Master Thesis

Inventory reduction based on the example of a German SME in the steel wire rope industry

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Special thanks go to Pfeifer Drako for giving me the chance to get a practical overview. All the employees supported me with time to answer my questions and thus provided me with the necessary empirical data as well as with interesting insights into the steel rope industry.

I finish the acknowledgement with a line from the “famous” singer Scatman: “Everybody stutters one way or the other so check out my message to you. As a matter of fact don’t let nothing hold you back, if the Scatman can do it so can you”.
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II. List of abbreviations

ATO= assemble to order  MTO= make to order
BOM= bill of material  MTS= make to stock
CEN= European Committee for standardization
CEO= Chief executive officer
DCP= decoupling point
Drako= Drahtseilerei Gustav Kocks GmbH & Co
ERP= Enterprise resource planning
ETO= engineer to order
EU= European Union
EUR= Euro
EWIRS= European Federation of wire rope industries
ibid= ibidem
IWRC= independent wire rope core
km= kilometre
LEO= link everything online
m= metre
M= million
min= minutes

OEE= overall equipment effectiveness
OEM= Original Equipment Manufacture
OIPEEC= International Organization for the Study of the Endurance of Ropes
OITAF= Organizzazione Internazionale Transporti a Fune
OPP= order penetration point
p.= page
pp.= pages
SME= small and medium-sized enterprises
SWOT= Strength, Weakness, Opportunity and Threat
t= ton
TPM= Total productive maintenance
TPS= Toyota production system
WIP= Work in progress
Ill. Summary English

The purpose of this master thesis is to point out possibilities for reducing the inventory of semi-finished products based on the example of a German SME (small and medium-sized enterprises) in the steel rope industry. Inventory reduction increases the flexibility of the company and decreases tied up capital. Therefore it is necessary to identify the factors which are influencing the inventory level. Theory provided market related, product related and production related factors. These factors have been analysed by collecting empirical data and comparing these results with theory.

Product delivery strategy, decoupling point strategy and postponement strategy are the theoretical framework used to answer the main research question:

**How can the decrease of inventory of semi-finished products be exemplified without reducing the ability to deliver based on product delivery strategies?**

The main result of this thesis is that Drako is not able to move the decoupling point dramatically because this change would increase the set-up times. Therefore postponement strategies have to be applied to delay the point of product definition. This can be achieved on the one hand by ensuring that components are usable for other products. Nowadays this point of product definition occurs in the first production step when the chosen wire is fixed in the stranding machine. On the other hand it is easily possible to use free capacity so that the production process can be split up on more machines. The utilisation of the relevant machines for producing elevator steel wire rope is very low.

Based on the value stream analysis, which was the major source for collection of the empirical data, waste in the production has been identified. Quality checks at the end of a process are not sufficient, because it is not possible to repair errors. Also the rewinding of the wire is wasted time for the company because the supplier is able to deliver the raw material also on bobbins, which avoids the rewinding process. All in all it can be said that the current production strategy of Drako allows many proposals for inventory reduction.
IV. Summary German


Methoden zur Erfüllung des Kundenbedarfs wie MTS, ATO, MTO und ETO, Theorien über den Entkopplungspunkt und Möglichkeiten zur Verschiebung des Variantenbildungspunktes bilden die theoretischen Grundkonzepte der Diplomarbeit um die folgende Hauptforschungsfrage zu beantworten:

Wie kann der Bestand von Zwischenproduktion beispielhaft mit Produktionsmethoden reduziert werden ohne die Liefertreue zu verschlechtern?


Mittels einer Wertstromanalyse, welche als Grundlage für die empirische Datenerhebung verwendet wurde, wurde festgestellt, dass sich im Produktionsablauf Verschwendungen eingeschlichen haben. Zum einen gibt es am Ende der Produktion eine Qualitätskontrolle. Bei dieser „Leichenbeschau“ ist es nicht mehr möglich Fehler zu korrigieren, deshalb muss die Prozessstabilität erhöht werden um die geforderte Qualität sicherstellen zu können. Zum an-
deren wird der Draht von machen Lieferanten ohne Spulen geliefert. Das führt dazu, dass das Unternehmen einen Umspulvorgang einführen muss, welcher keine wertschöpfende Tätigkeit ist und somit vermieden werden sollte.
1. Introduction

The purpose of this Introduction chapter is to present the basic theoretical methods applied in this thesis. Therefore this first chapter is divided into subchapters. The Background chapter gives a brief overview about the topic and the industry. The problem discussion funnels the field down to the research question. This is followed by the definition of the objectives of this master thesis. Since it is necessary to narrow the scope of the thesis, limitations are presented to emphasise the focus of the master thesis. A discussion of the theoretical and practical relevance of the material is presented in the following. The Introduction chapter ends with a short disposition.

1.1. Background

This thesis is focusing on productions and distribution methods which are using resources to transform inputs, which can be raw material or products from other systems, into a desired output\(^1\). Many industries are facing strong global competition where product life cycles are shortened, time-to-market decreases and customers require fast deliveries for a variety of products of an appropriate quality\(^2\).

The steel rope industry also has to deal with decreased time-to-market periods. In this industry, the information flow between customer and supplier is in most cases not optimised even if the focus is internal\(^3\). Therefore the steel rope industry is chosen as an example for this master thesis. Not sharing the demand information within the different production steps, can result in the bullwhip or Forester effect. This effect describes a lack of synchronisation among the different steps of production and distribution and the resulting exaggeration of stock levels\(^4\).

The steel rope industry all over the world uses similar manufacturing processes since there are only a few equipment manufacturers. That increases the threat of new entrances. Therefore it

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\(^1\) Chase, 2004, p. 8  
\(^2\) Javalgi, 2005, p. 213  
\(^3\) Production Manager Pfeifer Drako  
\(^4\) Chase, 2004, p. 368
Introduction

is absolutely necessary that a company ensures that the right product in the right quality is available to the customer in the right quantity at the right time\(^5\).

In this industry, one has to distinguish between larger projects and everyday smaller business. In the daily business, customers expect immediate delivery after an order is placed. In the case of larger projects, customers are willing to wait for the finished product since none of the competitors are able to satisfy their customer immediately. More precisely, the replenishment time of a raw material like the steel wire may take more time than the whole production process. In this business companies have to deal with a raw material bottleneck.

“A highly market-oriented company will focus on meeting or exceeding customer expectations [...]”\(^6\). That means that the company has to develop methods which allow them to satisfy the customer needs on time. Delivery reliability refers to on time delivery in each case because a firm has to “supply the product or service on or before a promised delivery due date”\(^7\).

In the steel rope industry the question of stocking semi-finished products is important because semi-finished product require a high amount of tied up capital within a company. Pfeifer Drako, one of the key competitors in the steel rope industry, has been selected for further investigation.

1.2. Problem discussion

A company— also Drako – has to deal nowadays with several threats including demanding customers, global competition, a fast pace of change, unpredictable surroundings, and the general availability of resources\(^8\). One possibility to influence these aspects is an optimisation of production. Pfeifer Drako, a steel rope manufacturer situated in Germany, is taking possibilities for optimising their production into consideration. To reduce the scope to manageable levels, only elevator ropes, Pfeifer Drako’s most important type of steel wire ropes, are investigated. Their main target is to decrease the inventory level of semi-finished products in order to decrease the time for manufacturing steel wire ropes. Theory provides many concepts for

\(^{5}\) Lambert, 1998, pp. 3  
\(^{6}\) Arnold, 1991/2001, p. 3  
\(^{7}\) Chase, 2004, pp. 25  
\(^{8}\) Lutz, 2003, p. 217
reducing inventory levels like lean manufacturing, postponement, forecasts, increasing inventory turnover, improving the order cycle process.\(^9\)

### 1.2.1. Decrease Inventory

Why then is inventory necessary? Theory claims that inventory refers to waste.\(^10\) However, "in environments where an organisation suffers form poor cash flow or lacks strong control over (i) electronic information transfer among all departments and all significant suppliers, (ii) lead times, and (iii) quality of material received, inventory plays important roles."\(^11\) In the production inventory can be categorised into raw material, finished goods and work in progress (WIP). Hence, this leads again to the assumption that inventory is only necessary in case of wrong planning activities. This results in the attempt to reduce inventory. Reducing the inventory levels result in a reduction of costs.\(^12\) Of course one has to ensure that the output of the system is the same before applying changes. A reduction of inventory levels should reduce the tied up capital and on the other hand, flexibility for reacting to changes in the marked situation should be increased.\(^13\) Therefore the pull point, which is the point where products are not produced "according to actual demand and instead are made against forecasts alone", should be provided if it is possible to move it to the demand side with postponement and decoupling strategies. A value stream analysis should attempt proposals for this reduction.

### 1.2.2. Product delivery strategies

Porter’s value chain illustrated in Figure 1.1 is based on the process view of an organisation.\(^14\) The value chain consists of the information, material and financial flow. This thesis is focusing on the material flow but also the information flow is taken into consideration. According to Drakos’s target of reducing the inventory level the focus of this thesis is put on the red circled activities which are inbound logistics and operations. These activities should be aligning to the customer needs whereas waste, which is not paid by the customer, should be reduced.

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\(^9\) Case, 2004, pp. X
\(^10\) Hines, 1997, p. 47
\(^11\) Muller, 2003, p. 3
\(^12\) Lutz, 2003, p. 217
The product delivery strategies which describe if the product is produced on stock or for a customer influence the inventory level. Therefore this thesis is focusing on these product delivery strategies. Due to the reason that the financial flow is not considered a connection to the final customer, it is necessary to ensure that the needs are satisfied. By implementing the contribution margin or other related financial measurements the customer side would be included. But as stated before the financial flow is not considered. Therefore other methods have to be applied.

1.2.3. Ability to deliver

Delivery is the connection to the final customer of steel ropes. It is important that the delivery reliability is not reduced by a new strategy. Market-orientated companies have to take the customer’s view into consideration. Not only the final customer has to be satisfied but also internal customers have to be treated like a final customer. That means each concept or method which can be applied for an external customer is also valid for an internal one.

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13 Production Manager Pfeifer Drako
14 Porter, 1985, pp. 11
16 Reeve, 2005, pp. 50
1.3. Research question

The considerations presented in this chapter lead to the following research question for the master thesis:

**How can the decrease of inventory of semi-finished products be exemplified without reducing the ability to deliver based on product delivery strategies?**

In order to answer the main research question the following sub question is important, in which the factors influencing the inventory level are identified.

**What are the main factors influencing the inventory level of semi-finished products?**

1.4. Objectives

The objective of this master thesis is to find possibilities of reducing the inventory of semi-finished products in steel wire rope industry without reducing the ability to deliver. The sub objective of this thesis is to identify the main factors which are influencing the inventory level of semi-finished products.

1.5. Limitations

In order to focus on aspects that are of profound interest, the research needs to be narrowed down. The main points of discussion are summarised below:

- Elevator ropes of Pfeifer Drako
- No financial calculations
- No suppliers and external customers are investigated

1.6. Theoretical and practical relevance

The thesis is relevant from several perspectives: On the one hand, the theoretical relevance of the thesis emphasises various related theories published in recent years and puts them together
in a conceptual model for the steel rope industry. At present, no studies for reducing inventory levels in the steel rope industry are available.

On the other hand, Pfeifer Drako and the other manufacturers of steel wire ropes are getting proposals for reducing their inventory of semi-finished products. Less inventory means less tied up capital, which can be used for a better satisfaction of customer demands. Pfeifer Drako will get a thorough analysis of their delivery strategy and a valuable industry comparison. As the author is not involved in the daily business of the company, he can make his proposals from a neutral standpoint.

1.7. Disposition

Chapter 1, the Introduction, discusses the background of the problem by narrowing down the field to the research question in the problem discussion. The Introduction chapter ends with the objectives and limitations for this master thesis. The applied methodology for this case study is discussed and defined in Chapter 2. In Chapter 3 the theoretical framework is presented whereby a conceptual model is developed for answering the research question. Further on, in chapter 4, the collected empirical data is highlighted. Theory and empirical data are compared in chapter 5. Finally, in chapter 6 the concluding ideas are illustrated.
Figure 1.2: Disposition
2. Methodology

This chapter presents the research methodology used in this master thesis. In the beginning the scientific perspective is discussed, followed by the research strategy and data collection process. This is followed by a discussion about the scientific creditability. In the end of this chapter the development of the research process is explained.

2.1. Scientific perspective

The aim of this master thesis is to reduce the inventory for semi-finished products. In order to be able to conduct this study the following chapter is necessary to ensure the quality of the research.

2.1.1. Deductive versus inductive methods

The deductive approach “begins with an abstract, logical relationship among concepts, then moves toward concrete empirical evidence”\(^{17}\). Indeed, the deductive process is based on finding a conclusion about a particular phenomenon or fact based on general principles\(^{18}\). It is to say that choosing the deductive approach means having a theoretical starting point and leading a research to confirm or infirm those theories relatively to a more concrete case.

Induction could be understood to be the opposite of the deduction. It consists of conclusions based on empirical observations\(^{19}\). One begins with “detailed observations of the world and move toward more abstract generalization and ideas”\(^{20}\). In that sense, the inductive path of thoughts means to seek for new theories. It follows another structure than the deduction approach and allows the researcher to generalise what he/she studied.

Concerning this research, a deductive process is followed, which means this thesis will first start with theories used for answering the research question and then apply them to make the case concrete. The thesis will be constructed from the theories concerning inventories to establish a theoretical model and then the theoretical framework is confronted with the reality through em-

\(^{17}\) Neuman, 2003 p. 51  
\(^{18}\) http://www.socialresearchmethods.net/kb/dedind.htm 2005/11/05  
\(^{19}\) ibid
empirical data. The empirical data is gathered from Drako, a German steel rope manufacturer. Indeed, for a student, it appears that starting with studying theoretical framework first would be the best way to learn and conduct a research.

2.1.2. Positivistic paradigm versus hermeneutic paradigm

Methodology theory provides two different main paradigms concerning the scientific perspective. According to Gummesson, “The positivistic researcher aims at being a spectator whereas the hermeneutic researcher endeavours to be part of the action”\(^{21}\). A brief explanation of the main characteristics of each approach is following.

The positivistic approach is mainly descriptive and explanatory. Indeed, it studies facts and precise cases, using mainly quantitative data and aiming at generalisation and abstraction. Thus it is primarily a deductive approach\(^{22}\).

In contrast, the hermeneutic approach is more focused on understanding and on the interpretation of data. It concentrates more on facts and data and thus can be considered as mostly inductive\(^{23}\). Understanding is the main purpose of this approach, which is why it should focus on qualitative data more than quantitative data.

The positivistic paradigm clearly appears as the most appropriate to reach the goal of this research. In the theory chapter the applied theories and concepts used in steel rope industry, especially focused on Pfeifer Drako are presented. Moreover, the conducted research is limited to the possibilities of reducing the inventory levels. Therefore no holistic view of the company or the whole steel rope industry is applied, but rather a focus on reducing the inventory levels. Also the research question, especially in word “exemplified”, highlights this choice. Exemplify means: “To illustrate by example”\(^{24}\). That means, proposals for inventory reduction should be given in the end of the thesis. This is done with a rationalised model.

\(^{20}\) Neuman, 2003. p. 51
\(^{21}\) Gummesson, 2000, p. 179
\(^{22}\) Gummesson, 2000, p. 178
\(^{23}\) ibid
\(^{24}\) http://dictionary.reference.com/search?q=exemplified 2006/04/21
2.1.3. Qualitative versus quantitative methods

There are two methods concerning the data analysis used: the quantitative and the qualitative method\textsuperscript{25}. The quantitative\textsuperscript{26} method is based on concrete data, on more figures; on the other hand, the qualitative method requires for the researcher to analyse these according to the objectives of the thesis\textsuperscript{27}. It seems to be more open than the quantitative method but can also be biased by researcher analysis.

The quantitative method for gathering information will be the one used throughout this research as it appears the most appropriate, because it is necessary to collect more quantitative data for fulfilling the positivistic approach than qualitative data. Therefore a value stream analysis is conducted to gather the information of the current situation. Qualitative data is surveyed by open discussions, in which the production manager and the plant manager were involved. As this thesis aims to be scientific and objective, its target is not interpretation but about demonstration.

For conducting the analysis, the quantitative data is translated into qualitative data. This is done to execute a qualitative analysis of the theoretical framework and empirical data. Therefore a SWOT (Strength, Weakness, Opportunity and Threat) analysis is conducted. In other words, a deep financial analysis of the results is not applied. This paper deals with theoretical approaches to reducing the inventory levels. Therefore the nature of the used data is both qualitative and quantitative. But the focus is on the quantitative method for collecting data due to the chosen positivistic approach. But the analysis is done by qualitative methods, translating the quantitative data into qualitative data.

2.2. Research strategy and data collection

This part explains why a case study approach is chosen for this master thesis. This is followed by the introduction of the data collection process. Finally the population and sample for this case study is defined.

\textsuperscript{25} \url{http://www.bibl.ulaval.ca/info/rechqual.html} 2005/11/05  
\textsuperscript{26} Ibid.  
\textsuperscript{27} \url{http://www.socialresearchmethods.net/kb/qual.htm} 2005/11/05
2.2.1. Research strategy

The choice of the research strategy undoubtedly affects the whole research from the method to the outcome and it strongly depends on the form of the research question.

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Form of Research Question</th>
<th>Requires Control of Behavioural Events?</th>
<th>Focuses on Contemporary Events</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experiment</td>
<td>how, why?</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Survey</td>
<td>who, what, where, how many, how much?</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Archival analysis</td>
<td>who, what, where, how many, how much?</td>
<td>No</td>
<td>Yes/No</td>
</tr>
<tr>
<td>History</td>
<td>how, why?</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Case Study</td>
<td>how, why?</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Figure 2.1: Different research strategies

As seen in the figure above, three possibilities for answering the research question are supposable, which are Case Study, History and Experiment. This thesis aims to explore how it is possible to reduce the inventory levels. The archival analysis is not applicable due to the reason that the “why” which is necessary to support the importance of the results is missing.

The second criterion Yin provides after the form of the research question is the extent of the researcher’s control over behavioural events. Only the experiment is able to control the relevant behaviours. However, the goal of this master thesis is to reduce the existing inventory levels by analysing the current situation. Therefore no need of control behavioural events is supposed. Thus, the experiment strategy can be barred.

The third criterion defined by Yin refers to focuses on contemporary events. The history is applied if it is only possible to answer the research question by studying historical data especially when dealing with the “dead” past. The investigated industry and company are exist-

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28 Yin, 2003, p. 5
29 Yin, 2003, pp. 7
30 ibid
Methodology

ing and therefore accurate data can be gathered. The above discussion leads to a case study strategy for the master thesis.

2.2.2. Population and Sample

For this thesis an industry has been chosen where few studies based on manufacturing optimisation have been conducted so far. Due to the fact that almost no investigations have been made, potential for manufacturing optimisation is in place. As mentioned in the limitations, the thesis focuses on elevator steel wire ropes. In this industry five major companies are competing \(^{31}\), which represent the defined population shown in the figure below:

<table>
<thead>
<tr>
<th>Population</th>
<th>Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uscha / India</td>
<td>Pfeifer Drako / Germany</td>
</tr>
<tr>
<td>Wolf(^{32}) / Germany</td>
<td></td>
</tr>
<tr>
<td>Pfeifer Drako(^{33}) / Germany</td>
<td></td>
</tr>
<tr>
<td>Trefil &amp; Brock(^{34}) / France</td>
<td></td>
</tr>
<tr>
<td>Brugg(^{35}) / Switzerland</td>
<td></td>
</tr>
</tbody>
</table>

*Figure 2.2: Population, Sample*

The steel rope industry all over the world uses similar manufacturing processes since there are only a few equipment manufacturers for the steel rope industry available. Pfeifer Drako is chosen for the empirical source for this master thesis because they have started working on concepts for reducing inventory. By visiting the company one can see the raw material and semi-finished products stocked directly on the walkway of the production facility. Moreover they recognised the importance of being flexible in production by lowering the tied up capital of their inventory.

\(^{31}\) Technical manager Pfeifer Drako  
\(^{32}\) [http://www.gustav-wolf.de/sites/produkt.html](http://www.gustav-wolf.de/sites/produkt.html) 2006/03/26  
\(^{33}\) [http://www.drako.de](http://www.drako.de) 2006/04/21  
\(^{34}\) [http://www.trefilcable.com](http://www.trefilcable.com) 2006/03/26  
\(^{35}\) [http://www.brugg.com](http://www.brugg.com) 2006/03/26
Drako offers a wide range of products. Therefore an ABC analysis has been conducted as seen in the Appendix. The result is that more than 70% of the turnover is created by elevator ropes. Therefore the Drako 250T family has been chosen for further investigation. Data is collected for the 8mm and 10mm diameter rope, whereas the data of the 8mm rope is presented in the Appendix because the results are similar.

2.2.3. Data collection sources

There are three main sources of data for researchers, which are interviews, text analysis and observation\textsuperscript{36}. This paper applies all of them for collecting the empirical data. For gathering the theoretical data, only text analysis is used.

2.2.3.1. Observation

This part introduces the value stream analysis, which is used as an observation method. The value stream analysis is a method of identifying the material and information flow in a company, with the target to detect non value-adding processes\textsuperscript{37}. "Value-added” describes processes for which the customer is willing to pay\textsuperscript{38}. In order to be a value-added action, the action must meet two more criteria. On the one hand, it must be done right the first time and on the other hand the action must somehow change the product or service in some manner\textsuperscript{39}.

Non-value-adding refers to waste. Therefore it is important that the material and information flow is aligned to the needs of the customer to ensure customer satisfaction and profitability. The value stream analysis is a part of the lean manufacturing philosophy\textsuperscript{40}. Lean manufacturing tries to avoid waste, which is not paid by the customer. Between 1950 and 1955 Taiichi Ohno developed lean manufacturing for Toyota Motor Corporation\textsuperscript{41}. Due to the fact that continuous improvement is an important part of this philosophy, lean manufacturing has been improved and adapted by many companies all over the world but Toyota has never lost its leading position in avoiding waste and process stability\textsuperscript{42}. “Lean manufacturing means devel-

\textsuperscript{36}Kociatkiewicz, 2005
\textsuperscript{37}http://www.4managers.de/10-Inhalte/asp/wertstromdesign.asp 2006/04/07
\textsuperscript{38}Böge, 1997, p. 476
\textsuperscript{39}http://www.isixsigma.com/dictionary/Value-Added-134.htm 2006/04/11
\textsuperscript{40}http://www.gepro.com/wertstromfabrik/de/Flyer_Wertstrom-Kompaktseminar_.pdf 2006/04/07
\textsuperscript{41}Smalley, 2005, p. 8
\textsuperscript{42}Taylor, 1997
oping an environment which is conductive to [...] elimination of waste such as bottlenecks of information or material movements, smooth flow of work, rationalize committee structure, etc.43. The value stream analysis is one part of lean manufacturing which allows identifying waste.

The Frauenhofer Institut44, a German research centre, has created a description of the value stream analysis, which is presented and supported by literature from other authors in this chapter. The value stream analysis is a simple method for identifying the current state of the material and information flow by visualisation of possible improvements. Therefore distinct symbols should be used to illustrate the circumstance45. This should improve the communication between the different departments to identify the cause of problems. The value stream analysis focuses on lead times and the connection of different processes, in which the relationship between processing time and idle time is important. By understanding this relationship it is possible to reduce the inventory level of raw material, semi-finished products, finished products and WIP.

According to the 80:20 rule or Pareto law, which says that 20% of the causes results in 80% of impact46, only the important facts are mapped briefly. This puts the focus on the essential data of the processes. This screening of the current state is called value stream analysis. Using the whole potential of this analysis, it is important to describe the target state to ensure that correct changes can be applied to satisfy both the internal and external customers.

The target state of processes, in which the non value-added time is avoided47, should be created. After illustrating the important facts of the current state the target state should be derived. One has to identify the value adding time, which is paid by the customer and the non value adding time, which is not paid. Therefore the non value adding time has to be reduced to a minimum.

43 Zaremba, 1994, pp. 14
44 http://www.ipa.fhg.de/Arbeitsgebiete/fabrik-produktionsmanagement/org/wert_ana.php 2006/04/07
45 Glover, 2005, p. 18
46 Timischl, 2002, p. 10
47 Phyllis, 2006, p. 23
2.2.3.2. Interview

Considering to the research question it has been decided to lead a deep case study at Pfeifer Drako by conducting explorative interviews with the plant manager, production manager, CEO and a member of the controlling department. These interviews are necessary to identify the applied theory at Pfeifer Drako and to collect the empirical framework. Moreover, text analysis of the financial reports and the ERP system of Drako is necessary to gather the quantitative information like inventory levels, costs, turnover, lead-times and utilisation of the machinery. To improve the concept-finding process, several discussions among production manager, plant manager and the author of this thesis were held. Moreover, employees from the process engineering department have been interviewed, because these people are working daily with scheduling the different orders. The following figure presents the interviewed employees of Drako:
<table>
<thead>
<tr>
<th>Name</th>
<th>Function</th>
<th>Email</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buschmann Holger</td>
<td>Process engineering department</td>
<td><a href="mailto:buschmann.holger@drako.de">buschmann.holger@drako.de</a></td>
</tr>
<tr>
<td>Hübl Marcel</td>
<td>Controlling</td>
<td><a href="mailto:huebl.marcel@drako.de">huebl.marcel@drako.de</a></td>
</tr>
<tr>
<td>Jakuboswki Jörg</td>
<td>Process engineering department</td>
<td><a href="mailto:jakuboswki.joerg@drako.de">jakuboswki.joerg@drako.de</a></td>
</tr>
<tr>
<td>Kolodziej Stefan</td>
<td>Process engineering department</td>
<td><a href="mailto:kolodziej.stefan@drako.de">kolodziej.stefan@drako.de</a></td>
</tr>
<tr>
<td>Konieczny Ralf</td>
<td>Process engineering department</td>
<td><a href="mailto:konieczny.ralf@drako.de">konieczny.ralf@drako.de</a></td>
</tr>
<tr>
<td>Niederholz Friedhelm</td>
<td>Head of maintenance</td>
<td><a href="mailto:niederholz.friedhelm@drako.de">niederholz.friedhelm@drako.de</a></td>
</tr>
<tr>
<td>Niggeweg Roland</td>
<td>Production manager</td>
<td><a href="mailto:niggeweg.roland@drako.de">niggeweg.roland@drako.de</a></td>
</tr>
<tr>
<td>Scheunemann Wolfgang</td>
<td>Plant manager / Technical Manager</td>
<td><a href="mailto:scheunemann.wolfgang@drako.de">scheunemann.wolfgang@drako.de</a></td>
</tr>
<tr>
<td>Schiffer Roland</td>
<td>TIBIS consultant</td>
<td><a href="mailto:schiffer.roland@drako.de">schiffer.roland@drako.de</a></td>
</tr>
<tr>
<td>Sieber Lothar</td>
<td>Product manager elevator ropes</td>
<td><a href="mailto:sieber.lothar@drako.de">sieber.lothar@drako.de</a></td>
</tr>
<tr>
<td>Watermann Bastian</td>
<td>CEO Drako</td>
<td><a href="mailto:waterman.bastian@drako.de">waterman.bastian@drako.de</a></td>
</tr>
</tbody>
</table>

**Figure 2.3: Interviewee**

The reason for choosing these people is the organisation chart of Drako pictured in Figure 2.4, illustrating the responsibilities of the functions.
Figure 2.4: Organisation chart of Drako

All in all the aim was to involve all participating people into the empirical research, which has been fulfilled by conducting this master thesis.

2.2.3.3. Text analysis

Pfeifer Drako has installed Tibis as ERP system to monitor and calculate the financial flow and material flow of their produced goods and services. One of the tasks for this master thesis is to understand the important and necessary transactions of this system to be able to identify the crucial data for the empirical analysis.

The main source of the theoretical data is the Växjö University library, including the ELIN database to find literature concerning the subject of reducing inventory levels. Internet sources were chosen carefully in order not to bias the research by non-accurate information. Moreover the aim was to use internet sources only if it was not possible to find other theoretical data. For translating the German technical language the CEN dictionary\(^{48}\) and the online dictionary LEO (link everything online) from the Technical University of Munich\(^{49}\) have been used. CEN is the European Committee for standardisation\(^{50}\).

\(^{48}\)CEN\(^{49}\)http://dict.leo.org 2006/04/27\(^{50}\)http://www.cenorm.be/cenorm/index.htm 2006/04/26
2.3. Scientific credibility

“Credibility is the believability of a statement, action, or source, and the ability of the observer to believe that statement”\(^{51}\). This chapter establishes the scientific credibility for this master thesis.

2.3.1. Scientific validity

The validity of a research is how well it describes reality. It “refers to the match between a construct (...) and a measure”\(^{52}\). Three main types of validity can be distinguished: construct validity, internal validity and external validity.

2.3.1.1. Construct validity

The aim of construct validity is to avoid subjective judgements in the data collection phase\(^{53}\). Multiple sources of evidence in the data collection process and establishing a chain of evidence are necessary to construct validity, which uses multiple indicators. It can be divided into two subtypes: “one looks at how well similar indicators converge, the other one looks at how well different indicators diverge or distinguish differences”\(^{54}\). Therefore, for the theoretical part of this thesis, several books and internet sources are used to build up a model in the end of the theory chapter. Due to the fact that the theory chapter ends up with a model, which is the main source for the data collection process, construct validity can be guarantied.

2.3.1.2. External validity

External validity can be defined as “the ability to generalize from experimental research to settings or people that differ from the specific conditions of the study”\(^{55}\). Moreover, external validity deals with the question to which degree a conclusion of a case study can be generalised. As explained in the development of the sample all steel rope manufacturers are dependent on a few equipment suppliers. This results in similar processes for production including

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\(^{52}\) Neuman, 2003, p. 179
\(^{53}\) Yin, 2003, pp. 34-35
\(^{54}\) Neuman, 2003, Glossary
\(^{55}\) ibid
the problematic of inventory. The findings should therefore be relevant to the wire rope industry as a whole.

2.3.1.3. **Internal validity**

According to Yin, internal validity only applies to explanatory or causal studies but not for descriptive or exploratory ones\(^{56}\). Due to the fact that this master thesis has chosen the positivistic paradigm, internal validity is not a subject for this thesis.

2.3.2. **Scientific reliability**

According to Neuman\(^{57}\), reliability means dependability or consistency. In other words, it means that under similar conditions, other researchers would find the same results. Indeed, “the results should not depend on the characteristics of the measurement or the measurement itself”\(^{58}\). Further studies which will use the same theory as provided in this thesis will come to the same conclusions, because to avoid mistakes during the gathering of empirical data explorative interviews are conducted with the technical manager, production manager, CEO and a member of the controlling department. This results in a reduction of errors caused by collecting wrong information. If antagonisms are occurring it is possible to verify the information with the interviewees easily.

2.4. **Development of the research process**

A company tries to get as many results as possible out of a study. This is due to the fact that a company is focusing on a high cost performance ratio, which means they try to get a maximum of performance with a minimum of cost. Therefore the criteria established by the company for this master thesis were extremely high. At the beginning, the whole product assortment should be taken into consideration. A reduction of inventory should be established in order to increase flexibility. Also the cause of changing the batch-size should be considered. The company also wanted a financial calculation, which would make it easy to measure the advantages and disadvantages of the proposals.

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\(^{56}\) Yin, 2003, p. 34
\(^{57}\) Neuman, 2003, p. 179
\(^{58}\) ibid
After collecting the first empirical data it turned out that it was necessary to focus on one product of the product assortment. Therefore a kind of ABC analysis has been conducted. The result presented in the Appendix shows that 74% of the whole turnover of Drako are generated by elevator ropes. At this point in time it was clear that the focus was to be on the elevator ropes. The production manager recommended investigating the Drako 250T family, which is a typical elevator rope.

During the development of the theory chapter, the problem of choosing the relevant theories occurred because theory about methods of reducing inventories, inventory evaluation, calculation and lean manufacturing would have been necessary to fulfil the global ideas of the company. Therefore it was necessary to limit the scope. No studies have been conducted before about inventory reduction at Pfeifer Drako. Only a study for reducing waste, especially scrap metal was accomplished by Andreas Rebhahn during the PIUS Check. Hence it was necessary to begin from scratch. This means, factors which cause inventory have been identified. Theory provided three major categories of factors, which are the product, production and market related factors. Then the theoretical know-how was applied by gathering the empirical data and the analysis. After this process the main thesis objective, possibilities for the reduction of inventory, could be established. Also the data for the 8mm rope were collected, as presented in the Appendix.

2.5. **Time schedule**

In the following figure the time schedule is presented. After finishing the writing task it was necessary to review the Introduction and Methodology chapter to adapt them, so that the whole thesis is consistent.

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59 Rebhahn, 2006, pp. 1
### 2.6. **Summary of the Methodology**

The figure below summarises the applied Methodology for this thesis:

<table>
<thead>
<tr>
<th>Scientific perspective</th>
<th>Positiveistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scientific approach</td>
<td>Deduction</td>
</tr>
<tr>
<td>Data analysis method</td>
<td>Qualitative</td>
</tr>
<tr>
<td>Nature of data</td>
<td>Qualitative and quantitative</td>
</tr>
<tr>
<td>Research strategy</td>
<td>Case study</td>
</tr>
</tbody>
</table>

**Figure 2.6: Summary Methodology**
3. Theory

In this section the steel wire rope is introduced to the reader. This is necessary in order to understand the different components of a steel rope and how they are produced and assembled. This is followed by an overview of the four basic product delivery strategies. These strategies influence the postponement and decoupling point strategies, which are explained next. An introduction into the service level and delivery delay in order to be able to measure the logistical performance of the inventory process continues this chapter. In the end of this theory chapter a conceptual model is established for answering the research question by collecting the empirical data.

3.1. Steel wire rope

This chapter gives a short overview over the historical development of steel wire ropes in order to understand the purpose of producing steel wire ropes. This is followed by a short introduction over the main components of a rope. Afterwards the production process is introduced. At the end of this first theory chapter, the possible applications for a steel wire rope are detailed.

3.1.1. Historical Development

At the end of the 19th century, several important inventions such as dynamite, the steam engine and steel ropes were made, revolutionising the behaviour of companies and giving them new perspectives. The modern steel wire rope, which usually consists of several strands of metal wires twisted together, was invented by the German Wilhelm Albert between 1831 and 1834. Since Albert was a mining engineer, steel ropes were first used in mining. Technological developments and changes, which showed the way to the industrial revolution, led to increased technological requirements in coal mining and in steel production.

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60 http://www.kopalniasoli.pl/deu/kopalnia/index.html 2006/02/11
61 Wire rope technical board, 1993, pp. 3
62 Geiss, 1993, pp. 398
ropes therefore were quickly accepted as they proved superior to ropes made of hemp or of metal chains, the technology previously used\textsuperscript{63}.

"\textit{Wilhelm Albert's first ropes consisted of wires twisted about a hemp rope core, six such strands then being twisted around another hemp rope core in alternating directions for extra stability}\textsuperscript{64}. The process is in principle the same as the process for the production of natural fibre ropes. In manufacturing steel wire ropes, individual wires are first twisted into a strand, and then such strands are again twisted around a core, which consist of steel or even of natural fibres such as sisal, manila, henequen, jute, or hemp\textsuperscript{65}.

\subsection*{3.1.2. Components of steel rope}

Nowadays a steel wire rope consists of three basic components, as illustrated in Figure 3.1\textsuperscript{66}:

- wires forming the strand
- multi-wire strands laid helically around a core
- the core, which is the centre and is sometimes called heart of a wire rope

![Figure 3.1: Components of a steel wire rope\textsuperscript{67}]

"\textit{Wire-rope cores are made of fibre, cotton, asbestos, polyvinyl plastic or wire}" depending on the loads and needs\textsuperscript{68}. Although these components are few in number, they can vary in both

\begin{itemize}
\item \textsuperscript{63} Bahke in Beisteiner, 1984, p. 1.2
\item \textsuperscript{64} Wire rope technical board, 1993, pp. 3
\item \textsuperscript{65} \url{http://www.inventionfactory.com/history/RHAwire/introwr/introwre.html} 2006/03/06
\item \textsuperscript{66} Wire rope technical board, 1993, p. 7
\item \textsuperscript{67} ibid
\item \textsuperscript{68} \url{http://www.inventionfactory.com/history/RHAwire/introwr/introwre.html} 2006/03/06
\end{itemize}
complexity and composition in order to meet the need of the specific application of the steel wire rope. Due to the fact that the core is the heart of the wire rope, the core has to support the compressive load imposed, otherwise the rope will lose its clearance between the strands and its service life will be shortened. The wire is made of several materials, with high carbon steel being the most common. The state of the art of the technology in the steel rope industry is compiled at the International Organisation for the Study of the Endurance of Ropes (OIPEEC)\textsuperscript{69,70}, European Federation of wire rope industries (EWIRS)\textsuperscript{71} and Organizzazione Internazionale Transporti a Fune (OITAF)\textsuperscript{72}.

### 3.1.3. Production process

The following paragraphs explain briefly the production process of steel wire ropes at present: Different types of machines for producing steel wire ropes or strands are arranged in a certain production sequence. The procedure of manufacturing the finished steel wire rope and the procedure of manufacturing the semi-finished product strand or the wire core are identical, but the size of the production machines may differ. The first steps are the production of the core and the production of the strands. If the core consists of steel, then the production process is similar to the production process of strands as described below. Otherwise natural or synthetic fibres are twisted to form the core or a plastic core is extruded\textsuperscript{73}. Strands are made from wires being pulled through a rotating machine from a breakable bobbin and wound together at the end as illustrated in the picture below.

\textsuperscript{69} http://www.oipeec.org 2006/02/16
\textsuperscript{70} Wire rope technical board, 1993, p. 8
\textsuperscript{71} http://www.eurocord.com/ 2006/02/25
\textsuperscript{72} http://www.oitaf.org/ 2006/02/25
\textsuperscript{73} http://www.inventionfactory.com/history/RHAwire/introwr/introwre.html 2006/03/06
Finally, the actual steel wire rope is manufactured. Strands of wire are pulled through a rotating machine from a breakable bobbin in a very similar fashion to that used when the strands are produced. Due to the fact that the strands are wound together around the core in the centre, the strands have to be longer than the core. More precisely, the length of the strands is approximately 2 to 5 % longer than the core. A wire rope normally has 3 to 18 outer-strands, depending on the requirements of the specific application. Due to the length and the number of the strands, a wire rope plant needs more capacity to produce strands than to produce cores. Normally the steel core is produced in a separate production process with a centre strand and the surrounding strands. The one or more layers of the closing process are manufactured in a separate step. It is of course possible to produce two layers of strands as in the case of Warrington, Seale, or Filler construction patterns, which is the so-called parallel closing as shown in figure below.

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74 [http://www.gustav-wolf.de/img/6.3.jpg](http://www.gustav-wolf.de/img/6.3.jpg) 2006/03/04
75 Wire rope technical board, pp. 9
Theory

Single. The most common example of the single layer wire strand is a single wire strand with six wires of the same size around it.

Seale. This construction has two layers of wires around a center with the same number of wires in each. All wires in each layer are the same size. The strand is designed so that the large outer wires rest in the valleys between the smaller inner wires, equal in number to the inner layer, and are laid in valleys of the outer strand. Example: 19-9-9.

Fille. This construction has two layers of wires around a center with the inner layer having half the number of wires as the outer layer. Small wires, equal in number to the inner layer, are laid in valleys of the outer strand. Example: 25 Filler -6-6-12.

Warrington. This construction has two layers with one more of the above constructions, it is referred to as a Warrington. Two diameters of wire alternating large and outer wires rest in the valleys, and the ones on the crown, of the inner strand. Example: 19-6(6+6).

Combined. When a strand is formed in a single operation more of the above constructions, it is referred to as a Combined. This example is a Seale construction in its first. The third layer utilizes Warrington and the outer layer is a Seale strand. It is as: 49 Seale Warrington -8-8(8+8-16).

Figure 3.3. Rope constructions

3.1.4. Applications of steel wire ropes

Steel ropes and wire strands are highly stressed mechanical parts, which are used to fulfill important tasks like carrying, conveying, lifting and clamping in different areas of engineering. Nowadays steel wire ropes are produced in different diameters for a wide range of applications such as for elevator installations, for the mechanical and the construction industry, for mining, shaft skinning, for the oilfield industry, cable ways, for the automotive and for the aviation industry. Due to the many applications, the tolerances in the production of steel ropes vary greatly. On the one hand, safety regulations have to be applied and on the other hand, the rope has to have the right property for the relevant application. In this paper, the emphasis is placed on the elevator industry in which steel wire ropes are widely used in buildings of various types, sizes and heights.

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76 http://www.thomasregister.com/olc/73539710/amrpg8b.htm 2006/03/08
77 Beisteiner, 1984, p. 2
3.2. Product delivery strategies

Before discussing the product delivery strategies the difference between pull and push will be highlighted. It is important to define both these strategies because these are the foundations for the product delivery strategies. The most common product delivery strategies illustrated in the following figure are explained briefly in this chapter. The pull point refers to the point in time in the manufacturing process where the product is made for a certain customer order. This point is later called decoupling point. This figure also shows the customer lead time or delivery time, which refers to time from the order entry to the delivery of the product.

![Four Basic Design Structures](image)

Figure 3.4: four basic design structures (adopted from Reeve 2005)
3.2.1. Pull versus Push systems

In order to explain the following concepts it is necessary to introduce the basic systems of pull and push. A push system is defined as a “system where the production and movement of inventory items is determined by a pre-existing schedule that authorizes a material issue or transfer, or a start of a production operation. The using department or location receives material when determining by the feeder location and not based on their own generation of a replenishment signal”\(^{78}\). The following figure illustrates the push system.

![Figure 3.5: A push system\(^{79}\)](http://www.bridgefieldgroup.com/glos7.htm 2006/02/20)

In contrast, a pull system describes “a system where the production or movement of inventory items is initiated as required by the using department or location, or to replace items removed from the authorization queue. Production and inventory moves are not done based on a predetermined schedule, but only when consumed or signalled by the point of usage”\(^{80}\). The push system was developed by Toyota to avoid the problem of overcapacity\(^{81}\). The pull system is pictured in the following illustration.

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\(^{78}\) http://www.bridgefieldgroup.com/glos7.htm 2006/02/20

\(^{79}\) Simchi-Levi, 2000, p. 118

\(^{80}\) http://www.bridgefieldgroup.com/glos7.htm 2006/02/20

\(^{81}\) Hines, 1997, p. 48
3.2.2. Make to stock

Make to stock (MTS): “A manufacturing method in which finished goods are produced and stocked prior to receipt of a customer order. It uses forecast based on past demand history to initiate production of end items when inventory has fallen below desired levels”\(^{83}\). The delivery lead times are short compared to the other strategies. But a lot of capital is tied up in the inventory. Consequently, the flexibility to adapt to changes in demand is quite low. Moreover, the customer can hardly influence the design.

3.2.3. Assemble to order

Assemble to order (ATO): “A manufacturing environment where the final product is assembled based on the receipt of a customer order. The assembly is normally performed using standard components, modules and customer orders to specify a custom combination of previously-defined standard options”\(^{84}\). ATO production enables a company to decrease its response time to its customers by staging inventory of components ahead of demand while postponing the final assembly until demand is realised\(^{85}\). This product delivery strategy is particularly valuable when component supply lead-times are long or the supply processes are capacitated. It is possible by applying ATO to reduce the costs by offering higher product variety. This can be done by a modular system constructed by using components, which al-

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\(^{82}\) Simchi-Levi, 2000, p. 119

\(^{83}\) [http://www.bridgefieldgroup.com/glos2.htm](http://www.bridgefieldgroup.com/glos2.htm) 2006/02/22

\(^{84}\) [http://www.bridgefieldgroup.com/glos2.htm](http://www.bridgefieldgroup.com/glos2.htm) 2006/02/22

\(^{85}\) Benjaafar, 2004, p. 2
allows an individualisation of final products\(^{86}\). For an ATO manufacturer, availability or quick access to common components or modules is absolute necessary\(^{87}\).

### 3.2.4. Make to order

Make to order (MTO): “A manufacturing method in which commonly-used raw materials and components may be stocked based on previous demand history, but further processing into higher-level items is not done until receipt of a customer order”\(^{88}\). In this case only the raw material and components are stocked, which reduces the inventory compared to the previous two strategies and increases flexibility when demand changes. MTO manufacturing decreases the risk of selling because each order has a customer, but calculation of the annual production program is difficult due to the long time horizon. Therefore the stocking of components and raw material depends on their replenishment lead-times. Even if the replenishment lead-time is enormous, the company has to ensure acceptable delivery times for the customers by using MTO\(^{89}\).

### 3.2.5. Engineer to order

Engineer to order (ETO): “The product is fabricated and assembled to order with unique parts and drawings”\(^{90}\). Here the customer is highly involved. The delivery lead time compared to the other methods is long since the designing of the product is included in the lead time\(^{91}\). This type of a product delivery strategy responds to a truly customised product that requires unique drawings and parts\(^{92}\).

### 3.2.6. Discussion of the product delivery strategies

This chapter emphasises the importance of choosing the right product delivery strategy. In the following a model of Wadhwa is presented\(^{93}\). The model is based on a customer demand. The

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\(^{86}\) Böge, 1997, p. 44  
\(^{87}\) Weil, 1999, p. 57  
\(^{88}\) [http://www.bridgefieldgroup.com/glos2.htm](http://www.bridgefieldgroup.com/glos2.htm) 2006/02/22  
\(^{89}\) Lechner, 2001, p. 373  
\(^{90}\) Reeve, 2005, p. 52  
\(^{91}\) Olhager, 2003, p. 320  
\(^{92}\) Reeve, 2005, p. 52  
\(^{93}\) Wadhwa, 2006, p. 310
target of a company is to satisfy this need. The first step consists in taking the company’s own capabilities into consideration. As shown in the figure below the company has to question themselves if the needed product has already been stocked. This can happen when a company has no interrelation between customer order and production release, which means they are using MTO as product delivery strategy. If the customer’s need is not accomplishable out of the inventory then perhaps it is possible to assemble a product out of the existing inventory as shown in the illustrated model below. If this behaviour is possible, the company is fulfilling an ATO product deliver strategy in order to satisfy the customer order. If it is not possible to apply the ATO strategy, the next step is to think about the existing design. The interesting question is if it is possible to satisfy the customer order with an existing design. If so, the product delivery strategy MTO is practicable. If it is not possible to use an existing design, the company has to modify the design. This product delivery strategy is called ETO. But if it is infeasible to adopt the design, then a new design should be created by using existing know-how or competence of the company. This product delivery strategy is named innovate to order. If the right competences are not available, this know-how has to be developed.
The figure above clearly shows the value chain whereby value is created. Each step in a value chain should add value. The value chain begins with designing new products by developing new competencies and ends by delivering the final product to the customer. But of course not the whole value chain has to be passed through by one company. They are able to buy know how or products from others and then add value to satisfy the needs of the customer. Hence, the value chain in a company can differ based on their product delivery strategy. Different manufacturing environments such as MTS, ATO, MTO and ETO all relate to different positions in the value chain, which can be described with the decoupling point (DCP) or order penetration point (OPP). The following figure summarises the most important differences between the product delivery strategies:

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94 Wadhwa, 2006, p. 310
95 Andrews, 1998, pp. 6
96 Kippenberger, 1997, p. 29
97 Ohlhager, 2003, p. 319


### 3.3. Decoupling point

After presenting the product delivery strategies the following chapter introduces the decoupling point concept. It is possible to define and change the location of the decoupling point by the product delivery strategies.

#### 3.3.1. Introduction

The OPP or DCP defines “the stage in the manufacturing value chain, where a particular product is linked to a specific customer order”\(^98\). The chosen product delivery strategy influences the decoupling point. The DCP “in the product delivery pipeline is where we store items as a deliberate but carefully crafted part of our supply strategy”\(^99\). The decoupling point is

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\(^{98}\) Ohlhager, 2003, p. 319

\(^{99}\) Towill, 2005, p. 36
the point where the push of the manufacturer meets the pull of the customer. This point divides activities which are forecast-driven from activities which are customer order-driven.\(^{100}\)

<table>
<thead>
<tr>
<th>Product delivery strategy</th>
<th>Design</th>
<th>Fabrication &amp; procurement</th>
<th>Final assembly</th>
<th>Shipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Make-to-stock</td>
<td></td>
<td></td>
<td></td>
<td>OPP</td>
</tr>
<tr>
<td>Assemble-to-order</td>
<td></td>
<td></td>
<td></td>
<td>OPP</td>
</tr>
<tr>
<td>Make-to-order</td>
<td></td>
<td></td>
<td></td>
<td>OPP</td>
</tr>
<tr>
<td>Engineer-to-order</td>
<td>OPP</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Figure 3.9: Different product delivery strategies relate to different DCP.\(^{101}\)**

Figure 3.9 illustrates a summary of the different product delivery strategies. The dotted lines in the figure above represents forecast driven activities, whereas the straight lines depict customer orientated or demand driven activities, longer straight lines indicate a longer delivery lead-time, which is defined as “the time from receipt of an order to the delivery of the product”.\(^{102}\)

### 3.3.2. Trade-off productivity versus flexibility

**Figure 3.10: Productivity flexibility trade-off (adopted from Rudberg 2004)**

The figure above illustrates the trade-off between productivity and flexibility. Here again the value chain describing the value-added material flow is used. “The further downstream in the value-adding material flow that the DCP is positioned, the higher the degree of emphasis on

\(^{100}\) Ohlhager, 2006, p. 21
\(^{101}\) Ohlhager, 2003, p. 320
\(^{102}\) Arnold, 1991/2001, p. 4
Theory

productivity in operations [...]"\(^{103}\). Therefore price and cost are normally the major competitive priority. "On the contrary, by positioning the DCP further upstream a company can achieve a higher degree of flexibility and the customers can gain a hearing for their specific requirements"\(^{104}\). All in all it means the further downstream the DCP is located, the more of the value-adding activities have to be carried out under speculation, and the further upstream the DCP is positioned, the more activities can be on order commitment like information exchange\(^{105}\). This shows that a company has to make a trade-off between customer requirements (flexibility) and the technological preconditions both product and processes. The ideal design is one in which a small number of components are used to configure a large variety of end products\(^{106}\).

3.3.3. Impact model

Ohlhager has developed the following model for analysing the position of the decoupling point\(^{107}\). The most important factors which define the position of the DCP can be divided into market, product and production characteristics.

3.3.3.1. Market related factors

Market related factors are delivery lead time requirement set by the market, the product delivery strategy, product volume and product range.

The delivery lead time requirement discusses the opportunity of how far back it is possible to locate the DCP in order to still fulfil the customer needs. In other words this depends on the willingness of the customer to wait for his ordered products.

The product delivery strategy enables a company either to make products to order or stock. Therefore forecasts or customer orders are important.

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\(^{103}\) Rudberg, 2004, p. 446  
^{104}\) Rudberg, 2004, p. 446  
^{105}\) Rudberg, 2004, p. 447  
^{106}\) Reeve, 2005, p. 53  
^{107}\) Ohlhager, 2003, pp. 332
The product range influences the product delivery strategy, because it is not possible to produce on stock by offering a wide range of products and still be competitive. The customer order-size and frequency of orders indicates the demand.

### 3.3.3.2. Product related factors

The product related factors are basically the customisation opportunities of a certain product. Here the discussion is about the easiness of customising a product. A short list of BOM (Bill of material) indicates products which are easier to customise. The BOM influences the list of operations of products. Reducing the length of the BOM means that fewer steps have to be taken by the company itself. A reduction of steps is possible when certain tasks are transferred to the supplier.

The raw material used also influences this discussion. That means the quality of the raw material defines the quality of the finished product. Therefore the company has to rely on the agreements with the supplier or the company has to inspect the quality of incoming material.

### 3.3.3.3. Production related factors

Finally the production related factors are the production lead time, bottlenecks, and flexibility of the production process.

“The production lead time is a major factor to consider with respect to the delivery lead time requirements set by the market”\(^{108}\). This relationship is the major constraint for the position of the decoupling point. It is necessary that a certain process offers high flexibility which means short set-up times at the machines. In other words, it means a reduction of waste.

### 3.3.3.4. Model

The market characteristics affect the product characteristics, whereby the product range and customisation opportunities interact with market expectations as illustrated in the figure below. This results in a delivery lead time which takes the product characteristics into consideration.

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\(^{108}\) Ohlhager, 2003, p. 322
The characteristics of production and product results in the production lead time. The delivery lead time and production lead time cause the major constraint for defining the position of the decoupling point.

3.3.4. Discussion

Dirk Pieter van Donk defined the following three reasons for the importance of the decoupling concept:\(^{110}\):

- The DCP separates the order-driven activities from the forecast-driven activities. This is not only important for the distinction of different types of activities, but also for the related information flows and the way the goods flow is planned and controlled.

- It is the main stock point from which deliveries to customers are made and the amount of stock should be sufficient to satisfy demand during a certain period.

- The upstream activities can be optimised in some way, as they are based on forecasts and are more or less independent from irregular demands in the market.

Postponing the decoupling point within the production process helps to increase the portion of standardised processes and therefore to reduce cost. From the perspective of the customer, delivery time is shortened, since the customer only observes the process time after the decoupling point. The concept of postponement supports this DCP concept. The idea of “postponement” is to move the decoupling point downstream so that certain tasks can be postponed or delayed when a demand occurs. “Postponing final manufacturing allows for the customisa-\(^{109}\) Ohlhager, 2003, p. 323
\(^{110}\) van Donk, 2001, p. 298
tion of products, while saving on inventory and other logistics costs”\textsuperscript{111}. One has to keep in mind that short delivery times can be achieved by moving the decoupling point towards the MTS position, where only standard products can be manufactured and almost no customisation is possible\textsuperscript{112}.

### 3.4. Postponement

Postponement is a combination of three generic postponement strategies introduced by Bowersox: form, time and place postponement\textsuperscript{113}. Form postponement refers to delaying the point of product differentiation by redesigning the value-adding process\textsuperscript{114}. Time postponement describes the delaying of the forward movement of goods until the company has received a customer order, which is a reconfiguration of the sequences\textsuperscript{115}. Finally place postponement refers to “the positioning of inventories upstream in centralized manufacturing or distribution operations to postpon the forward or downstream movement of goods”\textsuperscript{116}. Place postponement refers to geographical locations and is therefore not relevant for this thesis. When a demand occurs the company is able to satisfy the customer quickly by low delivery times and customised products\textsuperscript{117}. Postponed manufacturing strategies combine these three generic strategies:

“Final processing and manufacturing activities are postponed until customer orders have been received (time postponement) and are performed from central operations in the international supply chain (place postponement), to include customer and country-specific characteristics in the finished product (form postponement), frequently followed by direct delivery to retailers or customers”\textsuperscript{118}.

According to the definition of pull and push systems the integrated postponed manufacturing system is only solvable with a pull system in which the products are produced and assembled according the customer orders. Moreover the goods are stored downstream of the whole pro-

\textsuperscript{111} van Hoek, 1999, p. 18
\textsuperscript{112} van Donk, 2001, p. 299
\textsuperscript{113} van Hoek, 1997, p. 63
\textsuperscript{114} Enarsson, 2002, p. 21
\textsuperscript{115} Bowersox, 1996, p.56
\textsuperscript{116} van Hoek, 1997, p. 63
\textsuperscript{117} Wadhwa, 2006, p. 307
\textsuperscript{118} van Hoek, 1997, pp. 63

- 38 -
Production process. “Frequently the combination of three areas of postponement allows for customer service enhancements through customization and operating cost savings through lowered inventory carrying costs”\(^{119}\). This means that the use of postponement allows cost reduction along the manufacturing process, because the goal is to delay the point of product differentiation\(^{120}\).

\[\text{Figure 3.12: Postponement}\]

Figure 3.12 shows how a postponement strategy can be implemented. The situation before the postponement implementation was that for each different product family a different semi-finished product was necessary. After the implementation semi-finished products could be used interchangeably for different products families, because the point of product differentiation had been delayed.

Postponement strategy allows benefits for both volume mix and product mix flexibility\(^{122}\). This can be achieved by moving the product delivery strategy from a MTO to a more customer orientated one like ATO, which is already being implemented in the car manufacturing industry by the OEM (Original Equipment Manufacture). For this an ERP system can support the ATO product delivery strategy, because the so called product configuration functionality

\[^{119}\] van Hoek, 1997, p. 64
\[^{120}\] Wadhwa, 2006, p. 308
\[^{121}\] Reeve, 2005, p. 53
\[^{122}\] Wadhwa, 2006, p. 309
Theory

simplifies the order entry by asking for the needed customer options\textsuperscript{123}. Out of these entries the ERP system generates the BOM (bill of material) and the price calculations.

3.5. Measurements

In order to verify the changes in production, measurements are necessary to demonstrate whether an improvement has been achieved. This is necessary to evaluate the applied methods.

3.5.1. Main measurement metrics

Lutz has described two main measurement metrics in order to measure the logistical performance of the inventory process\textsuperscript{124}:

- Delivery delay: “The number of unavailable items each time there is a shortfall is multiplied by the length of time they are unavailable. This figure is then divided by the total demand for the item during the period under investigation”.

- Service level: The service level is defined by Lutz as “the number of orders (which may contain a varying number of articles) satisfactorily delivered to customers (OS) divided by the total number of customer orders (OT)”.

The measurement service level is to indicate the delivery performance at order level whereas the delivery delay indicates the delay of single items.

3.5.2. Evaluation of the inventory process

This concept developed by Wiendahl “allows the target oriented identification and control of those areas where improvements can be achieved within the related logistics processes”\textsuperscript{125}. This model consists of two parts, which are inventory throughput diagrams and inventory operating curves.

\textsuperscript{123} Weil, 1999, p. 57
\textsuperscript{124} Lutz, 2003, p. 218
\textsuperscript{125} Wiendahl et al. 1997 in Lutz, 2003, p. 219
3.5.2.1. Inventory throughput diagram

The inventory throughput diagram refers to a graphical way of illustrating the history of a single item over a certain timeframe. "An inventory throughput diagram depicts the performance of an article or a group of articles in the inventory in respect of the following key data"¹²⁶:

- Input
- Demand
- Output
- Inventory level

The following figure shows an example of such an inventory throughput diagram. The input and output quantities are plotted cumulatively as a function of time, with the starting point expressing the inventory level at the beginning of the investigated timeframe. The vertical distance between input and output level refers to the inventory level at one point in time.

Figure 3.13 Inventory throughput diagram¹²⁷

Moreover this figure shows the demand curve which is also a function of time. The demand can be generated by either customer or subsequent processes. Demand is defined as the date where an item is supposed to be withdrawn from inventory. Therefore demand is a planned output. This results in an easy comparison of planned or required and actual output. If demand occurs earlier than the output, the subsequent process or customer will not be satisfied

¹²⁶ Wiendahl et al., 1997 in Lutz, 2003, p. 219
¹²⁷ Lutz, 2003, p. 219
on time. On the other hand, if the required quantity has been successfully delivered on time, no lack in time will occur.

3.5.2.2. Inventory operating curves

Inventory operating curves answer the question of the amount of goods in stock necessary to satisfy the customer. Thus, these curves show the dependency between delivery capability and mean inventory level. Delivery capability is expressed by the two main measurement metrics of delivery delay and service level. Therefore one can distinguish among two inventory operating curves:

- Delivery delay operating curve
- Service level operating curve

a) Delivery delay operating curve

According to Wiendahl, the delivery delay operating curve has to be considered with respect to the input side, the output side and the planning quantity, which is the difference between the quantities of the planned dates and actual achieved dates, and the replenishment time. The following figure presents the general stock model for the delivery delay operating curves.

![Figure 3.14: General stock model](image)

The left part of the general stock model shows the development of the inventory over time. One can see the input and output quantities, which are decreasing or increasing the inventory level. This results in an ideal stock model with continuous output, illustrated on the right-hand side of the figure above. The main idea is that the ability to deliver is always maintained.
Therefore input, output, planning quantity and replenishment time have to be adjusted that no delivery shortage would occur. Also the availability of the safety stock can be changed.

The input side is influenced by:

- Delivery quantity
- Reliability of the delivery quantity
- Delivery date

One has to keep in mind that the input process can be either an external customer or an internal manufacturing process. The output side on the other hand is affected by:

- Required quantity
- Reliability of required quantity
- Requirement date

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128 Lutz, 2003, p. 221
Figure 3.15: delivery delay operating curve

One can see in the picture above that the mean inventory level is equal to the sum of overall safety stock and half the quantity of input lot size. No supply shortage occurs in case 1 of Figure 3.15 (left side), even if no safety stock is available as seen in case 2. By decreasing the mean inventory level not all items can be delivered on time as seen in case 3 in the figure above. This results in the right side of the figure above. According to Lutz, the relationship between the delivery delay and inventory level is not linear due to the usage of mean values for inventory level and delivery delay. Summing up this idea means that having a mean delivery delay of zero results in an infinite mean inventory level. In other words, it is not possible that every item is at all times available.

b) Service level operating curve

As previously described, the service level is “the proportion of customer orders which are delivered at the requested or agreed time to the total number of customer orders”\(^\text{130}\). Lutz has visualised the service level function:

\(^{129}\) Lutz, 2003, p. 222
\(^{130}\) Lutz, 2003, p. 223
In the figure above one can see that the service level remains stable after reaching $l_1$. This behaviour is due to the fact that the service level has reached its maximum. The idea of this relationship is that a company should define the target service level first and then it will be able to calculate the necessary mean inventory level.

### 3.5.3. Order cycle process

The order cycle process describes the procedures between the customer’s order placement and receipt of the product\(^{131}\). Here the communication with the customer and supplier is essential. The transfer of the right information at the right time allows to reduce the inventory levels. Information sharing via a common language is the basis upon which successful industries and supply chains are built. The rapid changes require concurrent changes in the common language of industry commerce. Today's economy and business climate depends on cross-border industry collaboration brought about in large measure through the increased use of IT tools\(^{132}\). A set of common document interfaces that would grant industry partners the ability to not only view data but also integrate the data with ERP or database systems is a compelling vision.

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\(^{131}\) Lambert, 1998, p. 46

\(^{132}\) Carroll; 2001; p.38
Christopher\textsuperscript{133} describes how the concept of Just in Time, or Quick Response, as it is called in the distribution of consumer goods, should be implemented, focussing especially on the pull principle as well as the substitution of inventories by information.

The overall idea of Just in Time is that “no activity should take place in a system until there is a need for it”\textsuperscript{134}. Usually statistical methods for inventory control are used to meet the customer requirements, which all share the weakness that these methods lead to lower or higher stock levels than necessary. Especially for dependent demands these methods lead to sub optimisation within the supply chain and foster the Forester Effect. The Japanese view is that inventory is waste and only hides the problems companies have. With the words of the Japanese Lake, the Kanban concept can be seen as a way to lower the water in the lake by progressively reducing the Kanban quantity which makes bottlenecks apparent. In the terms of EOQ, the Japanese approach is to shift the set-up cost curve to the left to create smaller optimal batch sizes. For the logistics sector the JIT concept means that all elements of the chain are synchronised, the requirements for replenishment and shipping are recognised early and there is a high level of planning discipline. Transportation of these previously mentioned small JIT batches can for example be organised on the milk round basis, where a third party service manages the pick-up of materials and delivers them to the customer direct.

Quick response (QR) is the implementation of the JIT principles presented above in the supply chain of consumer goods. “The basic idea behind quick response is that in order to reap the advantages of time-based competition it is necessary to develop systems that are responsive and fast”\textsuperscript{135}. The logic behind QR is to capture the demand as close to real time as possible. The development of information technology, especially electronic data interchange (EDI), bar coding and the use of electronic point of sale (EPOS) systems, has made QR possible. According to Christopher\textsuperscript{136} the QR concept, which has high fixed costs but low incremental costs for service improvement, represents a typical case of inventory substitution by information.

\textsuperscript{133} Christopher, 1998, pp. 177
\textsuperscript{134} Christopher, 1998, p. 179
\textsuperscript{135} Christopher, 1998, p. 192
\textsuperscript{136} Christopher, 1998, p. 193
3.5.4. Total productive maintenance

In 1971 total productive maintenance (TPM) was first defined by the Japan Institute of Plant Maintenance (JIPM). “TPM is a company wide strategy to increase the effectiveness of production environments, especially through methods for increasing the effectiveness of equipment”\textsuperscript{137}. OEE (overall equipment effectiveness) is the key metric for the TPM, with the three generic elements availability, performance and quality\textsuperscript{138}. The figure below illustrates that these measurements are necessary to define the OEE:

![OEE Diagram](image)

\textbf{Figure 3.17: OEE}\textsuperscript{139}

According to Pomorksi the three generic elements are defined as follows:

- Availability measures the effectiveness of maintaining tools in a condition capable of running product.
- Performance Efficiency measures how effectively equipment is utilised while for production.
- Rate of Quality measures the effectiveness of the manufacturing process in eliminating scrap, rework and yield loss.

\textsuperscript{137} http://www.oetoolkit.nl/community/OEEAlgemeen/what_is_oee.htm 2006/05/10
\textsuperscript{138} Pomorski, 1997, p. A-33
\textsuperscript{139} http://membres.lycos.fr/hconline/maintenance/trs_us.html 2006/05/10
Maintenance has traditionally been viewed as a separate entity outside the manufacturing process. As companies began to identify the role of maintenance in the production process, a shift in thinking occurred, including maintenance into the production system. “TPM emerged out of the need to integrate maintenance with manufacturing to improve productivity and asset availability.”

3.6. Conceptual Model

The aim of the conceptual model is to answer the research questions by combining the necessary theories in order to execute the analysis of the empirical data. The following figure presents the conceptual model of this master thesis:

Figure 3.18: Conceptual model

140 http://www.vorne.com/solutions/learning_center/tpm.htm 2006/05/10
The customer requirements define the product. Therefore this model starts with the customer. For different applications different ropes are needed. Due to the fact that this thesis focuses on elevator ropes, the input into the current situation is an elevator rope. The value stream analysis tries to identify the current situation and how the product is treated in the production. Special attention is paid to the semi-finished product. Therefore it is necessary to collect information about the product and its design. The ERP system TIBIS provides the information of the list of operations and bill of material, which include the design, production sequences, set-up times, production time. The product, production and market characteristic are gathered by explorative interviews with the employees of Drako listed in Figure 2.3.

In order to answer the main research question it is necessary to identify the product, production and market related factors. This identification and discussion process is the answer to the sub research question. The three kinds of characteristics influence the situation during production. Therefore the rationalised model has to take them into consideration. In order to be able to create a rationalised model in the production the presented theory is applied.

The target of the company is to satisfy the customer. Therefore the model implies customer satisfaction, with the two basic measurement metrics of delivery delay and customer service being applied as measurement for improvements. It is important that no reduction of the delivery ability should occur by the implanting of new proposals.
4. Empirical Data

This chapter presents the empirical data gathered by the interviews and the value stream analysis. In the beginning the company is introduced to the reader. This is followed by illustrating the production lay-out of Pfeifer Drako. The current situation of raw material, operating material and supplies is presented. Then the results of the value stream analysis are used to summarise the material flow, using the Drako 250T steel wire rope as an example. In the end a short overview of the current inventory situation is given.

4.1. Company presentation

The aim of this chapter is to introduce the chosen company Drako. Drako has been a member of the Pfeifer holding since 1994. The emphasis for the company description is therefore focused on Drako.

4.1.1. Holding

The Pfeifer Holding consists of three companies bundled together, two of which have subordinated companies. Drahtseilerei Gustav Kocks GmbH & Co (Drako), which is circled red in figure Figure 4.1, is the company investigated for this master thesis. In order to establish the legal form of GmbH & Co, the Pfeifer Kocks Verwaltungs GmbH was founded.
Figure 4.1: Pfeifer Holding

Pfeifer Drako has divided its business into five strategic divisions\textsuperscript{141}:

- Cable structures
- Attaching and lashing equipment
- Lifting equipment
- Building technology
- Ropes

Ropes are only manufactured by Drako in the whole holding. This results in Drako’s core competence for manufacturing steel ropes, because the focus is only on steel ropes especially elevator ropes.

\textsuperscript{141} http://www.pfeifer.de/44/o1-unt/index.html 2006/04/20
4.1.2. Drako

Drako was founded in 1810 to supply the customers of the merchant navy with simple hemp ropes. After the invention of steel wire ropes by Albert in 1834, Drako turned its business to steel wire ropes. In 1900 machines displaced most of the manual operation in the production process of Drako. The first elevator ropes were produced in 1928. The Kocks family, the owner of Drako sold the company to ARBED in 1968. In 1994, Pfeifer bought Drako, which made it the most important supplier for steel wire ropes in Germany. The following figures illustrate these important milestones for Drako:

- 1810 foundation of Drako
- 1834 production of steel ropes
- 1900 change to mass production
- 1928 first elevator rope
- 1968 Drako sold to ARBED
- 1994 Pfeifer bought Drako

Figure 4.2: milestones

Nowadays Drako has 166 employees, and a turnover in 2005 of 23 million Euros. It is to say, 7,450 tons of ropes were shipped to customers. 15,000km of steel ropes were produced in 2005. 72% of all products are delivered to customers outside Germany. The following figure illustrates these facts:
### 4.1.3. Product assortment

The following list provides the product assortment of Pfeifer Drako:\(^{142}\):

- Elevator technology: Elevator and compensation ropes
- Ropes for the mechanical and construction industry: full steel ropes for cranes and excavators, ropes for electric hoists, ropes for tower cranes and mobile cranes, clamshell ropes, pendant ropes, ropes for lifting stroke pulling machines
- Mining: drum hoist ropes, flat hoist ropes, flat balance ropes, round balance ropes (multi-layer flat strand ropes), haulage ropes for monorail conveyors, signal ropes, non-rotating ropes with inner electric conductors
- Shaft sinking: stage ropes, flat hoist ropes, clamshell ropes, guide ropes, direction survey ropes
- Oilfield industry: rotary drilling lines, swab and bailing lines, winch lines, percussion drilling lines, air winch lines, logging lines and wires, slings
- Ropes for Cable ways

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4.2. Production Layout

The production layout is necessary for conducting the empirical data collection. For this the value stream analysis is applied as explained in the Methodology chapter. The following Figure 4.4 illustrates the production layout of Drako. The layout is necessary to identify the material flow in this production facility. Hence five types of machines for producing steel wire ropes are used, which are:

- Bunching machines (blue area)
- Tubular machines (red area)
- Basket type machines (green area)
- Fibre core machines (purple area)
- Rewinding (orange area)

The difference between those machines for producing steel wire ropes, which are the first three of the list provided above, is based on technological methods. For instance there are different possibilities for arranging the bobbins or creating the closing point of the steel wire rope. For all three kinds of machines different sizes are available.
The fourth type of machines, the fibre core machines, produces fibre cores. The input of raw material and the output of the finished goods takes place at the entrance at the bottom of Figure 4.4. This is the only spot of the facility where a truck is able to unload or load goods. Finally the orange area shows where wire can be spooled on bobbins. The left-hand orange area is for small diameters and the right-hand area is for all other wires. Therefore the marginal diameter is at approximately 0,9mm. This means wires with a diameter below 0,9 have to be spooled in the left area, the rest goes through the right orange area.
4.3. **Raw material, operating material and supplies**

The raw material for producing steel wire rope is basically the wire. Drako 6,980 tons of wire converted in the last year. According to the rope construction illustrated in Figure 3.3 different diameters of the wires are necessary. In order to manufacture steel wire ropes with a fibre core, Drako needed an amount of 183 tons of fibre and yarn to produces these fibre cores. Some ropes need to be lubricated in order to fulfil technical requirements. Therefore 112 tons of grease was used.

<table>
<thead>
<tr>
<th>Raw-, operating material, supplies</th>
<th>Amount [t]</th>
<th>Costs [€]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wire</td>
<td>6.980</td>
<td>9,430,000</td>
</tr>
<tr>
<td>Fibre, yarn</td>
<td>183</td>
<td>450,000</td>
</tr>
<tr>
<td>grease</td>
<td>112</td>
<td>150,000</td>
</tr>
</tbody>
</table>

![Figure 4.5: Raw-, operating material, supplies](image)

But it is also necessary to ensure the availability of bobbins and reels. Without them it is not possible to activate the machines.

4.4. **Material flow**

This chapter addresses the material flow of semi-finished products. As explained in the introduction chapter and methodology chapter only elevator ropes are taken into consideration in this thesis to demonstrate the material flow based on the Drako 250T with 10mm diameter.
4.4.1. Flow chart of material flow

The figure above illustrates the material flow in the production facility. One can see that the strands which are produced in the red-marked area are delivered to the blue-marked area in the middle of the production hall. If a fibre core, which is produced near the entrance in the green area, is needed, the fibre core is also delivered to the blue-marked closing machines, where the core and the strands are assembled in order to receive a finished steel wire rope. The material flow is now pictured in the following flowchart of Drako’s production.
Figure 4.7: Material flow, all possibilities

Rewinding is necessary when the supplier does not deliver the wire on bobbins. Wire 1 and rewinding 1 are used for wires with small diameter and rewinding 2 and wire 2 are used for all other diameters, as already explained in the production layout. After the rewinding onto bobbins, these bobbins can be placed into the machine producing the strands. If a hemp core or fibre core is needed it is produced so that it is ready for the rope assembly. After finishing all the components, the rope is assembled and stored or it goes through the confectioning process where the desired length is cut for the customer.

The following part of this chapter demonstrates the material flow of the chosen example Drako 250T 10mm. The detailed lists of operations are published in the appendix in the end of this thesis. All time units are given in minutes and all lengths are measured in metres.

4.4.2. TL 129433 Drako 250T 10mm

The following figure shows the bill of material for rope with the part number TL 129433, which is a steel wire rope for elevators with a diameter of 10mm.
Figure 4.8: BOM TL 129433

The core strand 186692 and the outer strand 185304 are constructed in Warrington design, which is derived from the BOM. For both components a core wire with the numbers 182238 and 182238 is needed. The next layer is built up by six wires. Finally the third layer consists of 12 wires with two different diameters.

![Diagram showing the construction design of the steel wire rope with the part number 129433.](image)

Figure 4.9: Drako 250T 10mm

Figure 4.9 shows the whole construction design of the steel wire rope with the part number 129433. The colour code is defined in the bill of material, where the different part numbers are marked in different colours, which are used in the figure above. Now the Warrington construction can easily be seen in the figure. This rope consists of 10 raw material parts, which are the wires, and four semi-finished products, which are the IWRC and the three strands.
In order to appreciate the material flow it is necessary to see on which machines the different semi-finished products are manufactured. The list of operations for each semi-finished product provides information. The information concerning the production process rope number 129433 is gathered by list of operations and by analysing the material flow from the raw material to the finished product. Therefore also the information about the machine used in reality and the times needed for set-up and production are available for most of the components.

To collect this information it was necessary to identify a manufacturing order for the finished product. This order has the number WA 147643 and contains sub-orders for all the components of Drako 250T 10mm. The worker has to clock in and clock out every task. Therefore the information about the actual time is available in the system.

4.4.2.1. List of operations 188692 core strand of IWRC

As illustrated in the BOM one has to make sure that the parts of the IWRC TL 186654, which are the parts with the numbers 188692 and 185628, are manufactured first.

<table>
<thead>
<tr>
<th>task</th>
<th>work centre</th>
<th>cost centre</th>
<th>batch size: set-up time</th>
<th>80.960m E Zeit</th>
</tr>
</thead>
<tbody>
<tr>
<td>bobbin replacement</td>
<td>stranding F2</td>
<td>4102</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>set up</td>
<td>stranding F2</td>
<td>4102</td>
<td>905,3</td>
<td>0</td>
</tr>
<tr>
<td>reel replacement</td>
<td>stranding F2</td>
<td>4102</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>replacement of core</td>
<td>stranding F2</td>
<td>4102</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>change grease</td>
<td>stranding F2</td>
<td>4102</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>enclose wire</td>
<td>stranding F2</td>
<td>4102</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>run</td>
<td>stranding F2</td>
<td>4102</td>
<td>0</td>
<td>4223,4</td>
</tr>
</tbody>
</table>

Figure 4.10: List of operations TL 188692

The batch size is defined as 80.960 metres in the list of operations. It is not technically possible to produce the whole length at once because the reel onto which the finished core strand of the IWRC is spooled is not able to contain the whole batch size. Therefore the length has to be divided into sub batch sizes.

The first step is the replacement of the bobbins on which the wires as seen in the list of operations are spooled up. This is followed be the set-up of the machine. Then the reel where the finished core strand of the IWRC is spooled up after the production process is inserted into the machine F2. Then the core wire and the outer wires have to be pulled with the ends of a previous order through the whole machine, which is describes by the term “replacement
core”. For the part 186692 a lubrication process is mandatory. Therefore the necessary grease has to be prepared. Finally it is possible to produce the batch size of 80.960. The step “enclose wire” could not be found when conducting the value stream analysis. The responsible employee explained that this step in the list of operations is designed for a future implementation in the ERP system TIBS. Therefore this step is not used at the moment.

![List of operations for WA 146874]

The figure above shows the list of operations as the product is manufactured in reality.

### 4.4.2.2. List of operations TL 185628 outer strand of IWRC

The part with the number 185628 is the outer strand of the IWRC. This outer-strand consists of two different wires spooled on seven bobbins. The bill of material in Figure 4.8 indicates that eight outer strands are necessary for producing the IWRC. Therefore the length is at least eight times longer than the final steel wire rope.

![List of operations TL 185628](image)

The first step in producing the outer strand is to replace the bobbins with the wires as demonstrated in the figure above. Then the machine has to be adjusted. This is followed by the replacement of the reel the finished outer strand is spooled onto. The core wire and the outer wire of the strand have to be pulled through the machine F77. Then it is possible to produce the outer strand 185628.
Empirical Data

<table>
<thead>
<tr>
<th>WA: 150328</th>
<th>batch size: 173.600m</th>
</tr>
</thead>
<tbody>
<tr>
<td>task</td>
<td>work centre</td>
</tr>
<tr>
<td>bobbin replacement</td>
<td>stranding F71</td>
</tr>
<tr>
<td>set up</td>
<td>stranding F71</td>
</tr>
<tr>
<td>reel replacement</td>
<td>stranding F71</td>
</tr>
<tr>
<td>replacement core</td>
<td>stranding F71</td>
</tr>
<tr>
<td>run</td>
<td>stranding F71</td>
</tr>
</tbody>
</table>

Figure 4.13: List of operations for WA 150328

The figure above shows the list of operations as the product is manufactured in reality.

4.4.2.3. List of operations TL 186654 IWRC

After having finished both the production of the core strand and outer strand of the IWRC it is possible to assemble the IWRC. Figure 4.14 provides the information for the used work centre, cost centre, set-up time and production time used for a certain task. The work centre indicates where the particular task is executed.

<table>
<thead>
<tr>
<th>routeing TL 186654</th>
<th>work centre</th>
<th>cost centre</th>
<th>batch size: set-up time 20.000m E Zeit</th>
</tr>
</thead>
<tbody>
<tr>
<td>bobbin replacement</td>
<td>closing M3</td>
<td>4203</td>
<td>0</td>
</tr>
<tr>
<td>set up</td>
<td>closing M3</td>
<td>4203</td>
<td>140,6</td>
</tr>
<tr>
<td>reel replacement</td>
<td>closing M3</td>
<td>4203</td>
<td>0</td>
</tr>
<tr>
<td>replacement of core</td>
<td>closing M3</td>
<td>4203</td>
<td>0</td>
</tr>
<tr>
<td>run</td>
<td>closing M3</td>
<td>4203</td>
<td>0</td>
</tr>
</tbody>
</table>

Figure 4.14 List of operations TL 186654

The figure above shows that the assembling process for the IWRC should be clone on the machine M3. Therefore it is necessary to dismount the empty bobbins in the machine M3 and replace them with nine bobbins, whereby one bobbin contains the wound-up core strand 188692 and eight bobbins are spooled up with the strand 185628. Then one has to set-up the machine. This means that for example the lay length and lay direction are adjusted. This is followed by inserting a new reel into the machine M3. On this reel the semi-finished product IWRC 186654 is spooled. Finally the core of the rope has to be placed in the machine. It is important to know that the whole batch size does not fit on one reel. This means the batch size of 20,000m has to be divided into 4 parts. Due to this fact, also the bobbins have to be changed. The times declared in the list of operations above are in minutes, whereas they are the sum of all three sub batches. Now the core of Drako 250T is finished.
4.4.2.4. List of operations TL 185304 outer strand

For the final assembly, the outer strand for the finished rope is missing. Therefore the following figure illustrates the list of operations concerning this outer strand with the number 185304.

In the beginning the 19 bobbins with the wire illustrated in Figure 4.8 have to be put into the machine F2. Then this work centre has to be adjusted. This is followed by the replacement of the reel onto which the finished outer-strand is spooled. The wires are pulled through the machine with wires from a previous task. Therefore it is necessary to loosen the tie stock. The outer strand requires also a lubrication process. It is necessary to prepare the mandatory grease. After all these adjustments it is possible to manufacture the outer strand.

No information about the times is available because they have not been entered in the system yet for an unknown reason. But the machine F2 is used for the stranding and also the task sequence corresponds to the list of operations.
4.4.2.5. List of operations TL 129433

Finally the assembling process of the IWRC and the outer strand is designated in order to produce the Drako 250T 10mm. The following figure provides the list of operations.

<table>
<thead>
<tr>
<th>routeing TL 129433</th>
<th>work centre</th>
<th>cost centre</th>
<th>batch size: 20.000m</th>
<th>E Zeit</th>
</tr>
</thead>
<tbody>
<tr>
<td>rewinding</td>
<td>rewind through grease</td>
<td>4061</td>
<td>80</td>
<td>0</td>
</tr>
<tr>
<td>bobbin replacement</td>
<td>closing M1</td>
<td>4201</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>set up</td>
<td>closing M1</td>
<td>4201</td>
<td>239.8</td>
<td>0</td>
</tr>
<tr>
<td>reel replacement</td>
<td>closing M1</td>
<td>4201</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>replacement of core</td>
<td>closing M1</td>
<td>4201</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>run</td>
<td>closing M1</td>
<td>4201</td>
<td>0</td>
<td>610</td>
</tr>
<tr>
<td>set-up of test machine</td>
<td>testing</td>
<td>6602</td>
<td>97.5</td>
<td>0</td>
</tr>
<tr>
<td>test run</td>
<td>testing</td>
<td>6602</td>
<td>0</td>
<td>1166.7</td>
</tr>
</tbody>
</table>

Figure 4.17: List of operations TL 129433

In some cases lubrication in the machine is too complicated and soiling. In this case it is necessary to rewind the strands through grease. Then the bobbins with the IWRC and outer strands have to be fixed into the machine M1. This is followed by pulling the strands and IWRC through the whole machine by using strands of previous tasks. Then the batch size is produced in four equal sub batches due to technological restrictions. The final steel rope has to be tested according to quality regulations. Therefore the test machine has to be adjusted and finally the test run has to be made.

<table>
<thead>
<tr>
<th>WA 147643</th>
<th>work centre</th>
<th>batch size: 20.000m</th>
<th>20.000m</th>
</tr>
</thead>
<tbody>
<tr>
<td>rewriting</td>
<td>rewind through grease</td>
<td>4061</td>
<td>time</td>
</tr>
<tr>
<td>bobbin replacement</td>
<td>closing M1</td>
<td>4201</td>
<td>334.8</td>
</tr>
<tr>
<td>set up</td>
<td>closing M1</td>
<td>4201</td>
<td>334.8</td>
</tr>
<tr>
<td>reel replacement</td>
<td>closing M1</td>
<td>4201</td>
<td>778.8</td>
</tr>
<tr>
<td>replacement of core</td>
<td>closing M1</td>
<td>4201</td>
<td>250.2</td>
</tr>
<tr>
<td>run</td>
<td>closing M1</td>
<td>4201</td>
<td>1672</td>
</tr>
<tr>
<td>set-up of test machine</td>
<td>testing</td>
<td>6603</td>
<td>0</td>
</tr>
<tr>
<td>test run</td>
<td>testing</td>
<td>6603</td>
<td>1166.7</td>
</tr>
</tbody>
</table>

Figure 4.18: List of operations for WA 147643

The above figure shows the list of operations as the product is manufactured in reality.

4.5. Inventories in the production

This chapter illustrates where in the production inventory has been created. To collect the information of the inventories, a snapshot has been taken. This is to say, on the 24th of April
the current situation of the inventory was pictured. Out of this information Figure 4.19 has been created. The green-marked areas illustrate where raw material has been placed. Raw material can be both a wire delivery by the supplier and rewound wire, which already has the right batch size for the machines. The rewinding process happens in two areas in this facility. The left purple-marked area refers to the rewinding for fine wires. On the opposite in the right purple area only crass wires are rewound.

**Figure 4.19: Inventories**

Semi-finished products in the steel rope industry are for instance centre strand, outer strand, inner strand, fibre core and IWRC and they are stored on the orange areas. These products are stored mostly in front of the machines which are used next. Finished products are also stored in this facility even though there is a hall for finished products available as seen in the Appen-
dix. The areas where the finished steel wire ropes are stored are marked brown in Figure 4.19. The three red points indicate shelves. For the other areas, the goods are palletised on the floor.

Almost no finished products are on stock for the Drako 250T. Pfeifer Drako is not able to satisfy the demand of this product. Semi-finished products, which are used for assembling a finished Drako 250T, are stocked in the shelf for semi-finished products in Figure 4.19, in front of the machine which has produced the semi-finished product, and in front of the machine which needs this semi-finished product next.

### 4.6. Measurements

In the production no delivery delay and customer service is calculated. Even worse is the fact that no data is available for the inventory level of semi-finished products.
5. Analysis

In order to answer the research questions the empirical data and the theoretical framework are compared and discussed. The conceptual model created in the theoretical framework shows that market, product and production related factors influence the rationalised model. These factors are identified and discussed in order to answer the sub research question. This is followed by applying the decoupling point and postponement concept for developing this rationalised model, which consist of proposals, in order to answer the main research question. The result are discussed in the sub chapter Results.

5.1. Market related factors

As explained in the impact model presented in Figure 3.11 the market, product and production related factors are analysed, because they influence production lead-time and delivery lead-time. The correlation between those factors results into the creation and availability of inventory especially for semi-finished products.

The market related factor which influences the production system most is the chosen product delivery strategy. This shows if products, even semi-finished components, are produced on stock according to push strategies or if the products are produced for a customer, which is an internal one for semi-finished products, according to the pull strategy. The market factor Product range is not considered because the focus of the master thesis is only on one product of the whole assortment.

5.1.1. Product delivery strategy

First of all it is necessary to identify the product delivery strategy used at Pfeifer Drako for the Drako 250T steel wire ropes. Therefore the model presented in Figure 3.7 is applied. The Drako 250T is a standard product, because all the design and development tasks have already been made. All the lists of operations for the offered ropes have been created and implemented into the ERP system. The workforce has been trained to be able to produce this product. This results in three possible product delivery strategies:

- MTS
It has to be taken into consideration that this thesis is focusing on semi-finished product. As described in the empirical data, no finished products of the Drako 250T are stocked. Drako is not able to satisfy all the demand of this product. They are working to satisfy the demand but with the current production strategy it is not possible to fulfil this aim.

The situation for semi-finished products is different, because they are stocked due to the optimisation of set-up times. That means more metres of components are produced than needed for a certain batch-size of a finished steel wire rope. Generally, it is a multiple of the needed amount. The metres not used are stocked. Most of the products are not stocked in the shelf but they are in front of the machines. The order for producing semi-finished products is theoretically released by the need of a finished product. That means a pull strategy should be applied. The reason for having semi-finished products stocked are based on the priority of orders and personnel utilisation. As seen in Figure 5.6, the utilisation of the machines can not be a problem.

The finished product is produced without end-customer orders. That means if the inventory level is below a certain level, a production order is released. Due to the reason that there are no products on stock, the Drako 250T is scheduled frequently. Even if it looks like an MTO product delivery strategy, because no products are stocked, Pfeifer Drako uses an MTS strategy. This assumption is derived from the discussion above.

### 5.1.2. Delivery Lead time

As described earlier in this thesis, business at Pfeifer Drako is divided into daily business and projects. Due to the fact that the Drako 250T rope family is a standard product and has a steady demand all over the year, it is handled as daily business. Another fact which highlights this assumption is that customers do not order a whole reel of finished rope. According to the product manager for elevator ropes of Pfeifer Drako, delivery lead time is longer than the due to date given by the customer. The customer needs his product earlier than the company is able to produce it, if the company started the ordering of the raw material as soon as getting the customer order. Therefore the product manager would appreciate a safety stock for Drako.
250T. At the moment no stock for finished products is available. This results in long delivery times and the need to negotiate with the customer about accepting these delivery times.

### 5.1. Product Volume

As captured in the Empirical Data collection Drako is not able to satisfy the whole demand of the Drako 250T family. In other words, if Drako could produce more, the customer would buy more. Consequently, the target should be to increase the produced product volume to gain more profit.

### 5.2. Product Related Factors

As shown in the empirical data, the BOM consists of five assembling processes. In the beginning the strands for IWRC of the Drako 250T have to be produced, using steel wire. After producing the two components for the IWRC the IWRC is assembled. This is followed by the production of the outer strands of the steel wire rope. These strands are made by using wires. Then the IWRC and the outer strands are assembled. This results into the five steps of the BOM. In the following subchapter the BOM of the chosen steel wire ropes is analysed.

#### 5.2.1. Drako 250T 10mm

Generally speaking, batch-sizes mentioned in the list of operations are based on the amount which has been spooled on the bobbins, which means that one reel is not able to cover all the demand. Therefore more reels are necessary and production has to cut the produced length.

Real time data is available for the Drako 250T 10mm, so a comparison between the planned time according to the list of operations and the actual time is possible. One can see that the actual time is longer than the planned time. This might enhance the assumption that the list of operations should be updated. To ensure this assumption more production orders should be analysed. The heading piece refers to the amount of parts which are necessary to produce this rope. The length describes the necessary length of the component when the finished product 129433 is one metre. The length multiplied by the pieces and the length of the batch sizes results into the volume need. The volume plan is the batch size which is deposited in the ERP system. As seen in the empirical data collection Drako is producing this deposited batch size. Therefore the planned and actual batch sizes are equal. Thus a gap between the Volume need
and Volume plan results in an overproduction, because more meters for semi-finished products are produced than actually needed.

<table>
<thead>
<tr>
<th>piece</th>
<th>length</th>
<th>planned time</th>
<th>time actual</th>
<th>Volume plan</th>
<th>Volume need</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drako 250 T 10mm</td>
<td>1</td>
<td>1</td>
<td>2194,0</td>
<td>3035,8</td>
<td>20000</td>
</tr>
<tr>
<td>IWRC 5.01 1x19W + 8x7 U1770 zZ</td>
<td>1</td>
<td>1</td>
<td>657,3</td>
<td>1399,2</td>
<td>20000</td>
</tr>
<tr>
<td>core strand 2,71 1x19W 1770 Zu</td>
<td>1</td>
<td>1,012</td>
<td>5128,7</td>
<td>6267</td>
<td>80960</td>
</tr>
<tr>
<td>strand 1,31 1x7 1770 Zu</td>
<td>8</td>
<td>1,085</td>
<td>4434,6</td>
<td>10035</td>
<td>173600</td>
</tr>
<tr>
<td>strand 2,71 1x19W 1570/1770 U s</td>
<td>8</td>
<td>1,08</td>
<td>9527,2</td>
<td>172800</td>
<td>172800</td>
</tr>
</tbody>
</table>

Figure 5.1: Analysis Drako 250T 10mm

In the above figure the volume need is almost equal to the planned volume. Only the produced batch size for the core of the IWRC is higher than the needed amount. This phenomenon has also occurred for the 8mm rope. Results of the 8mm rope are published in the Appendix.

Drako saves set-up times by producing more than the needed amount. The reel which pulls the semi-finished product is only able to take 20,000m. That means that production has to stop in order to cut the rope, change the bobbin and then continue. In other words it is not possible to produce the whole batch size at once. This situation optimizes the set-up times, because for the core strand 19 reels of wire have to be changed. Changing one reel takes about 10 minutes, presumed that the reel has already been delivered to the machine. For all 19 reels 190 minutes are necessary. If the amount of wire for one batch-size is spooled on the reel, this set-up occurs four times as compared to once for the 80960m. Production saves about 10 hours of set-up time (190min multiplied with 3) with this situation.

5.2.2. Raw material

The used material is largely defined by law because the rope for elevators has to fulfil certain criteria e.g. for tensile strength and flexing cycles. Therefore Pfeifer Drako has to purchase the needed raw material from suppliers which are able to deliver the material with the specified requirements.
5.3. **Production related factors**

The production related factors are covered by the analysis of the material flow and a discussion about the utilisation of machines, which can be used for producing steel wire ropes for elevators. That means only the relevant machines of Drako are investigated.

### 5.3.1. Material flow

The following figure indicates which machine was scheduled for producing the Drako 250T 10mm steel wire rope and which machine was actually for producing this product. The machine F2 was planned for producing the core strand of the IWRC and the outer strand of the steel wire rope, because the design of both strands is the same. But in reality M7 was chosen for producing the core strand of the IWRC.

<table>
<thead>
<tr>
<th>BOM</th>
<th>planned machine</th>
<th>used machine</th>
</tr>
</thead>
<tbody>
<tr>
<td>129433 Drako 250 T 10mm</td>
<td>closing M1</td>
<td>closing M1</td>
</tr>
<tr>
<td>186654 IWRC 5,01 1x19W + 8x7 U1770 zZ</td>
<td>closing M3</td>
<td>closing M3</td>
</tr>
<tr>
<td>188692 core strand 2,71 1x19W 1770 Zu</td>
<td>stranding F2</td>
<td>stranding M7</td>
</tr>
<tr>
<td>185628 strand 1,31 1x7 1770 Zu</td>
<td>stranding F77</td>
<td>stranding F71</td>
</tr>
<tr>
<td>185304 strand 2,71 1x19W 1570/1770 U s</td>
<td>stranding F2</td>
<td>stranding F2</td>
</tr>
</tbody>
</table>

**Figure 5.2: Planned vs. used machines**

Figure 5.3 illustrates the current situation of the material flow for producing the Drako 250T 10mm wire rope. The green-labelled machines and arrows indicate the list of operations of this rope. The red-labelled machines and arrows refer to the current procedure. This results into a gap. Different machines have different costs according to the machine hourly rate. In this case the M7 is more expensive than the F2. Hence production cost increases. But on the other hand, production lead-time is reduced because the task can be performed in parallel. In this case market pressure was too high, so that the production had to change the list of operations.
Figure 5.3: Material flow Drako 250T 10m
One can see that no fibre cores are needed for the Drako 250T 10mm. Therefore no arrow is linked with the green marked area. The following picture shows the result of the value stream analysis for the material flow of the Drako 250T:

**Figure 5.4: Analysis production layout**

The raw material supplier delivers the wire spooled on bobbins or without bobbins. In case the wire is not spooled, Drako has to rewind this wire on bobbins. Then the bobbins are stocked in the raw material inventory or in front of the machine. The next step is the strand production of the Drako 250T. As seen in the list of operations for the Drako 250T 10mm wire rope, only two different machines are scheduled for producing three different types of strands. In reality, three different types of machines are used.

For some reason the semi-finished product is stored in front of the machine and not on shelves, due to changes in the production schedule. Therefore a certain job has to be delayed so that another job can be performed. This results into the creation of inventory levels of semi-finished products, which is not illustrated in the flow chart due to the reason that this inventory is in front of all the used machines. As seen in the empirical data the set-up time is very long. This circumstance is illustrated by the following figure. But also the inbound logistics is really complex because the fork lift has less space as seen in Figure 4.19.
Figure 5.5: Set-up time Drako 250T 10mm

Figure 5.5 shows the set-up time compared to the production time for the Drako 250T 10mm. Set-up time is between 7% and 21% of the total time, which is the sum of set-up time and production time. The total set-up time amounts to 15.9% of the total time, which is approximately 3.480 minutes. This demonstrates that the set-up takes much time, which Drako should try to reduce.

After having produced all the necessary strands, the IWRC and rope is ready for the assembling process. This is followed by the quality check of the finished Drako 250T. Therefore the reel is spooled onto another reel as contactless measuring instruments are testing the steel rope.

5.3.2. Utilisation

The following figure shows the utilisation of the machines that can produce steel wire ropes for elevators. The machines can be found in the layout published in the Appendix according to their numbers.
<table>
<thead>
<tr>
<th>cost centre</th>
<th>number</th>
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![Figure 5.6: Utilisation](image)

The list above has been provided by Mr. Niederholz, who is the head of the infrastructure department. The used hours are the hours which a machine has been used for production. No set-up times are included. Max. hours indicates the maximum hours which a machine could have been used. This is calculated with the length of a shift multiplied by the amount of shifts during the period from January to Mai. The utilisation is calculated by dividing the used hours...
through the maximum hours. The machine hourly rate is about 130€ per hour for the stranding machines and for the closing machines around 150€ per hour.

The result is surprising because only the bunching machines, which are used as stranding machines, have an utilisation of more than 60%. The rest of the machines have a quite low degree of utilisation. On the other hand this behaviour shows the flexibility in the production layout. Because as seen in the example of Drako 250T 10mm rope, the machines which are indicated in the list of operations are not used in reality. Also interviews with the production manager have shown that there is not only one possible machine for producing a certain product. Moreover most of the machines are interchangeable. It is also possible to use a closing machine as a stranding machine.

One can see in the production facility that one worker is responsible for several machines. But not all available machines are used every time. This results in high know-how of the workforce because they have to be able to handle different machines and equipment. Due to the fact that no apprenticeship is available for making ropes, all the workers have to be trained by the company. According to the production manager it takes about two to four years for a person to be able to work on a closing machine without any help. Therefore the human resource planning is quite important.

Summing up these facts, set-up time for elevator ropes is between 10 to 20% of the overall production time. Taking the utilisation of the machines into consideration, none of the machines are operating at maximum level. Consequently there is enough space for including decoupling point and postponement strategies into the production.

5.3.3. Waste identification

The discussion in the analysing chapter highlights the following potential for improvements in order to reduce the inventory level for semi-finished products:

- Reduce the list of operations, BOM
- Set-up times
- Process stability
To reduce the complexity in production, the length of the BOM should be reduced, because the BOM influences the list of operations. At the beginning of the production process the wire has to be spooled on bobbins. Some suppliers already deliver the wire on the required bobbins. Rewinding wire adds no value to the product. Therefore this process is waste. The supplier should be contacted to find out if it is possible to deliver the wires on bobbins.

As seen in the analysis, set-up times are around 15% of the total production time. This is due to the fact that almost no high-tech equipment is used. All set-up tasks have to be done manually by the workers. Therefore a high amount of experience is necessary. But nowadays equipment is available as seen at the WIRE and TUBE 2006\textsuperscript{143} at Düsseldorf. The annual fair for wire and wire related technology presented equipment which could be implemented in the existing machines of Drako. This would reduce set-up time and increase quality.

At the moment Drako is testing the quality after the production process, which is quite bad because almost no changes can be made in the finished product. Therefore quality control should be focusing on the quality of processes and of the product during production. DI. Andreas Rebhahn, who conducted the PIUS check for Pfeifer Drako, also recommended in his report that Drako should implement a process control system for the production process to allow a quality control system during the process\textsuperscript{144}. This results in a reduction of defective goods, which in turn results in a reduction of inventory levels because less safety stock is required. By implanting this system it is possible to skip the quality control at the end of the process.

\textsuperscript{143} [http://www.messe-duesseldorf.de/wire/de/2006/05/10](http://www.messe-duesseldorf.de/wire/de/2006/05/10)
\textsuperscript{144} Rebhahn, 2006, pp. 13
Figure 5.7: Waste in the production

The figure shows the waste in the production layout of Pfeifer Drako as a result of the discussion above.

5.4. Measurements

As seen in the empirical data it was not possible to find measurements according to theory. Lutz stated in his article that it is possible for every company to calculate the input and output of inventory[145]. This statement is correct but it is a question of time and of the right equipment. That means the ERP system needs the function to prove the quantity of a certain product even if the products are semi-finished products. TIBIS has no function at the moment to calculate the actual inventory level of semi-finished products.

Due to the reason that Drako has many machines which are interchangeable the same product is produced at the same time one different machines. This makes it impossible to find out the in- and output into the stock of semi-finished products. But it is exactly the input and output which is the important metric for calculating the delivery delay and service level.

The discussion with the product manager for steel wire ropes showed an interesting circumstance. The target service level which is defined in the quality management book for the
whole Pfeifer Holding should be more than 90%. No accurate calculations concerning the service level are available but Mr. Sieber guessed that the service level is between 50% and 60% for the elevator ropes.

5.5. **SWOT analysis**

After having analysed the production, the next step in the analysis is to gather information concerning the company’s resources and capabilities to the competitive environment. The company can get this information by doing a SWOT analysis. By applying a SWOT analysis the company collects information regarding internal and external factors, which have or might have an impact on the company’s performance\(^\text{146}\).

SWOT is an abbreviation for strengths, weaknesses, opportunities, and threats. Accordingly, a SWOT analysis refers to “the analysis of an organisation’s internal and external environment with the aim of identifying internal strengths in order to take advantage of its external opportunities and avoid external (and possible internal) threats, while addressing its weaknesses”\(^\text{147}\). Therefore, this kind of analysis is highly relevant for corporate strategies, as it focuses on major issues impacting development and growth of a company. Furthermore, it identifies those internal and external factors which will influence the company’s strategy and success with maximum likelihood\(^\text{148}\). The focus is on the internal factors which influence production. The SWOT analysis is used to translate the quantitative data into qualitative data as stated in the Methodology Chapter. Therefore only production relevant internal and external factors are considered, which have been developed throughout the discussion in this chapter. The following figure shows the strengths, weaknesses, opportunities and threats of the production system used at Pfeifer Drako.

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\(^{145}\) Lutz, 2003, pp. 220  
\(^{146}\) Pickton, 1998, p. 103  
\(^{147}\) Panagiotou, 2003, pp. 8-10  
\(^{148}\) Pickton, 1998, p. 102
5.5.1. **Strength**

Drako’s production lay-out is very flexible because they have a lot of machines. Most of the machines, especially the tubular and basket type machines can be used as closing machines or stranding machines. The variety of machines requires skilled employees so that Drako is able to produce high-quality wire ropes. It takes between two and four years for a worker to be able to operate a closing machine himself. At the beginning he learns the rewinding of bobbins and helps other colleagues. It needs a lot of experience to adjust the brakes so that during the whole production process the tension of the strands or wires is equal.

Pfeifer Drako has developed a core competence for elevator ropes. They have developed the design of such ropes and are able to manufacture different diameters with the required tensile strength. Drako is able to produce fibre cores itself. This is necessary because the core of a rope is important for the character of the rope. Moreover Drako has the possibility for extrusions, in which the core of the rope is extruded to allow higher durability.
5.5.2. Weaknesses

Pfeifer Drako owns a lot of different machines. Over the years a continuous enlargement of machines has taken place. The durability of such machines is between 20 and 40 years. This means most of the machines are older than 15 years. This circumstance results in partly worn out equipment and in the current production lay-out, which is not optimised according to inbound logistics.

The production plan is located in a settlement area of Mülheim an der Ruhr. Therefore Drako has to observe government restrictions, which makes it hard to change the limitations for the shift operations. Furthermore, there is almost no space for enlargement activities like new buildings because Drako is sandwiched between a river and houses.

The fact that Drako needs high quality wires as raw material, for which there are not many suppliers, leads to a raw material bottleneck. Therefore Drako has to deal with long purchasing lead times.

Drako was bought by Pfeifer in 1994. All Pfeifer-owned companies have to use the same ERP system, TIBIS. Basically TIBIS was developed for trading companies. Therefore the production applications have to be made by the company itself. Therefore it is complicate for TIBIS to monitor the performance. Drako has not yet implemented queries for inventory level of semi-finished products. So it is not possible to conduct the input and output for the semi-finished products into the inventory, which is extremely important, as shown in theory.

5.5.3. Opportunity

Drako has the possibility to increase productivity. This master thesis is intended to add an input. The increase of productivity is possibly by the reduction of inventory level, especially of semi-finished products. This enhances an optimisation of the material flow, BOM and the list of operations as explained in Impact model in 3.3.3. Drako could use the whole potential of this flexible production system. As seen in the utilisation discussion, spare capacity is still available.

If Drako is able to fulfil the customer requirements concerning delivery lead time and quality, customer satisfaction will increase as demonstrated in the conceptual model at the end of the Theory Chapter. It will also be possible to acquire new customers.
5.5.4. Threats

If Drako is not able to increase the delivery reliability of below 60%, customers might quit business relationship with Drako. There are other competitors, which are able to fulfil the same task then Drako.

The process of recruiting new employees is not easy even if unemployment is very high in Germany. As explained earlier, no apprenticeship for making wire ropes is offered in the whole EU. Therefore Drako has to educate the workforce itself, which takes between two and four years.

5.5.5. Integration of SW with TO

After identifying the strengths/weaknesses and opportunities/threats, they are put together in a portfolio to derive strategies to use the strengths effectively and to develop the weaknesses. It is crucial for a company to know how to employ their strengths to gain a bigger competitive advantage compared to their competitors and to determine possibilities of reducing the weaknesses. The following figure shows the result of the SWOT analysis published in the previous chapter.
Figure 5.9: Result of SWOT analysis

5.5.5.1. Opportunities-Strengths

The strengths of Drako should be used to activate the identified opportunities. The machines for producing steel wire ropes are under-utilised as seen in the utilisation analysis in Figure 5.6. But this circumstance allows to focus on the core competence of Pfeifer Drako. Steel wire ropes for elevators is the business where Drako creates the most turnover, as seen in Fehler! Verweisquelle konnte nicht gefunden werden. The production is able to produce high quality elevator ropes, because the workforce has already gathered the experience and know-how to ensure the required quality standards of the customers. This is supported by offering extrusions technology, compact technology and fibre cores. Therefore Postponement strategies have to be applied, which allows doing certain tasks at the same time and the usage of components or modules in order to reduce inventory levels by delaying the point of differentia-
Analysis

tion. Therefore it might be necessary to change the product delivery strategy. By implementing these proposals, the customer satisfaction will be increased because the delivery lead time could be decreased.

5.5.5.2. Opportunities-Weaknesses

More productivity creates more cash flow, because more products can be sold. As seen in the market related analysis, Drako is not able to satisfy the entire demand. The potential for selling more products is available, which is necessary to increase the cash flow. The cash flow is necessary for investments into the production lay out, maintenance and new equipment. Due to the fact that the production lay-out is not optimised, the material flow of all products has to be analysed. Buying a new machine and placing it into a free space, as it has happened in Drako’s history, is not the best way for optimising the inbound logistics. The layout is at the moment not satisfactory because the inbound logistics needs too much time. Therefore the inventory level has to puffer this time. On the other hand, changing the order of machines needs large investments because most of them need a foundation. After moving such an old machine, quality problems can occur.

5.5.5.3. Threats-Strengths

Increasing productivity requires new employees in the production, so that most of the machines are able to operate at the same time, which is important for postponement and decoupling strategies. Know-how has to be transferred from the existing workforce to new employees, who have to learn to produce steel wire ropes from scratch. The focus on the core competence should avoid the risk of losing customers. Therefore it is also important to enlarge productivity, which allows investments and producing high quality steel wire ropes.

5.5.5.4. Threats-Weaknesses

The worst thing which could happen is for Pfeifer Drako to lose customers. Long delivery lead-times have been caused by a wrong production system and machine break downs are a reason for customers to quit business with Pfeifer Drako. Therefore the focus on the core competence is absolutely important to maintain the relationship with existing customers and acquire new customers. At the moment more customer orders are available than Drako is able
to produce. Also the reduction of waste is especially necessary to reduce the lead times. Qualified employees are important in the future.

5.6. Result

This chapter presents the result by presenting the rationalised model. The rationalised model consists of proposals which should be implemented in order to reduce the inventory levels of semi-finished products. Moreover, this reduction of inventory level will increase the flexibility and also the utilisation of the machines. The increased utilisation will lead to lowering of the machine hourly rate, which influences production costs. This is the final part of the value stream analysis which suggests proposals to develop the current situation. These proposals are the answer to the main research question.

5.6.1. Postponement

The list of operations for the 10mm Drako 250T instructs the production to use the same machine F2 twice. This circumstance has already been explained in Figure 5.2. According to theory, this leads to improvable potential, because if possible the task should be parallel, which reduces the overall production lead-time. Due to the fact that Drako has many machines which are able to execute the same task and that all machines have low utilisation as seen in Figure 5.6, it is also practically possible to split the task onto different machines. Of course this also requires an educated workforce. Drako already owns these machines but they are not being used. Consequently, an investment into the human capital could easily increase the production volume. This effect is of course time delayed because the education of new employees in the production takes about two to four years. It has to be kept in mind that there is no apprenticeship available.

The point of differentiation is currently at the first manufacturing process. The final product is defined where the strands are produced, because the used wire diameters are different for the whole product assortment. The target is now to delay this point of differentiation.

5.6.1.1. Time postponement

Time postponement, as explained in theory, describes the reconfiguration of the production sequences. The following picture illustrates this theory based on the Drako 250T 10mm rope.
The different processes are aligned so that production lead-time is minimised. In the beginning the outer-strand has to be produced because it needs the longest time. The production of the IWRC could be delayed.

![Diagram](image)

**Figure 5.10: Process sequence**

To arrange the production sequence illustrated above, at least three machines are necessary. Reducing the batch size should also taken into consideration. This reduces production times. Generally a customer needs between 70m and 200m of an elevator rope. But as seen in the empirical data collection, the batch size is between 16,000m and 20,000m. In the list of operations lager batch sizes are also published, but they are not used. Therefore set-up workshops have to be established to reduce set-up time. In order to be able to use the advantage of time postponement, Drako has to check all the existing lists of operations.

### 5.6.1.2. Form postponement

Form postponement refers to the redesigning of the value-adding process. As explained previously, the point of differentiation is set very early in the value-adding process. This is due to the fact that it is not possible to use strands produced for other ropes than the designated one. Therefore the R&D department is forced to verify the whole product assortment if it is technologically possible to use the same strands for other products.

As seen in Figure 3.7 the steel rope industry can benefit by moving from MTS to ATO and gain more flexibility. As Wadhwa stated in his article, there are both product mix flexibility
and volume mix flexibility advantages. This master thesis has also identified these advantages. It is possible to increase flexibility and productivity with the available machinery. This should be achieved by postponing the point of product definition and splitting up the tasks.

### 5.6.2. Decoupling strategy

The decoupling strategy is influenced by market-related factors, production-related factors and product-related factors as demonstrated in impact model in Figure 3.11. The delivery lead time is defined by the market characteristics and the product characteristics. In the first part of the analysis, these factors have been identified and analysed.

Due to the fact that Drako was previously able to deliver in one to two weeks after entering the order, the customer also expects this delivery time nowadays. The competition among the steel rope manufacturers is also increasing. There are other companies who are able to deliver the required quality in the required time frame, and Drako has to offer a delivery time for their elevator product assortment of one to two weeks to get an order from a customer. The decoupling point is situated at the end of the production process. The confectioning fulfils the customer order. The required length is cut from the reel, additional preparations are made and then the rope is sent to the customer. It is not possible to change this point for the finished product dramatically because otherwise the set-up times might get too long. Moreover it is only possible to try to reduce production time, set-up times and waste before the decoupling point by adapting the existing production strategy. ATO as product delivery strategy is possible if the technical restrictions for using same strands for different ropes are solved.

Production lead time is defined by the product and production characteristics. The product layout of Pfeifer Drako is very complex. This is a result of buying new machines without planning the material flow in the facility. Now it is difficult to transport all the material from one end of the hall to the other. One has to bear in mind that this transport is waste because it needs time.

As explained in the analysis Pfeifer Drako is using an MTS strategy for producing steel ropes. After implementing the form and time postponement, Drako will be able to change to product delivery strategy. Therefore the target for the semi-finished products should be the ATO strategy because this allows reduction of inventory levels. If the need for a finished product is
scheduled, only the batch-size optimised amount of components should be produced. That means the finished product pulls the demand of the components. MTO is not a sufficient strategy due to the set-up times it is not possible to produce the components for one customer order.

5.6.3. Measurements

An important step towards reducing the inventory level is for Drako to be able to measure the logistical performance of the inventory process. In order to achieve this, the ERP system has to be adapted. The queries have to be implemented and adjusted by experts. Investments are necessary, because this implantation process has to be bought from the Pfeifer Holding. As presented in the theory it is useful to analyze the input and output of an inventory. This allows an evaluation of the inventory performance, which is necessary for setting up new targets.

Generally speaking, increasing utilisation means that also the machine hourly rate will be influenced. More utilisation, or in other words, more produced tonnes leads to a lowering of the machine hourly rate. The postponement strategy tries to increase flexibility due to shorter production lead times. In this way, it is possible to increase productivity, which increases the utilisation of the machines. One has to keep in mind that the machine hourly rate differs among the machines and of course it is better to use the machine with the lowest rates.

TPM is used to drive waste out of the manufacturing process by reducing or eliminating production time lost to machine failures. The goal of any TPM program is to ensure that machinery and equipment is always available to manufacture products for the end customer. By minimizing rework, slow running equipment and downtime, maximum value is added at the minimum cost.

A successful implementation of TPM requires group work. This means the entire organisation works together to maintain and improve Drako’s machinery. At the beginning of the implementation process, Drako should form teams that are empowered to improve the process. It is important to know that flattening the organisational structure enables teams to address issues as soon as they occur.
6. Conclusion

At the beginning of this chapter a short resume summarizes the results of the analysis chapter. Then the implementation for the management of Drako is discussed. Also the implementation for theory is critically highlighted. Furthermore the generalisation is discussed. Finally reflection and criticism concerning scientific work and as well some suggestions for further research are given.

6.1. Resume

After the identification of the product, production and market related factors the research question is answered in the results of the analysis chapter. Drako is able to reduce the inventory level by implementing the following proposals. It is important to know that no reduction of the delivery ability will occur by the implementation these proposals.

- Implementation of performance metrics for the inventory control
- Optimize BOM and list of operations
- Reduction of non-value adding activities like quality check at the end of the process and rewinding
- Reduction of set-up times by workshops, Implementation of TPM
- Redesigning of the product so that the components are interchangeable

6.2. Implication for management

As seen in the results of this thesis, the management is forced to implement a measurement system, which enables the company to evaluate the logistic performance of the inventory process. At the beginning an open discussion has to be performed, whereas in the end a responsible person is announced. Therefore the management has to ensure that this person also gets the competence for make decisions. This is followed by the definitions of the performance measurement. As presented in theory, the delivery delay and the service level should be established. This implies that accurate data about the inventory level of all raw materials, semi-finished products and finished products have to be available.
Conclusion

At the moment the ERP system is charged with the input of the actual times in the production. The database of the ERP system knows when a product or semi-finished product has been successfully produced and is ready for stocking. Also, information about the time when the semi-finished product is used again is available. That means all necessary information concerning input and output are already stored in the database of the ERP system. Therefore the management has to ensure that the TIBIS is adapted by professionals. Perhaps TIBIS already has the function for the inventory process but it is not adjusted at the moment.

This implementation leads to further advantages because now it is possible to verify the plan times in the list of operations. As seen in the examples presented, the actual time in the production is longer than the times implanted in the list of operations. Time studies according to REFA might be conducted to ensure the quality of the list of operations. If Drako is not able to analyse the existing list of operations implemented in the ERP system, Drako should not hesitate to buy external know how in order to implement reality in the ERP system.

It is important to mention that in most ERP systems, best practice technologies are implanted. This means, non-crucial processes where no unique know how is applied should be adapted according to best practice. This reduces the software costs extremely because no changes are necessary. On the other hand the unique processes where the know-how is hidden should be done individually, because with these processes the company plans to create profit. Drako’s business is producing steel wire ropes and not stocking of goods. Therefore Drako should use existing procedures and should adapt the inventory process if necessary, so that it fits into the requirements of the ERP system.

Conviction is the key for success. All employees who are working with the inventory process have to be convinced that it is necessary to measure performance before implanting further steps. After the implanting phase of measurements for the logistics performance, Drako will be able to establish postponement and decoupling strategies for reducing the inventory levels of semi-finished products. Lower inventory levels results in less tied up capital, which increases the financial flexibility of Pfeifer Drako.
6.3. Implication for theory

As seen in the analysis part time and form postponement are adaptable in the steel wire rope industry especially at Drako. The reason is that the utilisation of the machinery is quite low. This situation enables the company to split certain tasks. It would be even harder if fewer machines were available or the utilisation was over 80% (80% plus set-up times equals more or less 100%), then no space for adjustments is easily available.

Lutz stated in his article that it is easy to implement the measurement metrics presented in the theory, because every one has to know when a product enters or leave the stock. The data is indeed available but it is not easily possible to work with the data, because a company produces more than one product at the same time. In the case of Drako it can happen that more than one 20.000m order is produced at the same time, which makes the situation even more complex. Without help of an ERP system it is not possible to gain the necessary information out of all these transactions. Even if some authors insist that theory is easy to implant, reality shows the limits.

6.4. Generalization

It is possible to generalize the result of the elevator ropes onto the rest of the product assortment of Drako even if this thesis is a case study for one single product of the Drako assortment. All other products will also profit by implementing the proposals mentioned above, because the production process is the same for all products. That means it would reduce the inventory levels for semi-finished products in the whole company.

The results are also applicable for the whole steel rope industry, because all competitors use the same machines for producing steel wire ropes. That means only bunching machines, tubular machines and basket-type machine are used for producing steel wire ropes. The know-how is hidden in the set-up of the machines and in the design of the product.

But also the fibre and cable industry use the same types of machines, as demonstrated at the WIRE 2006 in Düsseldorf\textsuperscript{149}. Such wires are applicable e.g. in the automobile industry.

\textsuperscript{149} http://www.messe-duesseldorf.de/wire/de 2006/05/10
6.5. **Reflection and criticism**

It was difficult to gather the necessary information, because it is stored in databases. Therefore it was important to understand the used ERP system, which has a very complicated structure. Only a basic documentation is available. No online help is applied in TIBES. So it took a lot of effort to finish the empirical data collection.

Also the huge amount of information caused problems, because it is important to focus on the relevant data. Therefore the theory chapter, which focused the relevant data, was very useful.

The empirical data collection demonstrates that Pfeifer Drako does not have the possibility at the moment to implement a performance measurement system for inventory management. Therefore it was not possible to evaluate certain proposals.

In spite of all these points of criticism, this thesis has achieved its main objectives of finding possibilities for reducing the inventory of semi-finished products in the steel wire rope industry without reducing the ability to deliver. The empirical study is backed up by investigation and discussion of different theoretical concepts.

6.6. **Suggestions for further research**

Further research could prove the financial feasibility of the proposals for reducing the inventory levels of semi-finished products. It would be interesting to investigate if it is possible to change the production lay-out by rearranging the machine order or reducing the number of machines.

Also a detailed analysis of waste according to lean manufacturing could help to improve the company’s performance. This also implies the development of set-up workshops for the employees to reduce set-up times.
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Appendix
I. Curriculum Vitae

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Wehrdienst

Appendix: B
Appendix

08.01-07.09.2001 Kampfunterstützungskompanie – Panzergrenadierbataillon 13, 4910 Ried im Innkreis, 8 Monate abgeleistet

Berufserfahrung


2002 27. August bis 11. September, Ferialarbeit Manpower Austria Personaldienstleistungen Ges.m.b.H., Gardegasse 4, 1070 Wien

2003 7. Juli bis 31. August; Ferialarbeit Entwicklung, Teufelberger Seil Ges.m.b.H., Vogelweiderstr. 50, 4602 Wels


Sonstiges

Führerscheine A,B,C,E,F

PC Kenntnisse MS Office, MS Access, MS Windows 2000, XP, C++, HTML, ASP

Sport

- Obmann des Sportvereines Taekwondo Amstetten, 40 Mitglieder
- Stv. Obmann des Sportvereins Taekwondo4you in Wels, 90 Mitglieder

Appendix: C
II. Affidavit – Eidesstattliche Erklärung

Hereby I declare that the master thesis “Inventory reduction based on the example of a German SME in the steel rope industry” has been written only by the undersigned and without any assistance from third parties. Furthermore, I confirm that no sources have been used in the preparation of this thesis other than those indicated in the thesis itself.

Ich erkläre an Eides statt, dass ich die Diplomarbeit mit dem Titel “Inventory reduction based on the example of a German SME in the steel rope industry” selbständig und ohne fremde Hilfe verfasst, andere als die angeführten Quellen und Hilfsmittel nicht benutzt und alle wörtlichen und inhaltlich entnommenen Stellen als solche gekennzeichnet habe.

Växjö, Sweden, 2006-06-01

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Alexander Hübl