock overview

In the stock overview panel, the different streams of stock of a certain item are displayed. A stock-in can be caused by a goods-delivery or a manual inventory change. A stock-out can be caused by a production ready notification or a manual inventory change. This panel gives a clear few on the frequency and the variance of stock-outs. Also, this panel gives information about quantities that are already reserved for orders. In the top of the overview, the physical stock and the economical stock

are given. In section 3.1 the explanation of these 2 stock levels are given. This dashboard is shown in Figure 3-2 Stock overview.

Figure 3-2 Stock overview

3.1.3 Assembly detail items

This panel can be used to see the amount of different assemblies in which the raw material is used. Also, it is possible to see whether an assembly is current or not. This information is needed to determine the certainty of the demand for a raw material. This dashboard is shown in Figure 3-3 Assembly detail items

Figure 3-3 Assembly detail items

3.1.4 Purchase proposal

This panel gives insight in the average annual demand for a raw material. Also, it gives an advice for the minimum stock and the purchasing volume. This advice is based on the average demand over the past 365 days. Depending on the lead-time of the supplier of the item, the minimum stock is higher or lower. This dashboard is shown in Figure 3-4 Purchase proposal.

Figure 3-4 Purchase proposal

3.1.5 Pricelists

Some suppliers provide a pricelist which show the priced per kilogram for a certain range of raw materials. This pricelist also contains information about tiered prices.[15] This dashboard is shown in Figure 3-5 Pricelist

[15] (W. Klumpers, 2018)

Figure 3-5 Pricelist

3.1.6 Alloy surcharge

In order to offset the rapid fluctuation in the costs of raw materials, the alloy surcharge is considered by alloyed steel trading companies. The alloy surcharge is an amount of money that is added on the basic price of steel when it comes to alloyed steels such as inox (inoxable).[16] Every month, the alloy surcharge is released and loaded into an Excel document that is accessible for all the employees in the office of the company. The purchasing manager uses this information to determine any advantages that can be gained because of the fluctuation in alloy surcharge. This dashboard is shown in Figure 3-6 Alloy surcharge.

[16] (Rolled Alloys, 2014)

2018\ maand->	Januari	februari	maart	april	mei	juni	juli	augustus	september	oktober	november
Werkstof-Nummer	€ / kg	€ / kg	€ / kg	€ / kg	€ / kg	€ / kg	€ / kg	€ / kg	€ / kg	€ / kg	€ / kg
1.4016	0,77	0,71	0,66	0,68	0,75	0,81	0,83	0,82	0,81	0,80	0,77
1.4021	0,68	0,64	0,59	0,61	0,66	0,71	0,73	0,72	0,72	0,70	0,69
1.4034	0,69	0,65	0,60	0,62	0,68	0,73	0,74	0,73	0,73	0,71	0,70
1.4104	0,83	0,79	0,75	0,77	0,84	0,90	0,91	0,90	0,90	0,89	0,87
1.4105	0,84	0,80	0,76	0,79	0,85	0,91	0,93	0,91	0,92	0,91	0,88
1.4113	0,97	0,96	0,94	0,97	1,03	1,09	1,10	1,08	1,11	1,09	1,07
1.4301	1,59	1,62	1,63	1,67	1,74	1,89	2,05	1,96	1,90	1,79	1,76
1.4303	1,86	1,91	1,95	1,99	2,07	2,25	2,45	2,33	2,25	2,12	2,07
1.4305	1,59	1,62	1,63	1,67	1,74	1,89	2,05	1,96	1,90	1,79	1,76
1.4306	1,79	1,83	1,86	1,90	1,98	2,15	2,34	2,23	2,15	2,03	1,99
1.4310	1,52	1,54	1,54	1,58	1,65	1,79	1,93	1,85	1,79	1,70	1,66
1.4362	1,39	1,37	1,34	1,38	1,47	1,59	1,68	1,62	1,60	1,54	1,50
1.4401	2,24	2,39	2,50	2,57	2,61	2,80	2,98	2,84	2,83	2,69	2,64

Figure 3-6 Alloy surcharge

3.2 Item characteristics

In order to make an adequate determination for purchasing volumes, it is important to distinguish items with different characteristics. In order to make this distinction, a semi structured interview is conducted with the purchasing manager of the company. Concluding there are 5 characteristics to distinguish.

- **Historic average demand:** the demand of an item can vary per item. Depending on the demand, the purchasing department can decide to purchase a certain amount of the item. Also, it is important to consider what the demand of other items supplied by the same supplier is.
- **Demand frequency:** the average demand of an item does not give a clear view on the pattern in which items are being used.
- **Fluctuation in demand quantity:** the fluctuation in demand is essential for the purchasing volume. In case of a predictable fluctuation, it is possible to determine the right purchasing volume. A fluctuating demand can result in stock-outs or on the other hand side to high inventory levels.
- **Price per quantity:** money used for the purchasing of inventory cannot be used for other investments. This means from a financial point of view, it is important to keep the inventory level in terms of money as low as possible.
- **Predictability:** as mentioned before, the predictability of an item is an important variable for purchasing strategies. A predictable demand leads to less purchasing risk.

These characteristics are all measurable by using data from the ERP-system. In Table 3-1 item characteristics these measures are defined.

Table 3-1 item characteristics

Variable	Parameter	Data	Unit	Effect on volume
Historic average demand	Volume of raw material consumed	Job order detail item	Quantity unit of raw material consumed/730 days	Positive
Demand Frequency	Amount of request for raw material in a certain amount of time	Job order detail item	Number of requests/730 days	Negative
Fluctuation in demand quantity	Variation in history requested volumes	Job order detail item	Standardisation of requested volume	Negative
Price per quantity	Value based on purchasing price with the current alloy surcharge considered	Last purchasing price - alloy surcharge last purchase + current alloy surcharge	Euro/purchasing price unit	Negative
Predict-ability	Call contract customer	Sales order detail item/assembly	Percentage of 2-yearly demand reserved for production	Positive

3.3 Item categories

In the previous section the different item variables are discussed. In order to make a distinction between different item categories, a pinball model is applied. A pinball-model is a categorising model that looks like a pinball game. The different items follow a route downwards, in which at certain moments choices have to be made. At the bottom of the pyramid, the different categories are being distinguished.

The characteristics that are distinguishable for the items of the company are defined in section 3.2. The characteristics are also quantified in order to measure the characteristics. These quantitative measures are derived from the ERP-system of the company for each item. After deleting some outliners such as an occupational demand for Titanium which is extremely expensive, the average of the different character measures is defined. Based on this average, the items can be qualitatively defined as “higher than average” or “lower than average”. In **Fout! Verwijzingsbron niet gevonden.**, the measures are defined as high or low by the colour green or red. The steps are displayed in **Fout! Verwijzingsbron niet gevonden.**model (figure book). The table should be read as follows: the items are categorised from top to bottom. First, the difference between low and high frequency is made. Based on this decision the item ends up on the left or the right pyramid. In this similar manner, the items flow down the pinball model.

In order to make the description of the items more understandable, an explanation of the structure is given in the next paragraph.

The raw material used at the company is made out of metal and mostly coiled on spools. The structure of DR03,00 1.0304 C9D Zn 600-800 N/mm^2 is displayed in Table 3-1 Item discription.

Table 3-1 Item discription

Shape	Dimensions	Metal grade	Alternative metal name	After treatment	Min tensile strength (N/mm^2)	Max tensile strength (N/mm^2)
DR	03,00	1.0304	C9D	Zn	600	800
DR(wire)/ BA(strip)	⌀/ Width X Height	indicates the composition of the metal	additional description	Heat treatment/ Surface treatment	Lowest allowed tension in which the wire/strip breaks	Highest allowed tension in which the wire/strip breaks

In order to give a more complete view on the items, some of the items are explained in the following sections.

DR01,60 1.4310 RVS302 1750-2012N/mm^2 (High Frequency-High Demand-Fluctuating-Inexpensive-Unpredictable)

This item is used within the production process of De Spiraal. Despite of the fact that the material is used for a product that is sold based on a call contract, the fluctuation is high. The reason for the high fluctuation is the fact that sometimes the material is used for other small orders.

DR02,00 1.4310 RVS302 1700-1955N/mm^2 (High Frequency-High Demand-Fluctuating-Inexpensive-Unpredictable)

This item is used within the production process of De Spiraal. The wire is applicable for the production of springs. Wire of this dimension is used in a lot of different springs and also for a lot of different customers which results in a low predictability. Therefor the demand is fluctuating as well as high frequent. Next to that, material is inexpensive.

BA02,50x13 1.1231 C67S Gesn 490-640N/mm^2 (High Frequency-High Demand-stable-Inexpensive-Unpredictable)

This item is used to make small plates that linked together in order to create a belt. The plates are standardised which results in a high demand. The frequency is high since it is easy to produce small batches. Because of the fixed batch sizes, the demand is stable.

DR14,00 1.0038 S235JR 450-530N/mm^2 (Low Frequency-High Demand-Stable-Inexpensive-Unpredictable)

This item is used within the production process of De Spiraal. The wire is used for a compression spring. This spring is coiled around a steel cable in order to prevent it from fraying. The low frequency / high demand ratio is caused by the fact that the products are significantly heavier than average. Since the demand is measured in number of kilograms, the demand is high. The constant demand is caused by the fact that the customer of the springs, arranged a constant batch size with De Spiraal.

DR00,60 2.4711 Elgiloy Phynox 1400-1900N/mm² (Low Frequency-Low Demand-Fluctuating-Expensive-Unpredictable)

Normally, an item with these characteristics is ordered to stock. In case of this item, De Spiraal holds inventory. One of the biggest customers of De Spiraal produces valves for the off-shore industry. Since the costumer wants to achieve short lead-times, De Spiraal is asked to hold inventory for the raw materials that are used in product of this customer. The costs of inventory can be charged at the customer.

DR01,20 1.4301 RVS304 600-750N/mm² (High Frequency-High Demand-Fluctuating-Inexpensive-Unpredictable)

Tribelt has a small amount of standardised finished goods. These finished goods are made to stock. One of these finished goods is the ClearTech belt. This belt is driven by a sprocket that fits the meshes of the belt.
This raw material is used in one of these finished goods. The demand is extremely high and because of the relatively small batch size, the frequency is also high. There is no standard batch-size which results in a high fluctuation.

DR01,60 1.0304 C9D Zn 400-550N/mm² (High Frequency-High Demand-Fluctuating-Inexpensive-Unpredictable)

This raw material is used in a belt that is made by Tribelt. This belt is used for safety screening in dangerous environments. It is made to order. The fact that the belts are requested by several customers, causes a highly fluctuating demand. The raw material contains inexpensive components which results in a low price.

DR04,50 1.4828 RVS309 600-750N/mm² (Low Frequency-High Demand-Constant-Expensive-Unpredictable)

The low frequency / high demand ratio is caused by the fact that the products are significantly heavier than average. Since the demand is measured in number of kilograms, the demand is high. The constant demand is caused by the fact that the customer for the belt arranged a constant batch size with Tribelt.

3.4 Key performance indicators

The last step of this sub-question is to figure out what key performance indicators (further called KPIs) are currently in place. KPIs are measurements set by the management on which the performance of a department can be measured. By doing this, the department can adequately adapt to changes.[17]
In case of the purchase department of the company, there are currently no actual KPIs in place. The purchasing department currently adjusts based comments that are made within and outside the department. Two main aspects are to be discussed within the company:
Costs of inventory: the costs of inventory are usually related to the amount of inventory. After buying products, the company has to pay the invoice of the incoming goods. These costs are not directly rewarding. As long as the materials are in stock, they are not being sold and there will not be any money in return for it. In other words, the company has a part of its money locked in inventory. As long as the money is locked in inventory, it is not possible to spend it on investments.
Lead-time issues: Since the company is a manufacturing company, all the products sold, are produced from goods that are purchased. This leads to a dependency on incoming goods and inventory levels. The total lead-time of an order is depending on the accessibility of raw materials.

[17] See (Weber Al & Thomas Ron, 2005)

3.5 Conclusion

This chapter has shown the complexity of the purchasing processes. Many steps have to be taken in order to purchase and receive raw material for the production process of the company. Next to that, the information that is necessary in order to make the right purchasing decision is shown.

Now that the current situation is clear, an analysis can be performed on the performance of the purchasing department. In the next chapter, the required data will be gathered in order to quantify the indicators.

4 Issues to be improved

Now that the current situation is clarified, the performance of this situation needs to be measured. By doing this, it is possible to determine whether there are problems to be solved. Also measuring the current situation is a possibility to check for improvement after changes are made. In this case, the performance is measured in two separate variables: in terms of costs in section 4.1and in terms of lead-times in section 4.2.

4.1 Performance in terms of costs

In order to determine the liquid position of the company, the finance department measures the inventory value related to the turnover that was made in a certain period. The inventory is made relatively to measure the stock turnover. The stock turnover is representing the number of times the total stock value is used to manufacture products.[18]
The data for these analyses are gathered from the ERP-system of the company. In this system, all the inventory changes are registered. Next to that, the quarterly turnover in terms of raw materials is measured. By dividing these 2 measures, a relative KPI is established.
To make relative measure for only stock value's, a graph is made in which 3 different lines are displayed:
Orange: inventory value
Blue: quarterly costs of sales in raw material
Grey: inventory turnover

[18] See (C. Madhusudhana Rao & K. Prahlaa Rao, 2009)

Figure 4-1 KPI Stock turnover Tribelt

For Tribelt, Figure 4-1 KPI Stock turnover Tribelt shows a significant increase in stock-value. The last year, the inventory value has increased with 10%. Also, there is an increase in quarterly costs of sales in raw material. The increase of both of these variables, leads to a relatively stable inventory turnover.

Figure 4-2 KPI Stock turnover De Spiraal

For De Spiraal, Figure 4-2 KPI Stock turnover De Spiraal shows a big increase in inventory value since 2017. Also, the quarterly costs of sales in raw material has increased significantly since 2017. However, there a difference between these measures which results in a decreasing inventory turnover.

4.2 Performance in terms of lead-times

The lead-time of the company is strongly depending on the accessibility of raw materials. This dependency is being quantifiable by measuring the amount of orders that are not produced because of stock outs. In order to measure the performance, data were gathered from 2 systems that are used by the company to align processes: the ERP-system and the scheduling-system in MS-Excel. First of all, the orders of the last 3 year are loaded in a MS-Excel sheet. Based on the scheduled production date, the demand date for raw material was determined. From the ERP-system the number of units needed and the available stock over the time was gathered. By combining this information, it is possible to calculate the number of stock-outs over a certain amount of time. Figure 4-3 KPI Stock-outs shows the percentage of order delays because of stock-outs.

Figure 4-3 KPI Stock-outs De Spiraal

According to the pivot **Fout! Verwijzingsbron niet gevonden.** that is use to analyse the data, *confidential* of the orders are delayed because of stock-outs. As shown in Figure 4-3 KPI Stock-outs De Spiraal, the amount of orders that are delayed because of stock-outs is increasing. This means that a higher percentage of all production-orders are delayed because of an insufficient quantity of raw material is available. It was not possible to measure the same KPI for Tribelt. The reason for that was that there were no historic data about the planned start date of the production.

4.3 Conclusion

The inventory turnover of Tribelt is more or less constant. However, there is an increase in inventory. In case of De Spiraal, the increase in inventory value is higher than the increase in cost of sales. However, this increase in inventory has not led to a lower stock-out rate. Now that the problem is quantified, a literature research can be conducted in order to find alternatives for solutions.

5 Theoretical framework

In this chapter the theory according to the subject of this study is discussed. This helps the researcher in making the right decisions with respect to the research method. The purpose of this research is to find models that are developed to determine the purchasing volume for raw materials. Also, research is conducted to gather information about the costs of inventory, ordering costs and costs of stock-outs. These are three variables that needs to be taken in account to have the right balance in inventory levels.

5.1 Costs of inventory

Durlingen (2005) writes in his article about the costs of inventory. First of all, he describes that a lot of logistical managers handle an annual holding cost percentage of 25% of the initial purchasing value of the inventory.[19] However, in the literature, there is a more sophisticated measure to determine the costs of inventory.
According to Durlingen (2005) there are three components to consider when making inventory decisions:

- Interest: This is the cost of the money that is captured in the inventory. Small businesses use the interest costs of their bank. Amore sophisticated measure is the opportunity cost. This is the potential value of the money if it was invested into other aspects.
- Space: Of course, all inventory has to be stored somewhere. Whether it is in the factory/distribution centre, the products have to be stored somewhere. Therefor there are costs to be made. These costs derive from many different aspects such as buildings, forklifts, Employees and automatization. The main issue for these costs is the fact that they are not directly assignable to the amount of stock. In other words: these costs are not linearly related to the inventory levels. These costs are likely to be about three to six percent.
- Risk: The obsolescence of items is the most probable risk that's has to be accounted for in inventory management. This risk is highly depended on the kind of business. I tis advised to relate the risk to a certain item category. A smaller share of the risk-costs is theft, damaging and insurance.[20]

The article of Durlingen mostly describes the different aspect. In order to make these aspects quantitative. Jan Heizer and Barry Render (2014) describe six different costs that are also quantified as shown in Table 5-1 Inventory costs.[21]

Table 5-1 Inventory costs

Category	Examples	Percentage of inventory value
Housing costs	Building depreciation and insurance	3%-10%
Handling costs	Fork lifts and racks	1% - 3,5%
Labour costs	Expedition employers	3% - 5%
Investment costs	Borrowing costs, insurance	6% - 24%
Overall costs		16% - 42,5%

[19] See (Paul Durlinger, 2005)
[20] See (Paul Durlinger, 2005)
[21] See (Jay Heizer & Barry Render, 2014)

5.2 Ordering costs

Every time the purchasing department places an order, there is a certain amount of time spend on processing this order. Examples of activities are: discussing with supplier, entering a preparing a purchasing order, guarding the delivery-times, unloading trucks, handling materials and register goods-delivery.
Jan Heizer and Barry Render (2014) distinguishes 2 different methods to determine order costs:

- Proportional to the amount ordered
- Partly proportional to the amount ordered, partly fixed[22]

For the company, the last, more sophisticated formula is chosen. The reason for this, is the fact that the company purchases various amounts of products. The increase of the number of products, is not expected to be linear related to the costs of ordering.

5.3 Stock-out costs

Stock-out costs are the costs that derive from the fact that the company runs out of stock. There are no direct costs that are the result of stock-outs. However, indirectly there will be costs made by the company in case of stock-outs:

- Back-ordering: delivering the items in 2 separate shipments
- Order-cancelling: The customer will order the item at another supplier
- Order-cancelling and customer-loss: The customer will order the item at another supplier and will leave the supplier. [23]

Charles Dominick (2010) developed a formula to calculate the cost of stock-outs. The formula is as follows:

CS = (NDOS x AUSPD x PPU) + CC

Where,
CS = Cost of a Stockout
NDOS = Number of Days Out of Stock
AUSPD = Average Units Sold Per Day
PPU = Price Per Unit (some use Profit Per Unit)
CC = Cost of Consequences [24]
Now that all 3 variables are quantified. It is possible to apply these measures in a model. These models will be discussed in the next section.

[22] See (Jay Heizer & Barry Render, 2014)
[23] See (Martin Murray, 2018)
[24] See (Charles Dominick, 2010)

5.4 Strategies per category

As shown in section 3.3, not every item has the same characteristics when it comes to value, demand and accessibility. In order to apply the right strategy on the right category. Bernd Noche (2015) distinguishes 2 types of analysis for inventory-strategies:

- ABC- Analysis: The importance of items divided into 3 groups
  - High value or share of sales percentage
  - Intermediate materials
  - Low value or share of sales percentage
- XYZ-Analysis: The fluctuation of demand divided into 3 groups
  - Constant
  - Wilder fluctuation
  - Completely unsteady[25]

In order to make a decision based on both analyses, a matrix is designed. The matrix as shown in Table 5-2 Distinguishing item categories.

Table 5-2 Distinguishing item categories

		High consumption	Medium consumption	Low consumption
		Importance ---------->		
		a	b	c
Reliable forecasts	x	- High consumption - Reliable forecasts	- Medium consumption - Reliable forecasts	- Low consumption - Reliable forecasts
Less Reliable forecasts	y	- High consumption - Less Reliable forecasts	- Medium consumption - Less Reliable forecasts	- Low consumption - Less Reliable forecasts
Unreliable forecast	z	- High consumption - Unreliable forecast	- Medium consumption - Unreliable forecast	- Low consumption - Unreliable forecast

<-----Fluctuation

[25] See (Bernd Noche, 2015)

5.5 Models to determine purchasing volume

5.5.1 Economic order quantity

This model is used to find the right balance between the costs of ordering and the costs of inventory. A high inventory will lead to inventory costs but prevents a high frequency of ordering. Figure 5-1 EOQ shows three lines in which the green one has an optimum that represents the aforementioned balance.

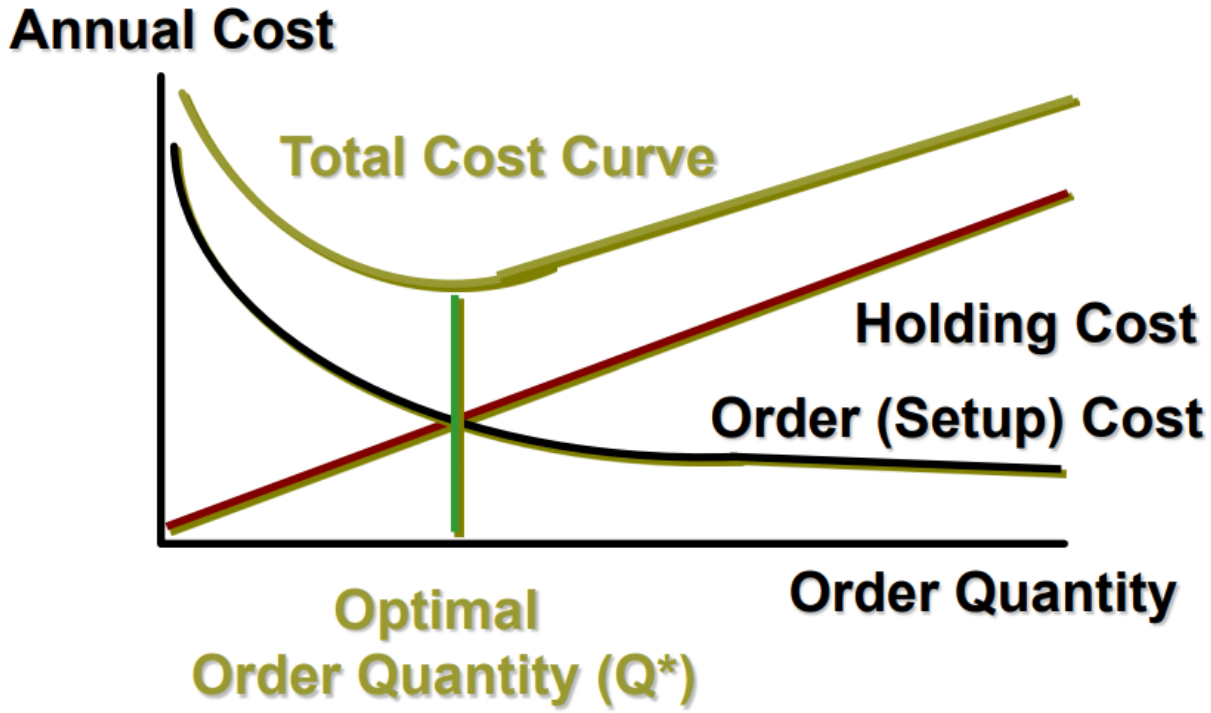


Figure 5-1 EOQ

6 variables have to be considered in order to create the formula that is shown in figure:

- D = Annual demand (Kg)
- C= Cost per unit (€)
- Q= Order quantity (Kg)
- S= Cost per order (€)
- H= Holding costs (€)
- H= Holding costs (€) = IxC [26]

$$EOQ = \sqrt{\frac{2 \times D \times S}{H}}$$

Figure 5-2 Formula EOQ

The Economic Order Quantity is a measure that is only applicable in companies that have a constant demand for a certain material. In the case of the company, the model is not applicable without taking the fluctuations in account.

[26] See (Ken Homa, 2018)

5.5.2 Constant model

Rainer Kleber (2006) describes a constant model as the simplest possible model for determining purchasing volumes. The model consists of 3 variables:

- x_t = demand in period $_t$;
- a = average demand per period;
- Ɛ = independent random deviation with mean zero.

These variables are combined to the following formula: $x_t = a + Ɛ_t$.[27]

This model can only be used in case of a constant demand. Examples of products with a constant demand are toothpaste, standard tools and spare parts.

5.5.3 Trend model

In case of a demand based on a certain trend, it is recommended to use a trend model. This model takes in account a trend variable. The model consists of 4 variables:

- x_t = demand in period $_t$;
- a = average demand per period;
- Ɛ = independent random deviation with mean zero;
- b= trend is the increase of a demand for the product.

These variables are combined to the following formula: $x_t = a + b_t + S$.[28]

Depending on the nature of the trend, the value of b can be positive or negative.

5.5.4 Trend-seasonal model

This model is applicable to product demand that is depending on a certain trend as well as seasonal influences.

- x_t = demand in period $_t$;
- a = average demand per period;
- Ɛ = independent random deviation with mean zero;
- b= trend is the increase of a demand for the product;
- F_t= seasonal index in period $_t$. This should be 1 + the proportional seasonal increase in demand for the product.

These variables are combined to the following formula: $x_t = (a + b_t)F_t + S$.

5.5.5 Moving average

The variable Ɛ describes te variation in a certain amount of time. However, the independent deviations cannot be predicted. In order to do so, the demand of the most recent periods have to be considered. This can be done by using the following variables:

- $\hat{a}_t$= estimate of a after based on the demand in period t
- $x_{t,T}$= forecast of period $_T$>$_t$ based on the observations of the demand over period t

These variables are combined to the following formula: $x_{t,T} = a_t = (x_T + x_{t-1} + x_{t-2+\ldots.+} x_{t-N+1})/N$. By using this formula, it is possible to determine the demand for a certain product based on recent data.

[27] See (Rainer Kleber, 2006)
[28] See (Jay Heizer & Barry Render, 2014)

5.5.6 Regression analysis

The previous discussed models are only based on historical demand. By doing a regression analysis, it is possible to relate the demand to other topical variables. Examples of topical variables are: weather forecasts, indices and steel prices.
The following variables are necessary in order to determine purchasing demand by conducting regression analysis:

- $\hat{Y}$: the value of the independent variable
- a: y-axis intercept
- b: slope of regression
- x: dependent variable[29]

The variables arise from the independent and dependent variables. For example, the number of ice-creams sold is related to the temperature. The variables are computed in the table below.

Table 5-1 Example regression analysis

day	temperature x	amount of ice-cream sold y	x^2	xy
1	20	10	400	200
2	30	28	900	840
3	25	43	625	1075
4	20	21	400	420
5	22	11	484	242
6	33	62	1089	2046
Totaal	**25**	**29,17**	**3898**	**4823**

$\bar{x}=\sum x/N=150/6=25$
$\bar{y}=\sum y/N=175/6=29.17$
$b= (\sum xy-n\bar{x}\bar{y})/(\sum x^2-n\bar{x}^2)=(4823-6*25*29.17)/(3898-6*25^2)=3.03$
$a= \bar{y}-b\bar{x}=29.17-3.03*25$
These variables are combined to the following formula: $\hat{Y}=a+bx=29.17+3.03*x$. For an x of 35º degrees, $\hat{Y}=29.17+3.03*35=135.22$ ice-creams.

5.5.7 Multiple-regression analysis

Multiple-regression analysis is an extension of the regression analysis. With this analysis, it is possible to relate the dependent variable to two or more independent variable. The variables are as follows:

- $\hat{Y}$: the value of the independent variable
- a: y-axis intercept
- b: slope of regression
- x_1 and x_2: 2 independent variables
- b_1 and b_2: coefficient for the two independent variables

These variables are combined to the following formula: $\hat{Y}=a+ b_1 x_1+ b_2 x_2$. Computing the coefficients is a difficult process. This can be done by using statistical programs such as SPSS.[30]

[29] See (Jay Heizer & Barry Render, 2014)
[30] (Jay Heizer & Barry Render, 2014)

5.5.8 Safety stock

In management an important concern is maintaining a certain service level. The service level is the amount of orders that can be delivered on time. Stock-outs are a cause of a decreasing service level. In order to ensure stock-outs, it is possible to apply a safety stock in a model for demand forecasting. Safety stock is a certain amount of stock that is not necessarily needed for bridging the purchasing lead-time. It is meant to intercept unforeseen circumstances.
For example, in the EOQ the inclusion of safety stock (ss) changes the formula to: EOQ= √(2xDxC/H)+ss

5.5.9 Safety stock with probabilistic demand

Heizer and Render (2014) describe probabilistic demand as a demand that is not known but can be specified by means of probability.[31] The re-ordering point (ROP) is determined by multiplying the average daily demand by the lead-time(dxL). For example, a product was taken with an average daily demand of 50 and an ordering lead-time of 12 days. This results in a ROP of 600 as shown in Table 5-3 Probability of demand.

Table 5-3 Probability of demand

number of days inventory	Inventory quantity	probability
2	100	20%
8	400	10%
12	**600**	**40%**
20	1000	20%
40	2000	10%

In order to find the right safety stock, the optimum between inventory holding costs and stock-out costs has to be determined. The formula to determine inventory costs is to be found in section 5.1 and the formula to determine stock-out costs is to be found in section 0. In Table 5-6 Calculation safety stock the ROP with safety stock for probabilistic demand is determined for the aforementioned data in combination with the variables in and Table 5-5 Variables for stock-out costs.

Table 5-4 Variables for inventory costs

variables for inventory costs	
Price per unit raw material	€ 4,00
Costs of sales (%)	30%
Gross margin	40%
Housing costs	8%
Handling costs	2%
Labour costs	3%
Investment costs	16%
Inventory costs	29%
Annual inventory costs per unit	€ 1,16
Costs of extra inventory	See table 5-6

[31] (Jay Heizer & Barry Render, 2014)

Table 5-5 Variables for stock-out costs

Variables for stock-out costs	
NDOS = Number of Days Out of Stock	See table 5-6
AUSPD = Average Units Sold Per Day	50
PPU = Price Per Unit (some use Profit Per Unit)	€ 5,33
CC = Cost of Consequences	50

Table 5-6 Calculation safety stock

safety stock	ROP (with safety stock	probability	additional holding costs (per year)	Stock-out costs	total costs
1.400	2.000	0,02	€ 1.624	€ -	**€ 1.624**
400	1.000	0,20	€ 464	€ 538	**€ 1.002**
-	600	0,40	€ -	€ 2.074	**€ 2.074**

[32]

Table 5-6 Calculation safety stock shows that a safety stock of 400 pieces will increase the holding costs with €464 and will lead to a stock-out risk of 538. This results in a total cost of €1.002. However, these total costs are lower than a safety stock of 0 as well as a safety-stock of €1.400. In this situation, it is advice to have a safety stock of 400 units.

5.6 Conclusion

This chapter has given insight in the different costs that should be considered when determining purchasing volume. Next to that, the different models that can be used to make a purchasing decision are described. Now it is possible to address the applicability of the different models to the situation of the company.

[32] (Jay Heizer & Barry Render, 2014)

6 Alternatives for solution

The different models that are found in the previous chapter, are scored based on applicability to the situation of the company. In section 3.2 the item characteristic that determine the purchasing decision are defined. In this chapter, the models found in the literature are scored based on the extent to which these item characteristics are considered. After scoring the models, prototypes are designed in order to make a combination of the different models.

6.1 Scoring models

A Pugh-matrix is used to give every alternative a certain value on an item character. In a Pugh- matrix the alternatives are displayed in the rows and the different criteria are displayed in the columns. In the cross-section, values are assigned. The matrix is shown in Table 6-1 Scoring models.

Table 6-1 Scoring models

Model	Frequency	Demand	Fluctuation	Price	Predictability
EOQ	-	+/-	-	+/-	-
Constant model	-	+/-	-	-	-
Trend model	-	+/-	+/-	-	-
Trend Seasonal model	-	+/-	+	-	-
Moving average	-	+	+/-	-	-
Regression analysis	+/-	+	+/-	-	+/-
Multiple regression analysis	+/-	+	+	-	+
Safety stock	-	+/-	+/-	-	-
Safety stock with probabilistic demand	+/-	+/-	+	+	+/-

Because of the fact that there are no models that consider all the item characteristics, it is decided that some models have to be combined. In order to test these models on their applicability on the company, the combined models are conducted in prototypes. These prototypes are explained in the next section.

6.2 Prototypes

In order to create a tool that is applicable on the situation of the company, this chapter represents 3 prototypes of the tool. These prototypes are based on the different models that are scored in the previous section. In the following paragraphs, the prototypes are displayed and described. For a more detailed projection it is possible to consult the figure book.

6.2.1 Regression analysis combined with moving average

Figure 6-1 Prototype 1 is based on the single regression analysis, as well as the moving average method. The purchaser can select a certain item or a certain item-group. The information from the ERP-system is automatically gathered into the tool. The tool consists of three different tabs. The first one gives a forecast based on the inquiry activity for this item(group). The second tab gives a forecast based on the moving average demand for this item(group). The last tab gives a forecast based on the number of visits on the webpages where products are represented that are made out of this item(group). In the upper-left table, the item information is presented. First, a suggestion is made by the tool by doing a regression analysis. The data can be overwritten by the purchaser in order to get other results. Upper-middle table gives the code and the description of the item(group). The upper-right table shows the products for which the raw material is used. Also, it gives insight on the demand for these products in the last 2 years. The lower-right table shows the current demand based on production orders that are already planned. The graph on the left shows the results of the regression analysis.

Figure 6-1 Prototype 1

6.2.2 Multiple-regression analysis with moving average

Figure 6-2 Prototype 2 combines the three predictors of the previous tool by executing a multiple regression analysis. By doing this, the purchaser does not have to interpret the 3 different tabs. In the upper-left table, the item information is presented. First, a suggestion is made by the tool by doing a regression analysis. The data can be overwritten by the purchaser in order to get other results. Upper-middle table gives the code and the description of the item(group). The upper-right table shows the products for which the raw material is used. Also, it gives insight on the demand for these products in the last 2 years. The lower-right table shows the current demand based on production orders that are already planned. The graph on the left shows the results of the regression analysis.

Figure 6-2 Prototype 2

6.2.3 Multiple-regression analysis with moving average and probabilistic demand

Figure 6-3 Prototype 3 also conducts a multiple-regression analysis. In the upper-left table, the item information is presented. First, a suggestion is made by the tool by doing a regression analysis. The data can be overwritten by the purchaser in order to get other results. Upper-middle table gives the code and the description of the item(group). The upper-right table shows the products for which the raw material is used. Also, it gives insight on the demand for these products in the last 2 years. The lower-right table shows the current demand based on production orders that are already planned. The graph on the left shows the results of the regression analysis.
Based on the proposed purchasing volume that is determined by the multiple-regression analysis, the lower-left table is filled. This table displays the total amount of costs(inventory costs+ probable stock-out costs). In the left column, the amount of safety stock is represented. In the next 4 columns the max demand that can be satisfied, purchasing volume, minimum stock and probability of the demand is calculated. In the last 3 columns, the additional inventory costs and stock-out costs are calculated. In the right column, the total costs are calculated. The green cells highlight the lowest total costs and represents the right safety-stock.

Figure 6-3 Prototype 3

7 Choice

In this chapter a decision-making process is conducted. The goal of this process is to figure out what the best suitable purchasing volume determination tool is for the purchasing department of the company. First of all, different characters are defined in order to score the purchasing volume determination tools. Secondly, the prototypes are scored individually.

7.1 Characteristics

In this section, the Analytic hierarchy process (further called: AHP)-model is used to define and valuate the criteria of purchasing volume determination tools. In this model, all the criteria are scored related to each other. In other words, one criterion is compared to another. The critic needs to decide to what extent one criteria is more or less important than another.[33] In a brainstorm session with the purchasing department, the different characteristics are defined. Also, the different tools are scored by the two purchasers of the company. The outcomes of this session are displayed in Table 7-1 AHP-scoring.

Table 7-1 AHP-scoring

	Purchaser 1	Purchaser 2
Appearance	4,5%	2,3%
Usability	43,2%	11,9%
Completeness	13,6%	15,5%
Easy to implement	3,8%	18,3%
Accuracy	17,8%	35,5%
Applicable on all categories	17,2%	16,5%
Consistency (1% high consistency 99% low consistency)	**10,0%**	**8,0%**

In the next section, these characteristics and their AHP-score are used to criticize the designed prototypes.

[33] (Shahroodi & Kambiz, 2012)

7.2 Scoring prototypes

In this section, the porotypes are scored by the purchasing department. The scoring is done based on the Likert Scale. The Likert Scale is a 5-point scale that offers a range of answer options — from one extreme attitude to another, like “extremely likely” to “not at all likely.” Typically, they include a moderate or neutral midpoint.[34]

Table 7-2 Scoring prototypes

		Appearance	Usability	Completeness	Easy to implement	Accuracy	Applicable on all categories	**Total score**
AHP-Score	Purchaser	4,5%	43,2%	13,6%	3,8%	17,8%	17,2%	
	Purchasing manager	2,3%	11,9%	15,5%	18,3%	35,5%	16,5%	
Prototype 1 regression analysis	Purchaser	4	2	2	5	2	2	
	Purchasing manager	4	1	2	3	2	3	
	Total score AVG (individual score*individual AHP-score)	0,14	0,49	0,29	0,37	0,53	0,42	**2,2405**
Prototype 2 multiple regression analysis with moving average	Purchaser	3	4	3	4	3	2	
	Purchasing manager	4	4	4	2	3	3	
	Total score AVG (individual score*individual AHP-score)	0,11	1,10	0,51	0,26	0,80	0,42	**3,2075**
Prototype 3 multiple regression analysis with probabilistic demand and moving average	Purchaser	2	3	4	3	4	4	
	Purchasing manager	5	4	5	1	4	3	
	Total score AVG (individual score*individual AHP-score)	0,10	0,89	0,66	0,15	1,07	0,59	**3,454**

In Table 7-2 Scoring prototypes the three prototypes are placed in the left column of the matrix. In the first 2 rows, the AHP-scores as defined in the previous section are shown. In the cross-table, the scores of both of the purchasers are displayed. In every third row, the total score is computed by considering the individual AHP-scores. Prototype 3 has the highest total-score of 3,45. Based on these results, an implementation proposal is conducted in the next section. This implementation

[34] (Survey monkey, 2018)

proposal gives the company a clear guideline to apply the outcomes of this research in order to improve the purchasing process.

8 Guide for the tool

In this chapter, the operation of the tool is explained. It is advised to consult **Fout! Verwijzingsbron niet gevonden. Fout! Verwijzingsbron niet gevonden.** while reading this manual. During the scoring session in section 6.1, a workshop about all 3 models was given to the purchasers. This manual can be used as reference work. This guide is separated into 2 sections; section 1 the steps to be followed by the user, section 2 how to interpret the data.

8.1 Steps

1. in the field <*item code*> fill in the item code or the item category code of the items that you want to analyse
2. in the field <*annual inventory costs unit*> fill in the inventory cost per unit. In a later stadium, these costs are calculated automatically. In the first phase, these costs can be determined by the finance department
3. in the field < *stock-out costs per quantity*> fill in the stock-out costs per quantity. In a later stadium, these costs are calculated automatically. In the first phase, these costs can be determined by the sales department
4. in the field <*amount of purchasing orders*> fill in the desired amount of orders you want to have annually

8.2 Interpret data

8.2.1 Graph

The graph displays three dashed lines. These lines are the input for a multiple regression analyses. This multiple regression analyses is executed by a tool within MS Excel. With the information of the 3 independent variables(dashed lines), the tool makes a prediction for the demand for the raw material. The independent variables are as follows:

- **Dashed blue:** This line gives the quantity of the raw material offered in inquiries. Logically, a higher amount of offered products in which the raw material is used, leads to a higher probable demand.
- **Dashed yellow:** This line gives the amount of website visits in that period. Logically, a higher amount of website visits leads to more requests for quotations which eventually leads to more demand.
- **Dashed green:** This line gives the moving average of the demand for the raw material. The moving average is measured at a certain point of time by taking the average of the last 365 days. By taking into consideration this measure, it is possible to detect a certain trend.

Next to the dashed lines, the graph displays 2 constant lines:

- **Orange:** This is the predicted demand based on the multiple regression analysis of the three dashed lines.
- **Black:** This line gives the actual demand for the raw material. The line is used to test if the prediction is accurate.

8.2.2 Upper left table(outcome of multiple regression)

The output of the graph is described in the upper left table.

- **Expected annual demand based on graph:** the predicted demand per year based on the graph.
- **Demand per period:** the predicted demand per week based on the graph.
- **Proposed purchasing volume:** the proposed purchasing volume based on the annual amount of purchasing orders and the demand per period.
- **Minimum stock:** this is the minimum stock in order to bridge the delivery lead-time
- **Accuracy:** this is the accuracy of the prediction. The accuracy is the percentage of the dependent variable that is explained by the independent variables

8.2.3 Assembly details

In this table, information is shown in which the material is used. Also the relative share in the total amount and the frequency is given. The user can determine the dependency of the raw material.

8.2.4 Current reservations

In this table, the current reservations of the raw material is shown. These are the current orders that are dependent of the raw material.

8.2.5 Probabilistic demand

In this table a trade-off is made between the costs of extra inventory and the costs of stock outs. In the first column, the purchaser can give in different percentages of safety stock in order to compare strategies. the next 4 columns the max demand that can be satisfied, purchasing volume, minimum stock and probability of the demand is calculated. In the last 3 columns, the additional inventory costs and stock-out costs are calculated. In the right column, the total costs are calculated. The green cells highlight the lowest total costs and represents the right safety-stock. The associated purchasing volume is consider as most economical.

9 Conclusions and discussion

In this chapter, the findings of the research are discussed. In the first section of this chapter, the key-findings of the research are discussed. The second section discussed the limitations of the research. In order to give advice to other researchers, the third section describes the future research. In the last section, an advice is given to the organisation.

9.1 Key findings

By analysing the current situation, it has become clear that the purchasers of the company need to consult 5 different dashboards in order to make the right purchasing discussion. This is a time-consuming process and frustrating process. Next to that, the purchasers do not have all the right information available. Sometimes, this leads to inadequate purchasing decisions.
The consequence of this lack of information leads to an increasing inventory value without a decrease of stock-outs. Especially the inventory of De Spiraal has increased significantly. The value of raw material inventory has increased with 50% over the last 2 years.
Because of these findings, it is decided to analyse literature in order to find models that can be used to make purchasing decisions. During this literature research, 9 models are found.
In order to measure the applicability to the situation of de company, a Pugh matrix is conducted. The conclusion of the Pugh matrix was that there was no model perfectly applicable on the situation of the company. However, 5 models were considered as useful. In order to find an applicable model, some of the most suitable models were combined into prototypes. This has led to 3 prototypes: “regression analysis combined with moving average”, “multiple-regression analysis with moving average” and “multiple-regression analysis with moving average and probabilistic demand”. These prototypes needed to be scored based on their applicability to the situation of the company.
In order to determine the preferred prototype, the purchasers filled out an AHP-form that defines the importance of 6 different features of the prototype. For purchaser 1, the most important feature is usability (43,2%), while purchaser 2 considers accuracy (35,5%) as the most important feature.
After filling out these forms, the three prototypes are presented to the purchasing department. The purchasers were asked to fill out a form to score the three prototypes on the aforementioned 6 different features based on the Likert Scale.
By considering all features and the importance per purchaser, the prototypes were provided with a total score. Prototype 3: “Multiple-regression analysis combined with moving average and probabilistic demand” is considered as the best applicable tool for the company.

9.2 Limitations of the research

This research was commissioned by De Spiraal and Tribelt. That is why the data collection is executed specifically for the company. Consequently, the results of the research are applicable for similar businesses. Next to that, the research has only focussed on the purchasing process of raw materials. Manufacturing supplies, services and machinery are not included. Therefore, the purchasing tool is limited applicable.

9.3 Future research

In order to get a more broadly applicable purchasing tool, it is advised to test the applicability of the of the tool on different kinds of businesses. For example, it is possible to hand out a free license for the tool to other companies under the condition that these companies give feedback on the tool. Next to that, more research should be done on the accuracy of the tool. The accuracy his tool is tested with fictional data because of the time-frame of the research. In future research, the accuracy of the tool can be tested with real data of the company. Companies that not seem to fit the tool, can follow the steps of this research from chapter 6 and 7 in order to acquire well fitted tool.

9.4 Practical implications

This research first of all has given insight in the performance of the purchasing department of the company. Both the purchasers are content with the insight in the KPIs. These KPIs can be used in the future to monitor the effects of the new tool. Also, it is recommended to measure the number of stock-outs for Tribelt as well. Therefor the company needs to keep records of the planned start date of production.

In order to implement the new tool, the company has to take a few steps. First of all, the tool needs to be tested with actual data of the company. In this way, the applicability is tested completely. The next step is to implement the tool into the ERP-system. This can be done by the software-supplier Ridder Data Systems. Of course, this investment needs to be approved by the directors of the company. After implementing the new tool, the purchasing department needs to be trained in how to use the tool. Since the company is operating in a rapidly changing environment, there is a possibility that the tool turns obsolete. In order to prevent obsolescence, the tool has to be reviewed on applicability.

The implementation of this tool can help the company to minimize inventory values without an increase of stock-outs. Also, the tool can give the purchasing department a better negotiation position because of all the available information about the demand. These advantages will lead to a lower cost price, as well as a decrease in stock-outs. All in all, this will keep the company competitive and therefore ready for the future.

10 Bibliography

Academy Behavioural Management Social Sciences. (2018, 30-08-2018). Master's programme Business Administration. Retrieved from https://www.utwente.nl/en/education/master/programmes/business-administration/#related-programmes-by-topic

Al, W., & Ron, T. (2005). Key Performance Indicatos. *Ivara*, 3.

Alloys, R. (2014). What are Stainless Steel Surcharges. Retrieved from https://www.rolledalloys.com/technical-resources/blog/what-are-stainless-steel-surcharges-

Dominick, C. (2010). Calculating The Cost of a Stockout. *PurchTips, 212*, 1.

Durlinger, P. (2005). *Vreemde EOQ waarden?* Retrieved from

Durlinger, P. (2005). *Wat kost voorraad?* Retrieved from

Heizer, J., & Render, B. (2014). *Operations Management* (Vol. 11): Pearson.

Homa, K. (2018). *EOQ Model*. Retrieved from Georgetown: http://faculty.msb.edu/homak/homahelpsite/webhelp/Content/EOQ.pdf

Kleber, R. (2006). Dynamic Inventory Management in Reverse Logistics. *Lecture Notes in Economics and Mathematical Systems*, 9.

Klumpers, W. (2018) *Current situation/Interviewer: R. Peters*.

Klumpers, W., & Veldhuis, H. (2018, 3-7-2018) *Defining the problem/Interviewer: R. Peters*.

monkey, S. (2018). What is a Likert Scale? Retrieved from https://www.surveymonkey.com/mp/likert-scale/

Muench, A. J. (1993). *Redefining the Aftermarket Demand Forecasting Process Using Enterprise Resource Planning.* (Bachelor of Sciense in Mechanical Engineering), United States Military Acedemy.

Murray, M. (2018). Stockout Costs and Effects on the Supply Chain. *Small business.*

Noche, B. (2015). *ABC-/XYZ Analysis Introduction*. Retrieved from https://www.uni-due.de/imperia/md/content/tul/download/en_ss2015_lm01_le_abc_analysis.pdf

Rao, C. M., & Rao, K. P. (2009). INVENTORY TURNOVER RATIO AS A SUPPLY CHAIN PERFORMANCE MEASURE *Serbian Journal of Management, 4*(1), 41 - 42.

RiQ. (2018). Delivery leadtime.

RiQ. (2018). Production leadtimes.

RiQ. (2018). Requested delivery times.

Shahroodi, & Kambiz. (2012). Application of Analytical Hierarchy Process (AHP) Technique To Evaluate and Selecting Suppliers in an Effective Supply Chain. *Kuwait Chapter of Arabian Journal of Business and Management Review, 1*(8), 1-8.

Sokovic, M., Pavletic, D., & Krulcic, E. (2006). Six Sigma process improvements in automotive parts production. *Journal of Achievements in Materials an Manufacturing Engineering, 19*(1), 96-97.

Twente, U. o. (2017). Master of Science in Business Administration, 9-11. Retrieved from

Veldhuis, H. (2018) *Current situation/Interviewer: R. Peters*.

Veldhuis, H. (2018). *De Spiraal From technical advice until the production within our own factory*. Retrieved from Haaksbergen:

veldhuis, H. (2018). *Tribelt From technical advice until the production within our own factory*. Retrieved from Haaksbergen: