--- Master Thesis ---

Cycles in the squirrel cage

A research into CODP positioning and standardization at the Dutch market leader of electric squirrel cage motors

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Enschede, Friday, 28 August 2009

I: Management Summary

Scope

This research is carried out within the frame of the Master Assignment for Industrial Engineering and Management at the University of Twente.

The scope of this research is the supply chain of Rotor B.V., a producer of electric squirrel cage motors in Eibergen. The different departments within Rotor are observed as well as direct customers and suppliers. The main focus is on the processes sales, purchasing and logistics.

Goal

The research goal is to determine the best position of the customer order decoupling point for Rotor in combination with standardization of stock in order for the company to be able to combine flexibility and short delivery times with less risk in stock and easier determination of stock motors. Additionally, this research also tries to bring to light rules of thumb used by the purchase and logistics managers in their daily routine and the possibilities for these rules to be embedded in a system and so to capture implicit, local knowledge, reduce the dependability on persons and develop the business processes towards lean.

Conclusions

The customer order decoupling point should be situated at the sales department of Rotor. At this point in the supply chain the customer order is received and it can be determined whether an order can be fulfilled by direct delivery from stock, by reconfiguration of a motor at the competence centre in Eibergen or by purchasing the specific motor from a supplier.

With the standardization of stock and the reduction of the number of configurations held on stock by 58%, Rotor is able to retain its flexibility while at the same time reducing the risk in stock. With the suggested standard stock list of 546 motors, Rotor is able to cover 96% of all configurations sold in 2008 from Eibergen, by using the reconfigurations possibilities of the competence centre. The use of Configure Bases lets the employees of Rotor easily select the appropriate motor for reconfiguration purposes and is a simple way of analyzing motors sold based on their unique elements.

The rules of thumb unearthed in this research and the suggested implementation of these rules enables Rotor to capture implicit and local knowledge and embed this in a system. Dependability on persons is this way reduced and a step is taken in the direction of lean business processes, especially for purchasing.

Recommendations

The first recommendation is the periodic evaluation of the Configure Bases and standard stock motors, to assure the correct motors are kept on stock and the flexibility and short delivery times will also in the future be maintained.

Secondly we recommend to roll out the standardization downstream of the customer order decoupling point. The total stock in this part of the supply chain can be lowered and more risk can be eliminated.

For the alignment with the UK branch of Rotor further research is recommended.

The implementation of performance measurement throughout the organization is recommended. This will enable the management team to analyse the performance of the departments and in case performance is inadequate, appropriate steering can be deployed to improve performance. For this to succeed a revision of the company's mission, vision, strategy and organizational goals is necessary.

Consequences

The implementation plan for the standardization of Rotor's stock describes the steps to be taken by Rotor in order to reap the benefits of the conclusions of this research. Support by the Board of Directors and the Management Team is essential. Moreover, the cooperation of the purchasing and logistic managers and the software developer is necessary for this implementation plan to succeed.

II: Table of contents

III: Lists of Figures, Tables and Abbreviations

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III.iii: Abbreviations

The abbreviations used in this thesis are explained in Table 1.

Abbreviation	Explanation
ATO	Assemble To Order
AX 3.0	Microsoft Axapta 3.0
AX 4.0	Microsoft Dynamics AX 4.0
BoD	Board of Directors
BOM	Bill of Material
CB	Configure Base(s)
CODP	Customer Order Decoupling Point
CODZ	Customer Order Decoupling Zone
DFS	Deliver From Stock, the wholesaler's variant to MTS
ERP	Enterprise Resource Planning
ETO	Engineer To Order
IEC	International Electrotechnical Commission
KPI	Key Performance Indicator
KSF	Key Success Factor
MA	Motor without additional BOM, as produced by the manufacturer (Dutch: Motor Artikel)
MB	Motor Base(s)
MOT A	Motors with IEC house size 56 - 160
MOT B	Motors with IEC house size 180 - 315
MOT C	Motors with IEC house size > 315
MSA	Motor with additional BOM, reconfigured at Rotor's competence centre (Dutch: Motor Stuklijst Artikel)
MT	Management Team
MTO	Make To Order
MTS	Make To Stock
OpenMT	meeting with the BoD, the MT and additional department heads (Logistics, Purchasing, Office Sales force, IT, Quality and certificates, Operations)
OPP	Order Penetration Point, this is the same as the CODP
P:D	Production to Delivery lead time ratio
PTO	Purchase To Order, the wholesaler's variant to MTO
RTO	Reconfigure To Order
SKU	Stock Keeping Unit
VMI	Vendor Managed Inventory

Table 1: Abbreviations used in the text and their explanations

IV: Prologue

Before you lies my Master Thesis, a written report about my final project of my Master Industrial Engineering and Management at the University of Twente.

Via networking I got in contact with one of the shareholders of Rotor B.V., Mr. Herbert Weekhout. In June 2008 there was an informal meeting at the company's head-office in Eibergen, with Mr. Mario Pistone , Mr. Weekhout and myself. Both shareholders introduced the company and explained what they saw as problems within the organization. I became interested in the organization, the problems and the challenges that were present and gladly accepted the opportunity to conduct my Master's Project at Rotor.

The project has been everything I hoped it would be. I loved the opportunities offered to me to conduct my own research and contribute to solving a practical problem. Furthermore, the cooperation with experienced colleagues inspired me time and time again and proved to be a great supplement to the more theoretical teachings at the University of Twente.

Although this research is my Master assignment, it was not possible without the contributions of several persons. I would like to thank everyone that helped me, in one way or another, in executing my Master Thesis. Without you, I would not have been able to bring it to this result.

In particular I would like to thank both Mr. Weekhout and Mr. Pistone for granting me the opportunities and for their continuing trust in me. A further word of gratitude goes to Mr. Katsma and Mr. Schuur, my examiners from the University of Twente. Time and time again they provided me with new and interesting insights and forced me to take a step back and apply a more holistic view of the assignment and not get bogged down on company specific details.

Several colleagues at Rotor helped me with this research, either by participating in discussions, expert meetings or via supplying me with relevant data. Though not by name, I would like to thank all those colleagues for their valueble contributions.

Last but not least I would like to express my appreciation to my parents for their enduring support, not only during this Master Asssignment but throughout my entire study at the University of Twente. Although sometimes I question whether they realize it, the truth is I could not have done it without them.

Enschede, Friday, 28 August 2009

Bert Beek

Chapter 1: Introduction to the problem

Paragraph 1.1: Introduction

We conduct this research within the frame of our Master study Industrial Engineering and Management at the University of Twente.

In this chapter we briefly introduce Rotor B.V. Furthermore we outline the origin of the problem to which this research seeks a solution. Finally, we present a reading guide in which we explain what the coming chapters contain.

Paragraph 1.2: A general description of Rotor B.V.

Rotor is a manufacturer of standard and specialized motors for use in shipping, offshore and industry ("Rotor Website," 2008). The company was founded in 1958 by Mr. Th. M. Kraakman and started with the import of standard motors from the Czech supplier MEZ. Rotor moved from its original location in The Hague to the town of Eibergen in 1974. In the following years, Rotor specialized in motors for the shipping, offshore and petrochemical industry. To enable this specialization, Rotor established a competence centre in Eibergen, where modification, painting and testing of the motors is conducted. In 1986, Rotor was the first in the industry to become ISO9001 certified. Since then, many motors of Rotor have been certified by several classification bureaus and thus Rotor has become a important player in the shipbuilding industry. In 1994, a third party acquired the Czech MEZ factories. Rotor and other former MEZ customers kept their privileges, such as the possibility to have an own motor brand produced.

Rotor´s original market area, the Netherlands, was enlarged by opening a sales office in Belgium (1997), by acquisition in the United Kingdom (2004) and by export, mainly to Asia. The sales office in Belgium became independent in January 2008. The main distribution channels of Rotor are:

- Service partners, technical service companies
- Original equipment manufacturers (OEMs) in machinery and shipping

Since the management buy-out in 2006, the company is owned by three shareholders. The turnover in 2007 was about 29 million euro with 75.000 motors sold. This turnover was realized with 53 employees (van Alten, Leijen, & van Sas, 2008).

Rotor purchases almost all motors from factories in the Czech Republic. These motors can be modified according to the customers wishes in the competence centre in Eibergen. The added value of Rotor lies first and foremost in:

- Product reliability, in which the companies own brand Rotor nl © plays an important role.
- Product certification, an important condition for critical usage, for instance in shipping.
- Solutions with advice, customization, flexibility and short lead times.

Paragraph 1.3: Origin of the problem

The problem at Rotor, as described by the board of directors, is finding the ‘best match motor’ for a customer. There are several facts that contribute to this problem.

First of all, both the sales and operations departments have a certain freedom to select (and change) the stock motor used to create the motor requested by the customer. This is due to an unclear product structure.

Secondly, the number of motor configurations is endless.

The third contributor to the research problem is the fact that customer demand is historically difficult to predict (van Alten, Leijen et al., 2008).

The fourth and final contributor to the problem is the data contamination in the ERP system. During the recent implementation of a new version of this ERP system this data contamination has become more evident.

A more detailed description of the problem and the research questions formulated for the problem can be found in the next chapter.

Paragraph 1.4: Reading guide

This reading guide explains what part of our research we address in what chapter. The reading guide is visualized in Figure 1.

This first chapter started with a brief introduction of the company of Rotor and an explaination of the originis of the problem to be addressed in this research.

In Chapter 2, we deduce from the rudimentary problem the problem definition and the research questions. Also, we present the research design.

In the 3rd chapter we give a more detailed description of Rotor.

Chapter 4 pertains to the first research question, Chapter 5 concerns the second research question and in Chapter 6 we deal with the third and final research question. In each of these chapters we discuss relevant literature as well as the research methods.

We summarize the main conclusions of this research in Chapter 7. In this final chapter we also address some interesting issues with regard to the conclusions. Furthermore, we make several recommandations with respect to future research and the implementation of this research at Rotor.

At the end of this thesis are the literature list and several figures and tables to which is referred in the preceding chapters. Also, an implementation plan for the repositioning of the stock is added.

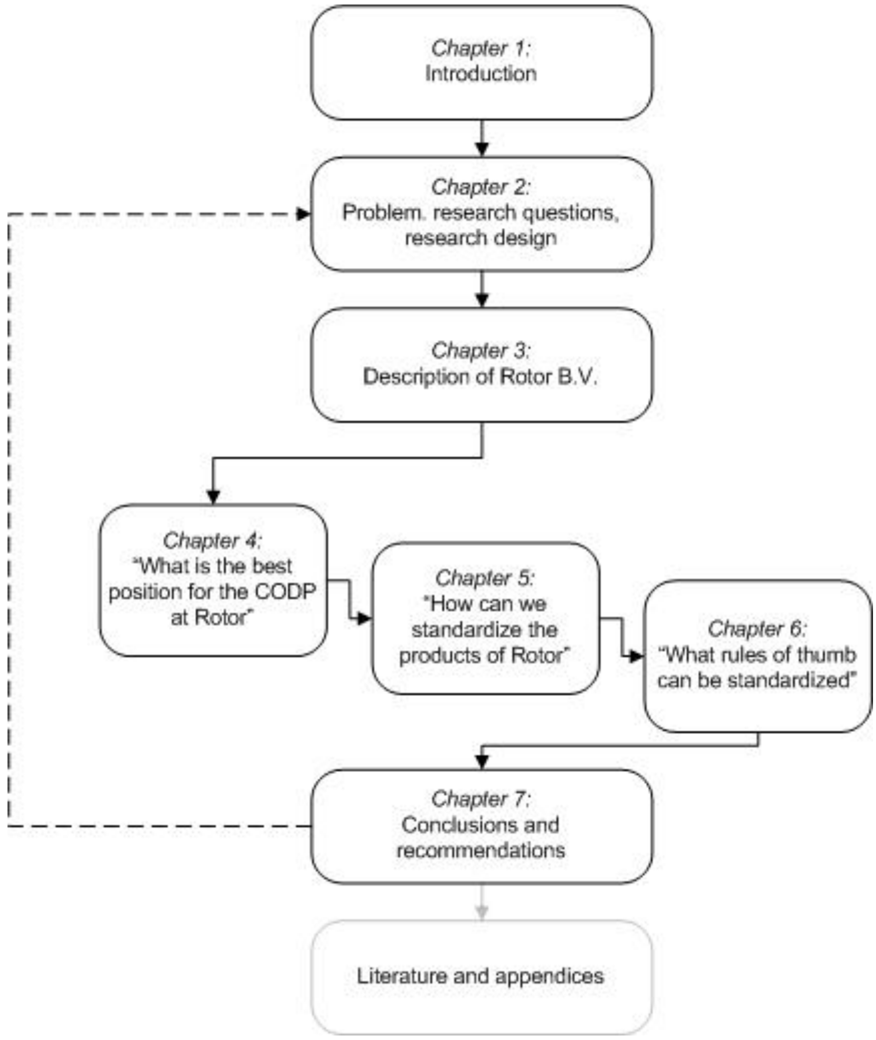

Figure 1: Reading guide

Chapter 2: Problem description and research questions

Paragraph 2.1: Introduction

As we briefly explained in the previous chapter, there are four different elements that contribute to the overall problem of not being able to find the best match motor. These four elements are further explained in this paragraph and together they form the rudimentary problem.

Paragraph 2.2: The rudimentary problem

After reading the four elements that contribute to the problem, there seems to be tension between formalization and flexibility. When processes are formalized, they will lose some flexibility and the other way around. But surprisingly there are aspects that come forth from both formalization and flexibility and that will pave the way for a solution.

Flexibility

The factors that stipulate flexibility are the short delivery times, the unpredictability of future demand and the infinite number of motors (mass customization). There are an infinite number of motor and option combinations possible. For orders with a long requested delivery time there is absolutely no problem, because the orders can be outsourced to the supplier. However, for orders with a relative short lead time it is a completely different story. These motors have to be available in the warehouse of Rotor or have to be produced in the competence center. It would be folly to put a great deal of these motors on stock to assure availability. So, flexibility is key. A factor that is closely related to the infinite number of motors is the delivery time. The service partners and sometimes also the OEMs require very short delivery times, say delivery within a week or less. To be able to comply with these short delivery times Rotor has to be very flexible with their stock and the production facilities in the competence center, since it is impossible to have all motors on stock.

The future demand is very difficult to predict. For Rotor to still be able to cope with uncertain demand they should be flexible with respect to their production, purchasing and stock.

Here we see that the flexibility is required in the final stage of the supply chain, where the customer order drives production and logistics (stock).

Formalization

Factors demanding formalization are the stock determination, an unclear product structure and the traceability of (historic) demand, the dependence on a single supplier and the new ERP system (reports). Customer demand is historically difficult to predict. To be able to cope better with this uncertainty, Rotor has to formalize the way the determine stock.

Due to an unclear product structure the sales and production departments have certain freedoms to configure a requested motor from a lot of different motors and options. And even when a selection has been made by the sales department, a change to this selection is possible by the production department. Rotor wants to formalize this so that a requested motor combination can only be selected in one way. Traceability of historic demand is very difficult due to this unclear product structure and since predicting future demand is extremely hard the historic demand is of great importance. This further stresses the need for formalization.

Because Rotor is for 95% dependent on a single supplier, the lead times of this supplier are rather vital. To offset the longer lead times offered by the supplier, Rotor has to formalize the purchasing of motors as much as possible. To manage the stock properly and assure high availability while at the same time reducing stock, Rotor should be able to create clever reports about motors sold, so that the stock can be determined based on previously sold motors.

It is apparent that formalization is required at Rotor at the purchasing department and for determining stock. For these processes a single customer order is not as important as for the flexibility described above.

Factors needing Formalization	Factors needing Flexibility
Stock determination	Infinite number of motor-option combinations
Unclear product structure and the traceability of historic demand	Short delivery times (<1 month)
Single supplier dependency	Uncertainty of future demand
New ERP package and reports	

Table 2: Formalization versus Flexibility

The different factors needing either flexibility or formalization are displayed in Table 2.

Approach to the solution and choices
As becomes clear in this paragraph, the tension between formalization and flexibility has much to do with supply chain management and the position of the Customer Order Decoupling Point. The position of the CODP will emphasize the need for flexibility downstream and formalization upstream of the CODP, just the things Rotor is struggling with.

The approach that we choose is focussing on the supply chain of Rotor and especially on the stock present at the warehouse in Eibergen.

Paragraph 2.3: Problem definition, research goal and research questions

2.3.1 Problem definition

We formulate the problem definition as follows:

> *"Rotor is functioning suboptimal due to an unclear position of the Customer Order Decoupling Point and an unclear setup of the supply chain around this CODP. "*

2.3.2 Research goal

The goal of this research is formulated as follows:

> *The goal of this research is to clearly position the CODP in the organization of Rotor and create a standard stock with which Rotor is able to continue offering flexibility and short delivery times to their customers while at the same time reducing risk and being able to determine stock with more accuracy.*
> *A further step is the deduction of rules of thumb concerning stock control and purchasing, and implementing these as good as possible in the ERP system. This way the standard tasks of the purchasing department can be automated.*

2.3.3 Research questions

The research questions are hence the following:

1. *What is the best position of the Customer Order Decoupling Point for Rotor?*
2. *What is the best way of creating standard stock so that Rotor can combine internal standardization with customization towards customers?*
3. *What information do the purchase and logistic managers use that can be put into rules of thumb and what rules can be programmed into the ERP system (automating stock control and purchasing of standard motors)?*

Paragraph 2.4: Research type, methods and technique

The next step is the transition from problem description to research design. In this step we describe the principal research form, the research type and the final research design.

According to Baarda and De Goede(2001), there are three different principal research forms namely explorative research, descriptive research and controlling or testing research. Van der Zwaan (2003) adds a fourth principal research form to this three-way categorization, that is the explanatory research. The difference between the principal research forms is made primarily by the amount of available literature and hypothesis made beforehand.

There is considerable literature available on the first research question. With the help of this literature we are able to describe the current situation as well as the desired situation. For the second research question we mainly use information about the ERP system and information gathered through observations and interviews. Thus we conclude that descriptive research is the principal research form best suited to both research questions.

Next to the principal research form there is the research type. The research types described by Van der Zwaan (2003) are experiments, case studies, comparative research, simulation research, action research and evaluation research. The research type is the framework for the research. The most appropriate research types for this research are the case-study and action research. A case-study would be well suited but due to the fact that the research also encompasses the implementation of the second and where possible the first research question, we believe that the action research type is better suited.
The final research design, influence by the research type action research, is comprised of the following steps:

- Interviews
- Desk study (document research)
- Field study (observations)
- Literature research

The information we would like to uncover and the functions from within Rotor that we would like to interview are listed in Table 3.

Function	Information to be acquired
Purchasing manager	Rules of thumb concerning purchasing, stock
Manager Logistics	Rules of thumb concerning stock
Senior manager Sales & Business Development	Customer characteristics
General Director	General knowledge of motors and data gathering using the ERP system
Commercial Director	Customer characteristics
IT developer	Knowledge of ERP system
Manager Rotor (UK) limited, responsible for purchasing	Purchasing rules

Table 3: Interviewees, their positions and the information to be acquired by the interview

The research design resembles a regulative cycle as described by Van Aken (1994), as is depicted in Figure 2. Because we conduct action research the reflective cycle is not appropriate, as is a multiple-case study.

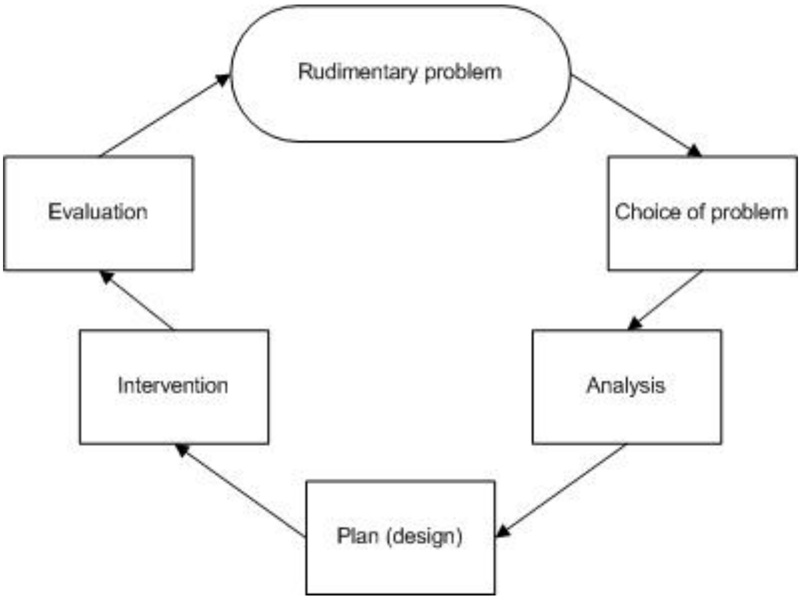

Figure 2: The regulative cycle (Van Aken, 1994)

Chapter 3: The unique aspects of Rotor

Paragraph 3.1: Introduction

In this chapter we explain the characteristics of Rotor, the characteristics of the product as well as the demand and supply characteristics. Furthermore we specify the current and desired logistical situation. We conclude this chapter by denoting the relevant findings for this research and by linking these findings with recent literature.

Paragraph 3.2: Division into three centres

The structure of Rotor is divided into three different centres, all situated in Eibergen. In the already mentioned competence centre, motors can be modified according to the customers wishes. The contact centre performs sales, purchasing, order entry and technical support for the customers. The third centre is the innovation centre. In the innovation centre, students from Universities of applied sciences and intermediate vocational education work on various assignments. The assignments are carried out throughout the company and innovative solutions are implemented regularly. Furthermore the finance and IT department is separate from the contact and competence centres. The organizational chart is depicted in Figure 3.

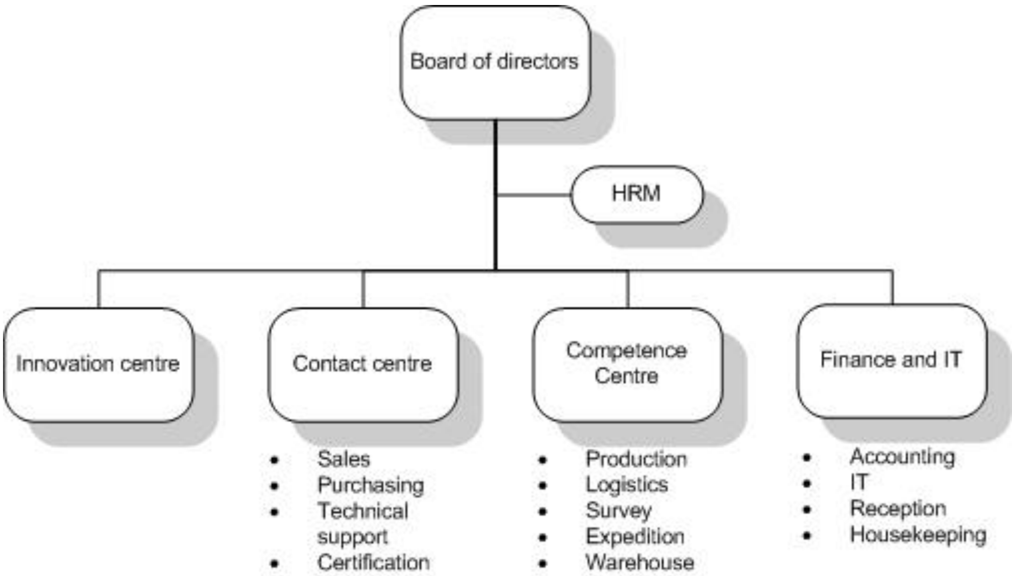

Figure 3: Organizational chart Rotor B.V.

Rotor UK Limited also has a competence and a contact centre, both situated in Wellingborough, Northamptonshire. The competence centre in Wellingborough does not modify motors like the competence centre in Eibergen. Actually, Rotor UK Limited is more like a service partner in the way that they have motors on stock to assure short lead times and order specific motors from either Rotor in Eibergen or from a third party.

Paragraph 3.3: Product variants and modularity

The characteristics of the product of Rotor can be split in the basic motor and the options. An electric motor, in the industry called a squirrel cage motor, consist of several parts. Figure 4 illustrates the different parts and Figure 5 is a picture of a squirrel cage motor. Figure 6 is a exploded view of a squirrel cage motor.

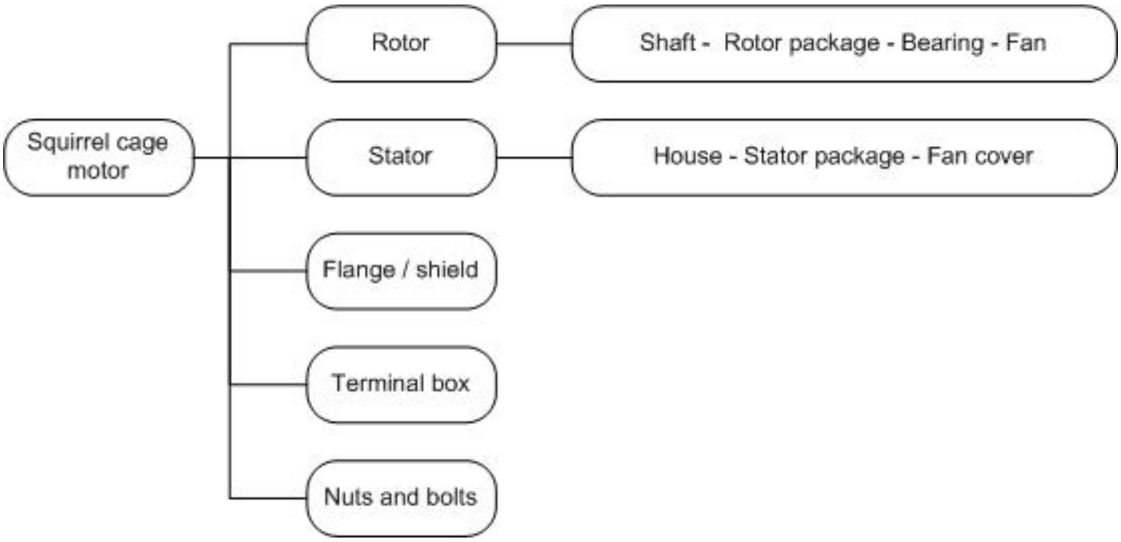

Figure 4: Basic motor parts (adapted from Van Alten et. al. (2008)).

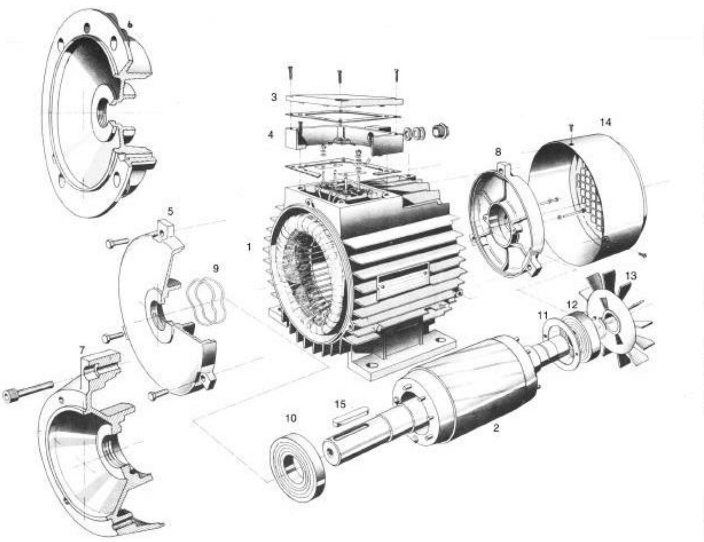

Figure 6: Exploded view of a squirrel cage motor

Figure 5: A squirrel cage motor

For the basic squirrel cage motor, Rotor has 22 different house sizes, conform the International Electrotechnical Commission (IEC) norms, available with:

- 10 rotor-stator variants
- 6 flange variants
- 6 terminal box variants

This results in almost 8000 possible configurations (theoretically). Besides the basic motor parts, there are several options a customer can choose from. These are:

- Encoder
- Thermistor
- Coating
- Brake
- Marine execution
- Survey

- Heating
- Protection class

Overall, the combination of basic squirrel cage motors and the aforementioned options result in infinite possible motor variants.

The IEC norm house sizes are divided in two categories:

- MOT A contains house sizes 56 – 160 (millimetre from base to the centre of the shaft), and
- MOT B contains house sizes 180 – 350.

Larger motors do exist and are part of MOT C but the number sold by Rotor is very small.

The IEC mounting positions, defining how a motor can be fitted to the machine, are described by a four digit number. In the appendix, Figure 29: IM coding of mounting positions, these mounting positions are explained.

Paragraph 3.4: Demand characteristics

The predictability of demand is very low. For instance, it is difficult to compare the demand in the years 2006 and 2007. Some interesting figures (van Alten, Leijen et al., 2008):

- 43% growth in turnover for the top 25 customers
- 68% of turnover 2007 (in euro's) is equal to 2006 (turnover/customer)
- 30% of customers 2007 did not order in 2006
- 59% of customers 2006 did not order in 2007

These figures indicate that there are limited possibilities to predict demand based on customer orders.

In the thesis of Van Alten, Leijen & Van Sas (2008) the demand characteristics are further explained. Approximately 10% of the customers are responsible for 80% of turnover, see Figure 7.

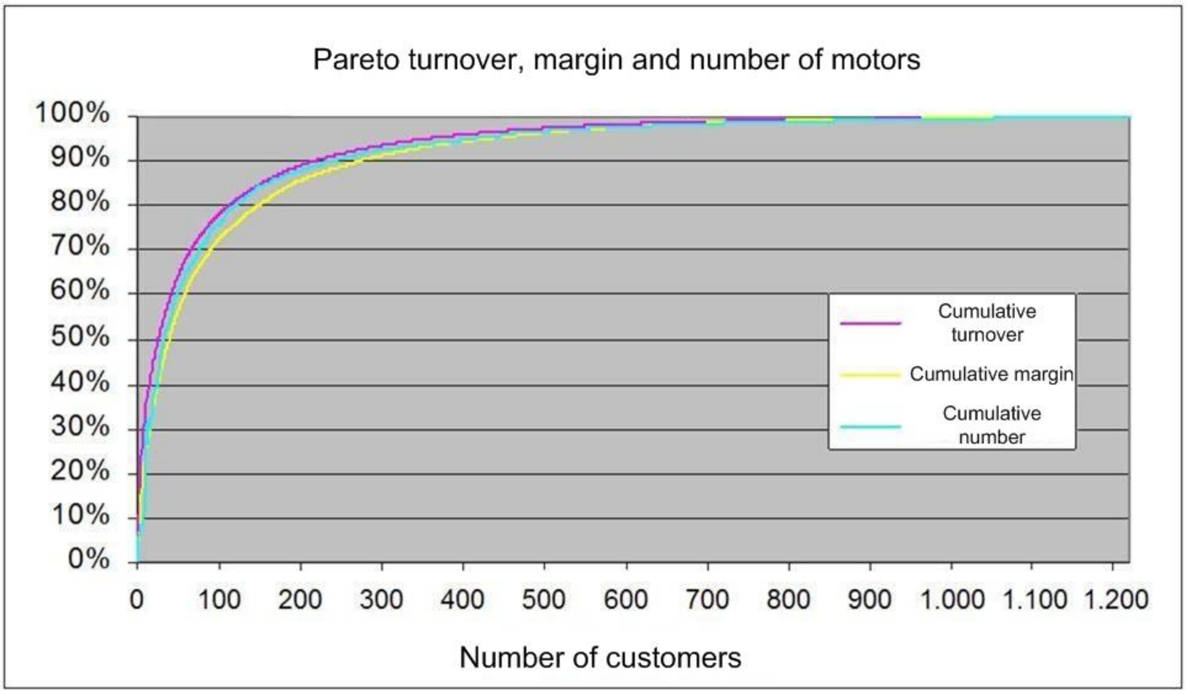

Figure 7: Number of customers and Pareto turnover (van Alten, Leijen et al., 2008)

The majority of motors is only ordered one or two quarters of a year during a two year period, see Figure 8.

The difference in requested delivery times between service partners (dealers) and OEMs (customers excl. dealers) is illustrated as follows: 80% of the service partners require delivery within 5 days, only 50% of the OEMs require delivery within 5 weeks (see Figure 9). 80% Of motors from the MOT A category and 75% of the MOT B category is delivered within 3 weeks from order intake (see Figure 10). The figures 7 till 9 from the thesis of Van Alten et. al. are included on the following page.

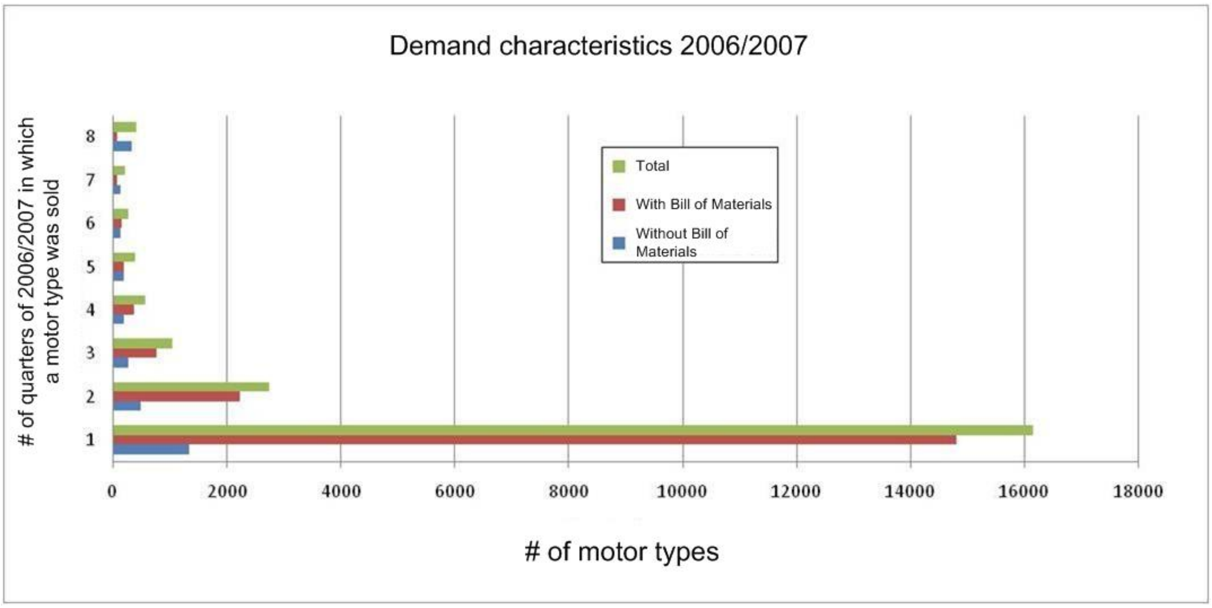

Figure 8: Number of times a motor is sold in the 8 quarters of 2006/2007 (van Alten, Leijen et al., 2008)

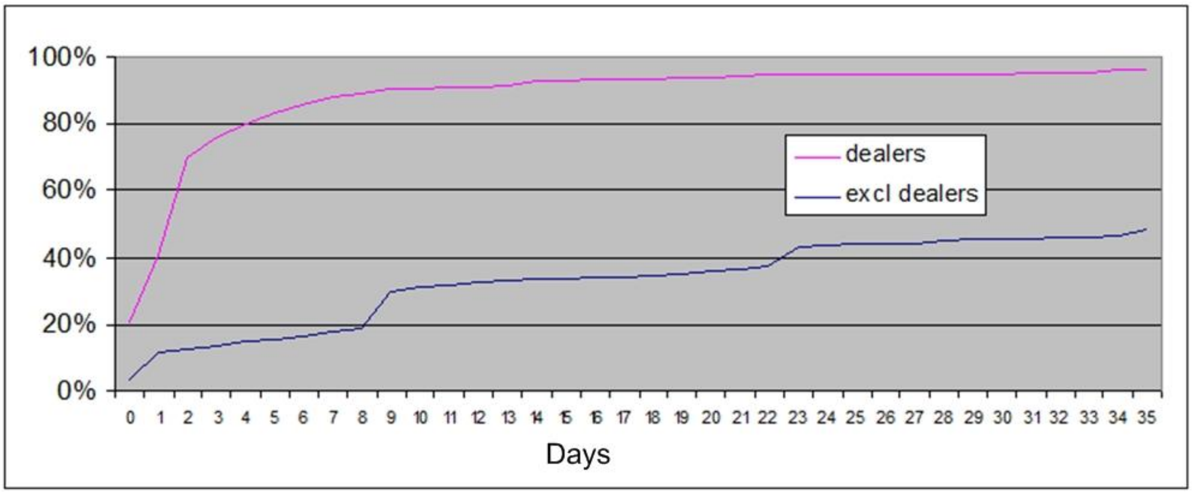

Figure 9: Delivery times in days of dealers and other customers (van Alten, Leijen et al., 2008)

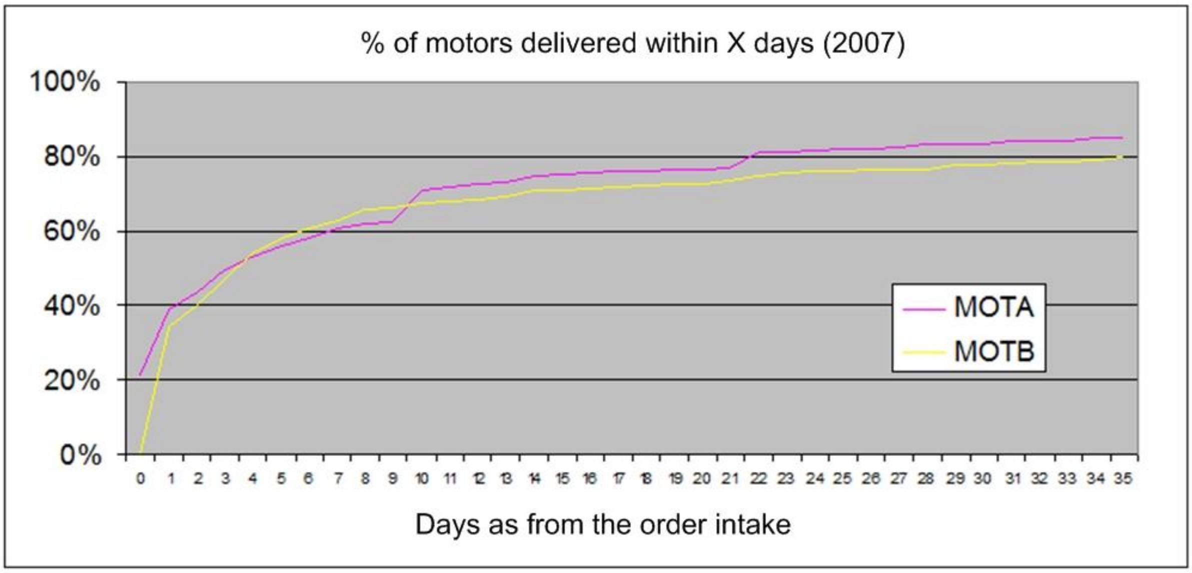

Figure 10: Delivery times in days of MOT A and MOT B (van Alten, Leijen et al., 2008)

The OEMs generally ask long lead times so that this demand can be planned more accurately. The service partners on the other hand often need motors for immediate replacement and hence require (very) short delivery times.

The main conclusion based on this information is that the demand pattern is unpredictable and that there are noteworthy dissimilarities in demand between the service partners and the OEMs.

Paragraph 3.5: Supply characteristics

Rotor purchases its motors for 95% from a single supplier. Only for the niche market of explosion proof motors, Rotor has a different supplier. It can be concluded that Rotor has a single sourcing situation, which has its origins in the MEZ history explained in the first paragraph.

The lead times of the main supplier have increased significantly over the past three years (see Figure 32 in the appendix). As can be seen in Figure 33 (also in the appendix), the motors of MOT B have as of the end of September a lead time of 115 working days (WD) and the motors of MOT A have a lead time of 50 WD. It goes to show that sudden changes in these lead times have an impact on the stock of Rotor and the availability of motors.

Rotor has a good relationship with its main supplier. A unique purchasing aspect for Rotor lies in the claiming of capacity at the supplier. The purchaser places orders for basic motors and he is allowed to change, to certain extend, the basic motor and/or add options to the purchased motors as long as actual production of the motors has not yet started. The main supplier is able to produce all motors with all options.

Paragraph 3.6: The current logistical situation

In the current logistical situation, Rotor has three manufacturing concepts of integral control (van Alten, Leijen et al., 2008):

- Deliver from stock (flow 1 in Figure 11), 30% of all motors
- Purchase to order (flow 2 in Figure 11), 10% of all motors
- Reconfigure to order (flow 3 in Figure 11), 60% of all motors

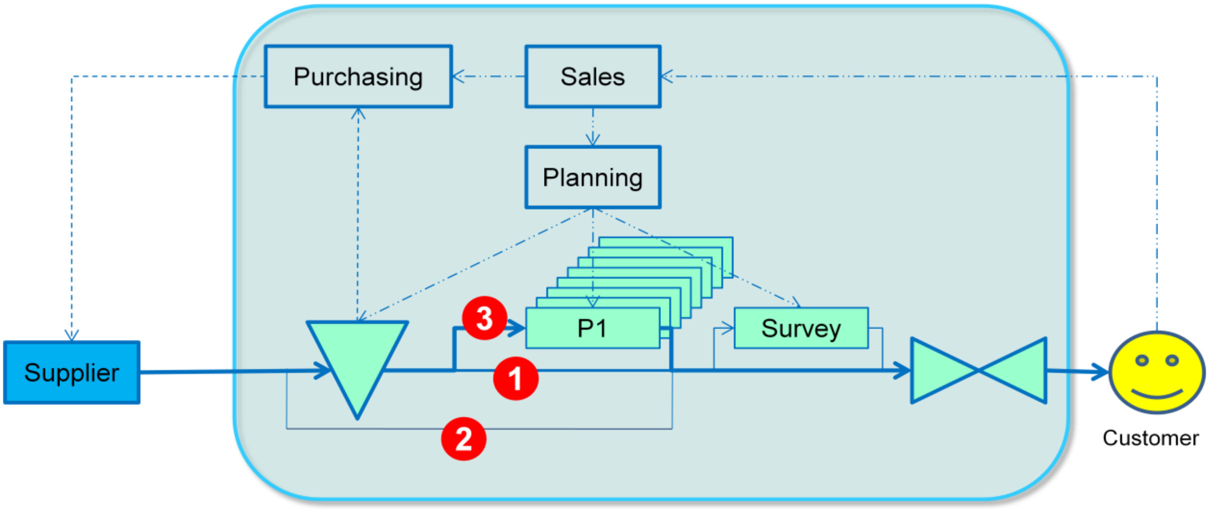

Figure 11: Current logistical situation at Rotor B.V. (van Alten, Leijen et al., 2008)

The manufacturing concepts of integral control originate from the study of Hoekstra, Romme and Argelo (1992) whereby the specific terms are slightly adapted to properly reflect the business of Rotor. Since Rotor purchases all motors, see also Chapter 1, the concepts of Make To Order (MTO), Assemble To Order (ATO) and Make To Stock (MTS) do not apply in that sense. MTO becomes PTS, ATO becomes RTO (it is not assembly of parts but changing some characteristics of an end product) and MTS becomes DFS.

About 55% of all motors is requested with a delivery lead time longer than the production lead time. These motors are ordered from the main supplier and 45% (of the total) of these motors is additionally reconfigured at the Competence Center in Eibergen. The main reconfigurations that are carried out for these motors are new type tags, certificates and surveys and painting.
The other 45% of all motors is requested with a delivery lead time shorter than the production lead time. These motors are delivery from the warehouse in Eibergen. Of these 45%, 10% (of the total) is additionally reconfigured at the Competence Center in Eibergen and then delivered to the customer. So, in conclusion, PTO accounts for 10% of all motors, DFS accounts for 30% and RTO accounts for 60% of all motors (van Alten, Leijen et al., 2008).

In 2007 the number of motors on stock is reduced from 7 million euro (approximately 36.000 SKUs) to 3.8 million euro (approximately 18.000 SKUs) predominately by removing slow- and non-movers. In October 2008, the number of motors on stock was 10.000 SKUs with a value of 2.3 million euro. According to Van Alten et. al (2008), the stock keeping decision is subjective and is based on historical demand and reconfiguration possibilities. The analysis is further complicated by the fact that similar motors cannot be traced by the ERP system due to an unstructured item table (article coding) and the use of additional component lists (Dutch: stuklijsten).

An age analysis of the stock gives more interesting insights in the current logistical situation (van Alten, Leijen et al., 2008). Almost a third of all motors on stock is kept on stock for more than four months and 15% of the stock is kept on stock for more than 10 months. The third of all motors that is on stock for more than four months accounts for almost 70% of the value of the stock. A conclusion based on these observations is that the slow-movers are relatively expensive motors. These facts are visualized in Figure 30 and Figure 31 in the appendix.

Paragraph 3.7: The desired logistical situation: Product-Market-Combination's (PMC's)

In the near future, the board of directors wants to change the logistical situation towards a situation more suited for PMC's. The board of directors of Rotor distinguishes between two distinctively different PMC's. The original equipment manufacturers ask long lead times and competitive prices. The unique selling points (USP's) or Unique Buying Reasons (UBR's) of Rotor for this PMC are its reliability (brand name Rotor nl®), product certification by classification bureaus and surveys. The service partners (dealers) ask short lead times. The UBR's of Rotor for this PMC are its flexibility (created by the competence centre in Eibergen), fast delivery (created by the stock in Eibergen) and reliability. Figure 12 graphically represents these two PMC's.

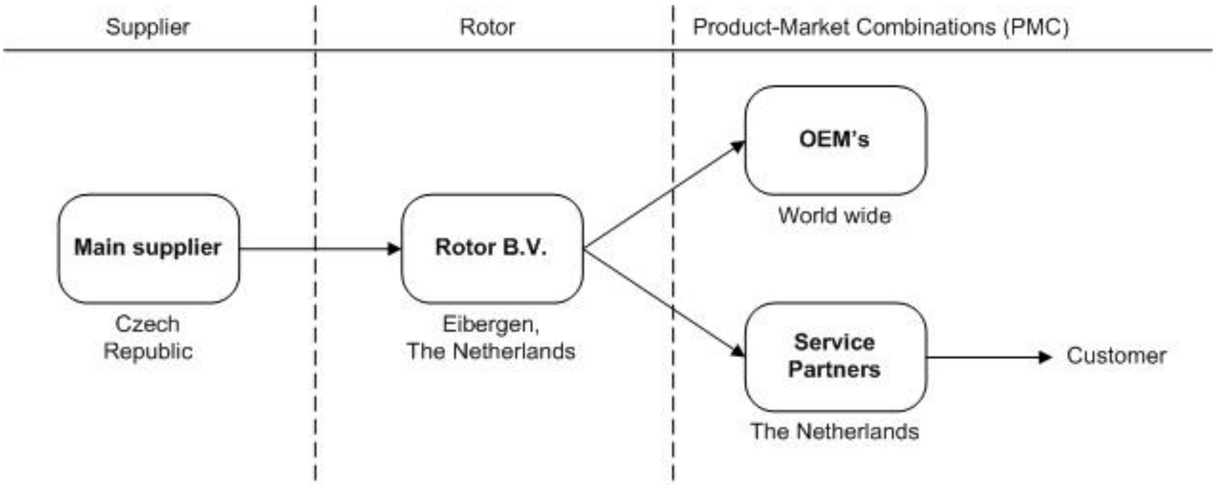

Figure 12: A simplified supply chain of Rotor

The board of directors wants to research the possibilities of supply chain management (SCM) to better control the supply and demand flows in the supply chain of Rotor. Furthermore, they see opportunities to increase efficiency in streamlining the Dutch and UK branches of the organization, with a possible growth (by acquisition) in 2009. This research is a part of the SCM efforts but does not cover the entire SCM spectrum. Our research is focussed on the position of the CODP for both PMC's and the standardization of stock at Rotor. Alternatives like vendor managed inventory with the service partners in the Netherlands and splitting up the warehouse and production facilities of Rotor are not covered by this research.

Paragraph 3.8: Relevant findings for this research

In this chapter we have reviewed the company of Rotor and described the product, demand, supply and logistic characteristics. Not all findings are just as relevant for this research. We believe the following findings to be relevant for the continuation of our research:

- Infinite motor variants
- Low predictability of demand
- Short delivery lead times (mostly Service Partners)
- Outsourced production
- Single sourcing situation (supplier dependency)
- Fluctuating production lead times
- Claiming of capacity at the supplier
- Reconfiguration of finished products

With the three research questions in mind, these findings will play an important role in the direction of our research and the possible solutions. With infinite motor variants, a low predictability of demand and short delivery lead times, Rotor has to have a great variety of motors available for the customer, either at its warehouse or from direct production. On the other hand, the outsourced production and fluctuating production lead times induce Rotor to indeed keep a large stock in order to reduce its (short time) supplier dependency. The reconfiguration possibilities and the claiming of capacity at the supplier are very interesting because it offers opportunities to re-build motors at the warehouse in Eibergen and thus reduces the need to keep a great variety of motors on stock.

The findings of this chapter are also relevant if we compare Rotor to its closest competitors. Rotor's main competitors, Siemens and ABB, also offer infinite motor variants to their customers and experience the same unpredictability of demand as Rotor (according to the senior manager sales and business development). But, both Siemens and ABB do not keep stock and so, offer their customer production lead times. This is where Rotor differs. The stock, reconfigurations possibilities and the claiming of capacity present Rotor the opportunity to offer their customers shorter delivery lead times than the production lead times.

In related literature there is a lot described about the CODP but we were not able to find anything about the reconfiguration of finished products. A more thorough description of related literature can be found in Paragraph 4.2. Based on the comparison with Rotor's main competitors and the related literature we can say that the reconfiguration of finished products and the possibility to offer short delivery lead times are Rotor specific.

Paragraph 3.9: Conclusion

In this chapter we analyzed the company of Rotor and determined the elements that are relevant for our research. Demand, supply, product and logistic characteristics were all considered. Many aspects are industry-specific but the reconfiguration of finished products and the offering of short delivery lead times are Rotor specific.

The first research question will feature the described relevant aspects of Rotor and also in answering the second research question these aspects will play an important role.

With the knowledge of the current situation acquired, we can now focus on our research questions. The next step in this research is the determination of the best position of the CODP for Rotor.

Chapter 4: CODP positioning at Rotor

Paragraph 4.1: Introduction

The first step in our research is positioning the Customer Order Decoupling Point. The position of the CODP will then be used to determine the influence on the stock and in Chapter 5, where we can standardize the product of Rotor upstream of the CODP. As stated in Chapter 2, the first research question that we seek to answer in this chapter is:

1. *What is the best position of the Customer Order Decoupling Point for Rotor?*

First we review relevant literature concerning the CODP in Paragraph 4.2. Next, in Paragraph 4.3 we evaluate the aspects involved in placing the CODP for Rotor based on the theoretical findings in Paragraph 4.2. After having positioned the CODP for Rotor we research the possibility to have multiple CODP's for Rotor in Paragraph 4.4. The influence of the position of the CODP on stock is determined in Paragraph 4.5 and this chapter is ended with a concluding paragraph.

Paragraph 4.2: Literature concerning the Customer Order Decoupling Point

In the supply chain the customer order decoupling point (CODP) pinpoints how far (upstream) the customer order penetrates the supply chain (Hoekstra & Romme, 1992). Hoekstra and Romme introduced a total of five CODP's:

- Purchase and Make to Order
- Make to Order
- Assemble to Order
- Make to Central Stock
- Make to Local Stock

A schematic representation of these CODP is given in Figure 13.

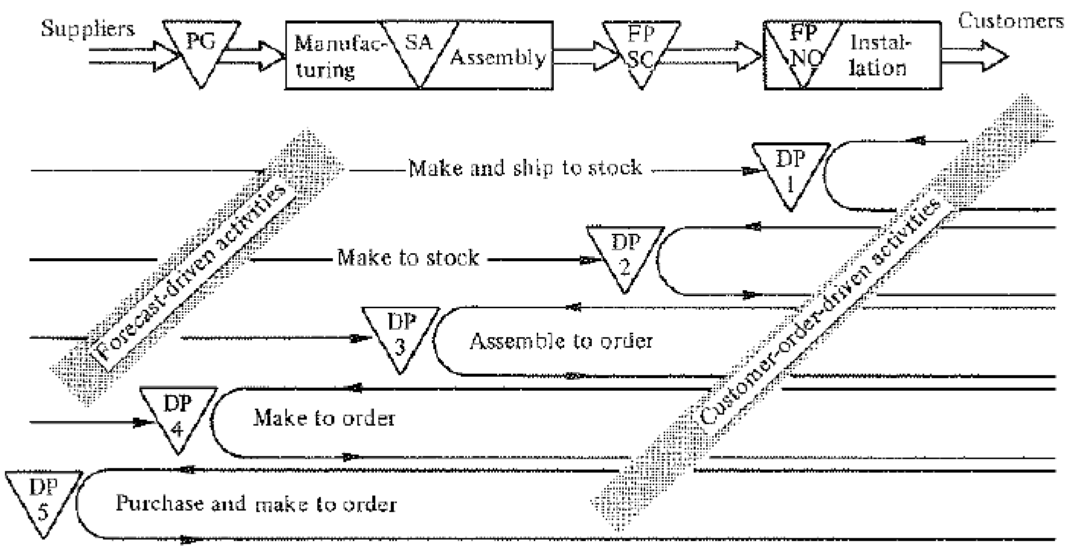

Figure 4.3 The decoupling point: the dominant factor for a logistic structure. Five DP positions represent five logistic structures: PG, purchased goods; SA, sub-assemblies; FP, finished products; SC, supply centre; NO, national organization. Open inverted triangles indicate possible stock points

Figure 13: The Customer Order Decoupling Point (Hoekstra & Romme, 1992)

The importance of the CODP is that the activities in the supply chain are split in two. The activities downstream of the CODP are based upon the actual customer order whilst the activities upstream of the CODP are based on forecasts and planning.

To emphasize the importance of the customer order in the positioning of the CODP, the CODP is sometimes called the order penetration point (OPP). Olhager (2003) states that different product delivery strategies relate to different CODP positions and he defines the following four, see also Figure 14:

- Engineer to Order (ETO)
- Make to Order (MTO)
- Assemble to Order (ATO)
- Make to Stock (MTS)

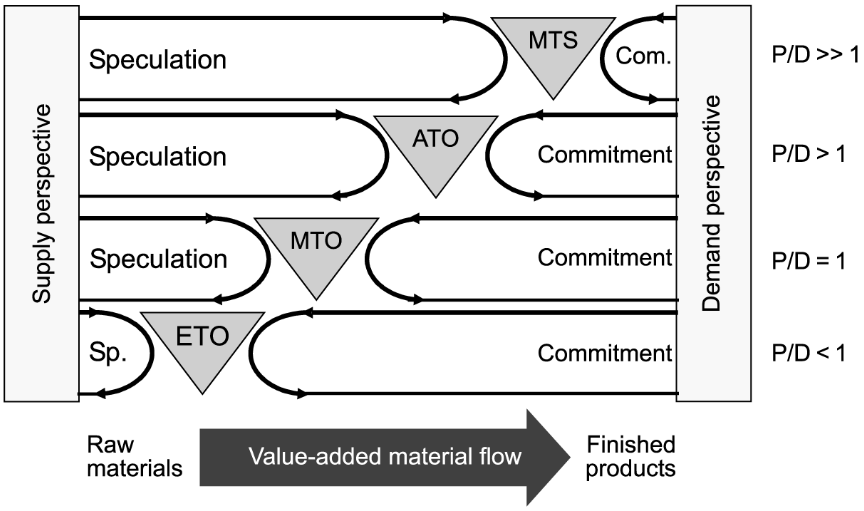

Figure 14: The different CODP's (Wikner & Rudberg, 2005)

There are several factors that influence the position of the CODP. An overview of articles describing the factors influencing the position of the CODP can be found in Olhager (2003). In the following bullet list, we summarize the factors, in which they are grouped into market-, product-, and production-related factors:

- Market
  - Delivery lead time requirements
  - Product demand volatility
  - Product volume
  - Product range and product customization requirements
  - Customer order size and frequency
  - Seasonality of demand
- Product
  - Modular product design
  - Customization opportunities
  - Material profile
  - Product structure
- Production
  - Production lead time
  - Number of planning points in production
  - Flexibility of the production process
  - Position of the bottleneck in production

- Sequence-dependent set-up times

The grouped factors and their influence on each other and on the CODP (in the figure called the OPP) are graphically depicted in Figure 15.

According to Olhager (2003), the main competitive priority that is related to the position of the CODP is delivery speed. Olhager explains that with delivery speed as order winner, the CODP should be positioned closer to the final goods inventory than that of the competitors.

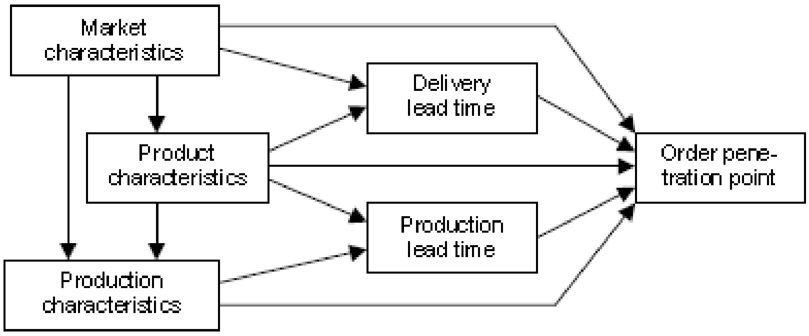

Figure 15: Conceptual impact model for factors influencing the CODP position (Olhager, 2003)

All the different notions of the CODP are certainly based upon the idea of the P:D ratio (Shingo, 1989), see Figure 16. The P (production lead time, the time it takes from to moment production starts until the moment the product is delivered) to D (delivery lead time, that what is requested by or offered to the customer) ratio indicates whether a product is more suitable to be made to stock (MTS) or to order (MTO). One can image that this relationship is most critical when D is smaller than P. Since both P and D are lengths of time and they are independent variables, the ratio does not represent a linkage between the two (Wikner & Rudberg, 2005).

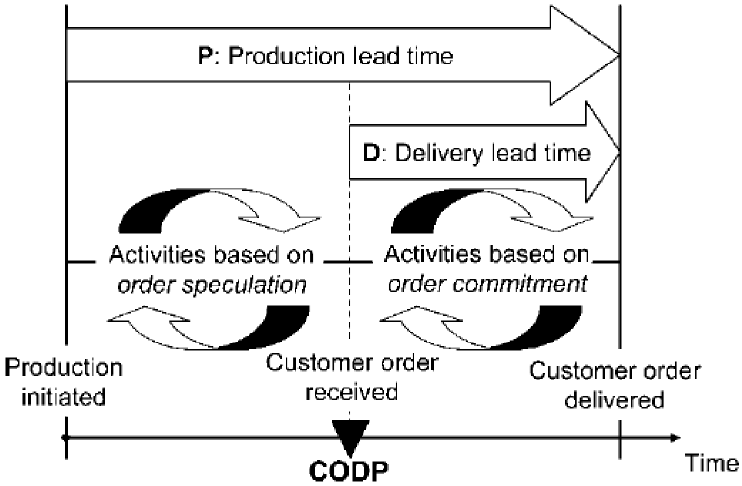

Figure 16: The concept of the P:D ratio (Wikner & Rudberg, 2005)

In the case D is larger than P, a product can be best made to order (MTO) and when a product has a D that is smaller than P, the best option is producing it to stock (MTS). Using the P:D ratio, we can thus determine the amount of planning and production that needs to be based on forecasting.

As explained, the CODP splits the supply chain in two with certain and uncertain information concerning customer demand divided between the downstream and upstream processes respectively. Upstream of the CODP a company must try to forecast customer demand and hope that the purchased products will eventually be bought. Downstream of the CODP all activities are based on actual customer demand and thus total certainty. Contrary to these two extremes presented in most CODP related literature, Wikner and Rudberg (2005) introduce a customer order decoupling zone (CODZ). This idea is based upon the notion that as time progresses, more and more information concerning customer demand becomes evident thus diminishing uncertainty. The information on customer demand is split into four issues: what, how much, when and where. The last customer information issue, "where", is not dealt with by Wikner and Rudberg because the company under scrutiny has but one location from where the products are offered to customers. For the purpose of this research, the "where" issue can also be omitted since Rotor Nl. only delivers products from Eibergen.

In Figure 17, a graphical representation of the three remaining customer information issues (aptly named the uncertainty cube) is presented and in Figure 18 the development of demand and the uncertainty within is depicted. Following this, Wikner and Rudberg explain, that the P:D ratio is mainly related with the "when" issue. Due to the fact that customers require products at a certain point in time, the related customer information issues need to be resolved while there still is some uncertainty.

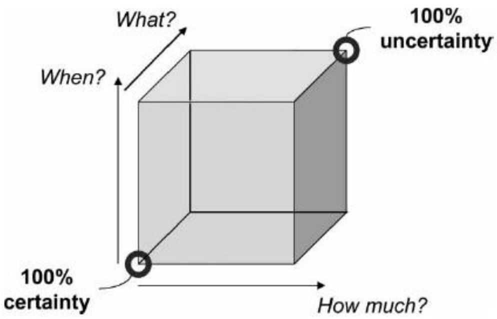

Figure 17: The uncertainty cube (Wikner & Rudberg, 2005)

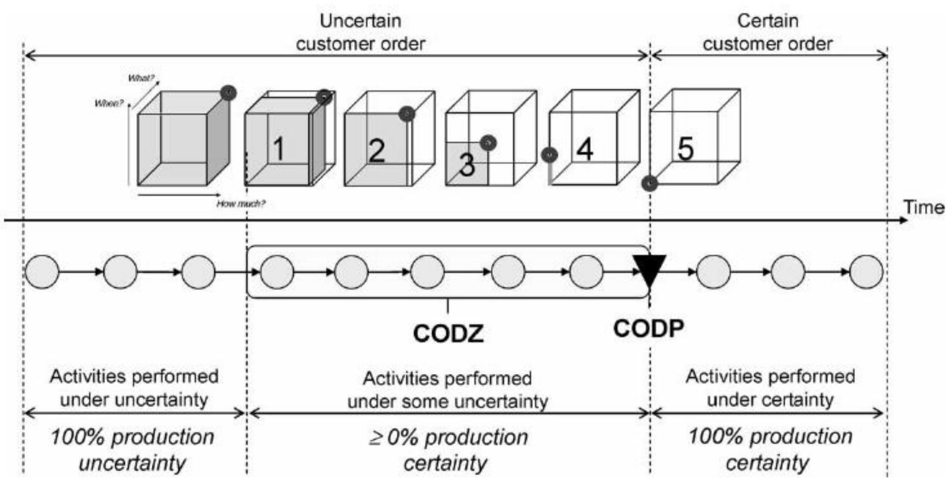

Figure 18: The customer order decoupling zone (Wikner & Rudberg, 2005)

Wikner and Rudberg (2005) suggest eight key decisions that must be made in relation to the CODP:

1) Position of the beginning of the CODZ

2) Position of the end of the CODZ
3) Deciding on a strategy before the CODP (MTS based)
4) Deciding on a strategy after the CODP (MTO based)
5) Decide on an uncertainty profile for the CODZ
6) Sizing of the total volume of the CODZ buffer
7) Decide on how to allocate the buffer in the CODZ (how to create a buffer that combines the features of a material buffer with those of a capacity buffer)
8) Decide on a strategy within the CODZ (MTO or MTS). Support for this decision can be derived from the uncertainty profile of the CODZ.

The different product-delivery strategies are modeled to facilitate choosing between them (Olhager, 2003), see Figure 19. Depending on the aforementioned P:D ratio and the relative demand volatility (coefficient of variation, i.e. the standard deviation of demand relative the average demand) a certain strategy is suggested.

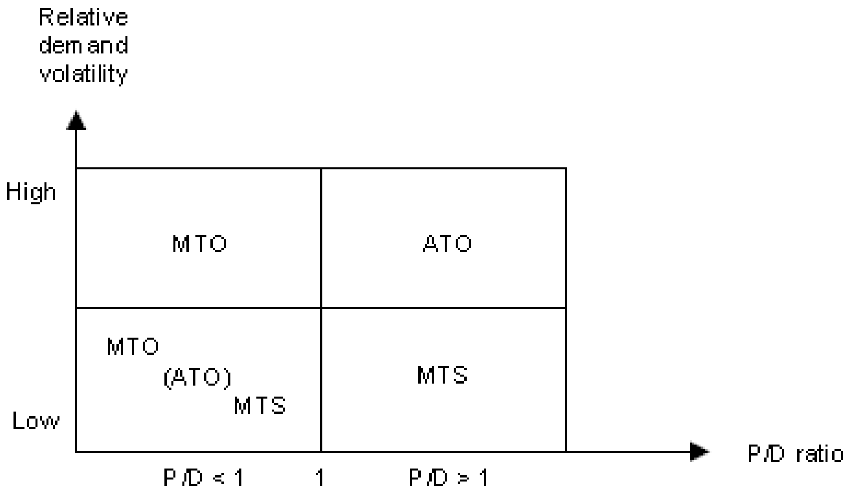

Figure 19: Model for choosing product- delivery strategy (Olhager, 2003)

What becomes apparent from the model of Olhager, and what is intuitively true, is that an MTO strategy is only feasible in case of a P:D ratio less than 1. Furthermore, an MTS strategy can best be deployed with low relative demand volatility.

Next to the aggregate level at which the ETO, MTO, ATO and MTS strategies are described, Verdouw et. al. (2008) describe the diversity of CODPs in practice by distinguishing CODPs in four dimensions. The dimensions described by Verdouw et. al. are the existence of the different CODPs per:

- Product, or product-market combination;
- Product component;
- Level of customer commitment;
- Interface in the chain network.

The customer requirements for a product and the delivery of products can result in different CODPs for specific product or product-market combinations within the same company. It is also possible that customization differs at the level of a product component which may lead to different CODPs for a single product. Verdouw et. al. further describe the difference between a contract and an call-off order for the same product with the same customer, resulting in a range of possible CODPs. Finally, in a supply chain network there is not a single CODP but the interfaces between supply chain partners results in CODPs.

Paragraph 4.3: Aspects involved in the position of the CODP for Rotor

We described the current logistical situation in Chapter 3 and there it became evident that at the moment Rotor has three different manufacturing concepts of integral control, namely PTO, RTO and DFS. Since Rotor is a wholesaler, the three concepts are similar to the customer order decoupling point (CODP) concepts for manufacturing firms. Deliver from stock is make-to-stock (MTS) and purchase to order is make-to-order (MTO).

Reconfigure to order is interesting because it is not described by Hoekstra and Romme (1992). It originates in the decision to bridge the gap in supplier (production) lead times and requested customer delivery times. The gap is bridged by keeping motors on stock in Eibergen and deploying a competence centre in which reconfiguration of motors is possible. This way, almost every motor can be produced in a relative short amount of time. These manufacturing concepts of integral control are summarized in Table 4.

Traditional manufacturing firms	Rotor (wholesaler)
Make To Order (MTO)	Purchase To Order (PTO)
Assemble To Order (ATO)	*Not used by Rotor*
Not described in literature	Reconfigure To Order (RTO)
Make To Stock (MTS)	Deliver From Stock (DFS)

Table 4: Manufacturing concepts of integral control for traditional manufacturing firms versus Rotor (wholesaler)

We described in Paragraph 4.2, that the main competitive priority related to the CODP positioning is delivery speed. As we described in the introduction in Chapter 1, delivery speed is an important competitive factor for Rotor. As mentioned before, Rotor bridges the gap in production and delivery lead time and this aspect is an integral part of Rotors raison d'être.

Furthermore, Rotor cannot produce the motors itself (e.g. the casting of the house) but can only reconfigure certain characteristics (e.g. adding/removing flanges, painting).

Summary of important aspects with respect to the position of the CODP:
- *Bridging the gap between (longer) production lead times and (shorter) delivery lead times.*
- *Delivery speed is competitive factor*
- *No motor production, only reconfiguration*

When we take the above mentioned aspects into consideration, the only viable conclusion with respect to the CODP position we can draw is, that it should be positioned at Eibergen. The reason for this is that Rotor has to keep motors on stock (finished products) since it cannot produce them itself. In addition, Rotor thrives on assuring speedy delivery and fills a niche market by bridging the gap in production and delivery lead times.

Paragraph 4.4: More than one CODP for Rotor?

But, is one single CODP enough for Rotor? To answer this question we apply the theory of the P:D ratio to the different products-market combinations at Rotor.

As we learned in Paragraph 4.2, the P:D ratio can be used to decide whether a product is more suitable to be made to stock or to order. Moreover, we discovered that the uncertainty in customer demand information is mainly concerned with the “when” issue.

The supply characteristics outlined in Chapter 3 made clear that production lead times are generally longer than the requested delivery lead times of customers, especially service partners and dealers. The product requested by those customers are thus candidates to keep on stock, wherever that stock may be located. The CODP for these motors is then located at the sales department, deciding whether a motor can be sent directly to the customer of whether reconfiguration is necessary.

On the other hand, delivery lead times requested by OEMs are generally speaking longer than the production lead times. This would mean, following literature on the P:D ratio, that the motors requested by the OEMs do not necessarily need be kept on stock. These motors can be purchased (produced) at the moment a customer request is received. Hence, the CODP for these motors is situated at the purchasing department of Rotor and should be PTO.

We see now that there can be a split in the CODP for Rotor and that one single CODP does not suffice anymore. As described in Paragraph 4.2, there is a different CODP for each product-market combination. PTO for the OEMs and DFS for the service partners. The RTO strategy enables Rotor to change certain product characteristics in Eibergen and is an addition to the DFS strategy. However, the department at Rotor where the decision is made whether a motor should be purchased, reconfigured in the competence centre or directly delivered from stock is the sales department. Or, more precisely, it is the Enterprise Resource Planning (ERP) system, Microsoft Dynamics AX 4.0 (AX 4), that makes this decision after sales enters a sales order. AX 4.0 bases the decision on the current production lead times and the motors on stock and their reconfiguration possibilities. AX 4.0 creates s purchasing order for motors with a longer requested delivery lead time than the production lead time and for motors that are not kept on stock and cannot be reconfigured from a stock motor. For motors that have delivery lead times shorter than the production lead time, AX 4.0 creates either a production order (if reconfiguration is necessary) or a shipping order.

With the decision being made at the sales department of Rotor, there are three CODPs that Rotor should use, based on the penetration of the customer order in the business process. Either purchasing, reconfiguration or shipping activities are performed after the customer order is received. The three manufacturing concepts of integral control that Rotor currently uses (PTO, RTO and DFS) can be maintained. Although many organizations use only one CODP and operate solely on either ETO (e.g. exclusive yacht building), MTO (e.g. automotive), ATO (e.g. computer industry) or MTS (e.g. apparel, fast moving consumer goods) strategy, there are also many companies that do use multiple CODPs (Verdouw et al., 2008). In this aspect Rotor is not unique.

The notion of multiple issues (what, how much, when and where) that form the uncertainty in customer demand information, as presented in Paragraph 4.2, is interesting when it is clear that parts of customer information become certain in time. Unfortunately, this is not the case. Forecasting customer demand is very difficult. Notwithstanding these difficulties, the concept of the uncertainty cube and the CODZ can be used by Rotor when it is possible to change running orders (claiming of capacity) at the manufacturer, as is pointed out in Chapter 3. Of course, to be able to appropriately execute this, at least some of the aspects of customer demand must be known or be forecasted with a reasonable certainty.

Paragraph 4.5: Influence of the CODPs on Rotor

The main influence the position of the CODP has on the stock is that Rotor should be able to respond to all demand with a requested lead time shorter than the actual production delivery lead times of the supplier(-s).

The three CODPs, as determined in Paragraph 4.4, are currently used by Rotor, as we described in Chapter 3. The organization around the CODPs is as follows. The sales department (Contact Center) is responsible for entering the sales orders in AX 4.0. The ERP system then determines how far the order penetrates the organization, i.e. whether the corresponding CODP is PTO, RTO or DFS. The sales department is in close contact with both the purchasing and the production departments to ensure that the customer order can indeed be processed within the requested time. The purchasing department (Contact Center) is responsible for the purchasing of motors for customers (PTO, orders with P/D ratio >1) and for purchasing motor to keep on stock in Eibergen. In the next Chapter we determine what motors should be kept on stock. The production department (Competence Center) reconfigures the motors according to the customers whishes (RTO). Finally, the shipping department (Competence Center) is responsible for the secure packaging and shipping of the motor to the customer (DFS).

Since Rotor already uses the three CODPs the impact of our findings in the chapter on the organization is limited. What does change is the way Rotor handles its stock. Rotor should be more aware why stock is kept at the location in Eibergen and for which customers. The two more classic CODPs, PTO and DFS now distinctly separate the two PMCs which Rotor recognizes. The RTO strategy gives Rotor an good opportunity to cost effectively organize the bridging of the gap between production and delivery lead times, a core competence. This is a contribution to our main research question and in Chapter 5 we research the possibilities to combine the DFS and RTO strategies and standardize the stock.

Paragraph 4.6: Conclusion

The conclusion of this chapter is that the Rotor should continue using the three CODPs it already uses. DFS at the shipping department, RTo at the production department and PTO at the sales department. The ERP system determines whether a motor will be purchased, reconfigured or simply delivered from stock.

By placing the CODPs there, the company is able to decouple the customer order from the production and delivery time of the manufacturer. The main order winner of delivery speed is thus secured. The position of the CODPs also contributes to the flexibility of Rotor, because next to the warehouse of Rotor is the Competence Center in which numerous reconfigurations can be carried out to customize the product. Despite the fickleness of production lead times and erratic movements of demand Rotor will be able combine mass customization, competitive delivery times with cost efficient logistic processes.
The three manufacturing concepts of integral control that Rotor currently uses are, after the reevaluation of the position of the CODP, maintained.

In Figure 20, the product delivery strategies are placed in a model similar to the model of Olhager (2003) that we saw in Chapter 4, with the P:D ratio and the relative demand volatility on the two axes. Only when the delivery lead time is larger than the production lead time (a P:D ratio smaller than 1) can Rotor purchase the motors to order (of course, if this is technical and technological possible). When the requested delivery lead times are shorter than the production lead times (a P:D ratio greater than 1) motors with stable demand or low demand volatility should be kept on stock in Eibergen and finally, the motors with a relative high demand volatility should be reconfigured to order. This way, there is less risk in stock, flexibility for orders with short delivery lead times and a greater margin can be attained by outsourcing all orders with a P:D ratio smaller than one.

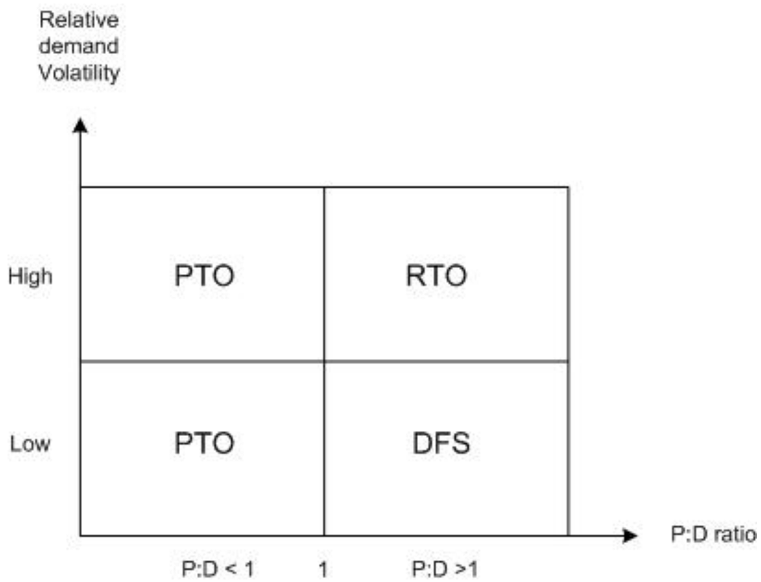

Figure 20: Rotor's product-delivery strategies and the corresponding CODP's

With the position of the CODP determined, we now know that the RTO strategy can give Rotor an advantage and the next step is to research the standardization of the stock upstream of the CODP. This research is carried out in Chapter 5.

Chapter 5: Clustering and Standardization upstream of the CODP

Paragraph 5.1: Introduction

In the previous chapter we have positioned the CODP of Rotor. The following step in our research is standardization upstream of the CODP.

This chapter is built up as follows. First we review relevant literature on standardization and clustering in Paragraph 5.2. Furthermore, we review literature on customization, because this is what Rotor wants to accomplish, customization downstream and standardization upstream of the CODP. After reviewing literature we explain the method used to standardize and cluster the motors of Rotor in Paragraph 5.3. Then in Paragraphs 5.4 and 5.5 we describe the results of both approaches and in Paragraph 5.6 we combine the two approaches into one final result. At the end of the chapter there is a concluding paragraph.

With these steps we answer the second research question:

2. *What is the best way of creating standard stock so that Rotor can combine internal standardization with customization towards customers?*

Paragraph 5.2: Literature concerning standardization and clustering

In the Chapter 4, we reviewed literature concerning the CODP and how to position this point in the supply chain. Subsequent to the positioning of the CODP, Visser and Van Goor (2004) stress that it is important to standardize products and production upstream of the CODP. Were there to be variation in products and production, multiple forecasts would be needed. A combination (after standardization) would be much easier to forecast.

Rotor wants to combine customization with cost efficient production and logistics. The concept of postponement is, according to Feitzinger and Lee (1997), the key to mass customization. Postponement can be split into time postponement and form postponement (Zinn & Bowersox, 1988), (Brown, Lee, & Petrakian, 2000), (Su, Chang, & Ferguson, 2005). Time or process postponement (logistical postponement) denotes the delaying of the product differentiation by manufacturing and distribution system design. Form or product postponement denotes the delaying of customization (modular design, standard components) by product design. As we have seen in the previous chapter, Rotor keeps finished products on stock and, based on actual customer demand, reconfigures these motors. This is not form postponement but it does have commonalities with time postponement. Although Rotor uses final products instead of semi-finished products, the final customization can be delayed using the reconfiguration possibilities in the Competence Center in Eibergen.

As Boylan et. al. (2008) describe, different stock keeping units (SKUs) require different methods for forecasting and stock control. These differences are based on the different underlying demand patterns of the SKUs. Consequently there is a need to categorize the SKUs and apply the appropriate method of forecasting and stock control in each category. The categorization or clustering of products can be carried out based on demand patterns, and often statistical clustering algorithms are used (Pepall, 1990) (Quintana & Iglesias, 2003).

In Chapter 3, we described the demand characteristics of Rotor. Due to the variability and the difficult predictability of customer demand these methods are less useful. However, the main reasons we cannot use the statistical clustering algorithms is that Rotor has an infinite number of products and historic demand is hard to specify due to the data contamination in the ERP system. So predicting future demand with the use of historic demand is also very hard. What can be said about the demand patterns is that OEMs normally accept longer lead times in contrast to service partners and dealers, who, in their turn, require very short delivery times.

If we compare the reconfiguration strategy with customization strategies described by Lampel and Mintzberg (1996), see Figure 21, it is somewhere between customized standardization (ATO as described in Chapter 4) and tailored customization (MTO/PTO as described in Chapter 4).

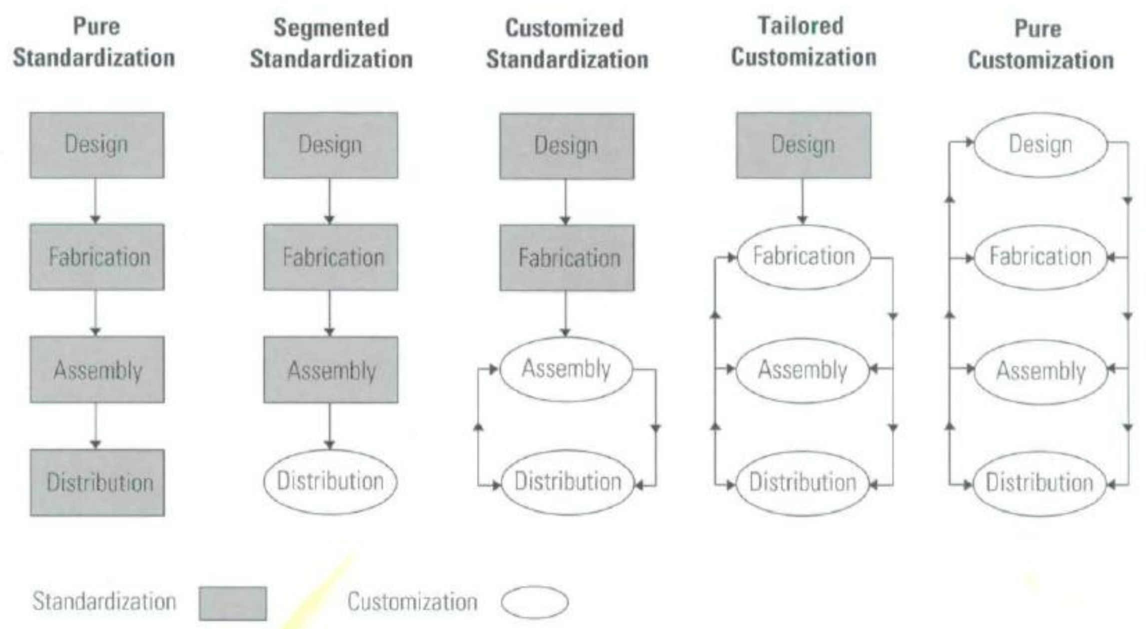

Figure 21: A continuum of strategies(Lampel & Mintzberg, 1996)

The fact remains that Rotor is not a manufacturer but a wholesaler with reconfiguration possibilities and moreover that Rotor uses finished products instead of semi-finished products (parts). An important similarity between the strategies described by Lampel and Mintzberg and the strategy used by Rotor is the influence of the customer. As Lampel and Mintzberg describe, the customers a company wants to serve determines how much customization an organization incorporates in its processes. The customers of Rotor demand motors specific for their product or application. To make this possible, Rotor can either purchase the motor as requested or deliver it directly from stock, if the motor is kept on stock. Furthermore, the customers' whishes determine whether or not reconfiguration is needed, and in what way.

In both the automotive and the personal computer industries the race for mass customization has been going on for several years. Customer-driven customization (Lee & Lee, 2005) and the involvement of the customer (Alford, Sackett, & Nelder, 2000) result in more and more choices for the customer but ever increasing costs for the manufacturers. This drives their need for organizing customization in a cost efficient way. Several strategies have been adopted, most of which resemble the strategies described by Lampel and Mintzberg.

We discovered that Rotor uses a postponement strategy with resemblance to time postponement. This is because with the reconfiguration possibilities of the Competence Center the customization (differentiation) of the final product is delayed. Furthermore we saw that the application of clustering algorithms is not possible. Finally we became aware that the reconfiguration strategy is unique to Rotor and places it somewhere between assembly and fabrication with respect to the most common strategies for standardization and customization. Unfortunately, we did not find a clear method for standardizing the stock of Rotor to accomplish offering customization in a cost efficient way.

Paragraph 5.3: Approach to standardization of stock

As we saw in our literature review in the previous paragraph, there is not a clear method for standardizing Rotor's stock. By combining some elements from literature, adapting these to the situation at hand and by conducting expert meetings and interviews we develop a method to standardize or cluster the motors. We use the expert meeting and interviews to benefit from the expertise of knowledgeable employees of Rotor in our quest to categorize or cluster the products.

The method we develop to standardize the stock is a combination of two approaches. First we use perceptual mapping via a classification schema to determine which motors need to be kept on stock based on the motors currently kept on stock. The second approach is an ERP analysis in which we adopt a higher level of abstraction and define the unique elements of a motor. We opt for this dual approach because this allows us to combine the knowledge and experience of those employees of Rotor that work on a day to day basis with the stock with the unique similarities and differences between all motors via a high level of abstraction. Our final solution is the combination of the two approaches. This method is visualized in Figure 22.

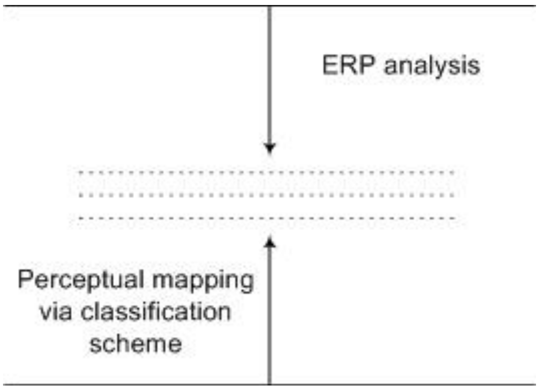

Figure 22: Visualization of the two approaches to standardize the stock

The employees we interview and let participate in the expert meetings are first of all the people summarized in Table 3. Furthermore, the senior manager and assistant manager of operations, the IT specialist and the company controller are asked to join the expert meetings. For the ERP analysis we team up with two employees who both have experience with the motors as well as experience with the ERP system and data collection and processing. The team members for the first approach are the purchase manager and the manager logistics.

The first approach is a combination of elements of perceptual mapping and a classification scheme. Perceptual (or projective) mapping, often the result of multidimensional scaling is a technique , regularly used in the field of marketing, to visualize consumer perceptions related to products or services. Positional mapping was first proposed by Hotelling (1929) but the most common type of map used in marketing, the perceptual map, was first proposed by Johnson (1971). As Urban and Hauser (1993) describe, the emphasis of perceptual mapping is on psychological positioning, not physical characteristics. This is where our approach differs, because we explicitly position motors based on their physical characteristics. In Figure 23 an example of a perceptual map is provided.

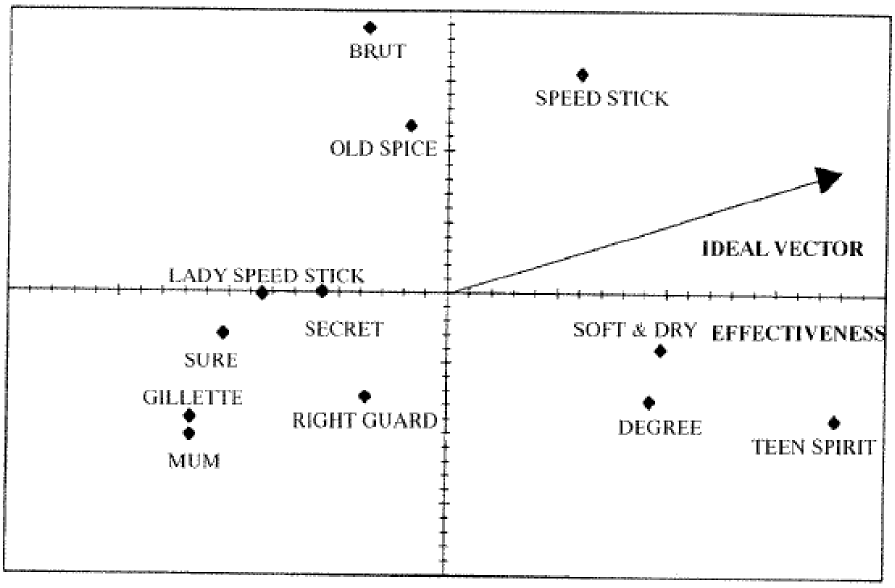

Figure 23: Example of a perceptual map of U.S. target market's perception of deodorant brands (Ganesh & Oakenfull, 1999)

Often a two dimensional scale is used but it is possible to use more than two scales. Visualization in a map however, would then be difficult and incomprehensible. The perceptual mapping technique can be used to determine the best strategy for new product development, the expected market share and the influence on the market share of close competitors. The method of expert meetings is similar in its approach to data clustering and product positioning as perceptual mapping, but as explained we look at physical characteristics.

We develop the classification scheme with the experiences and knowledge of Rotor's employees, gathered in the expert meetings.

To clarify the methods and the result of the clustering and standardization we use a running example. The example is introduced in this paragraph. The example is split into two paths, representing the two different approaches. In Figure 34 in the Appendix, the structure of the running example is visualized. The next paragraph deals with the perceptual mapping via a classification scheme and the subsequent paragraph deals with the ERP analysis.

Example 0: Introduction

Customer: I would like a motor for my ship. It will be used to bring in the anchor and needs to have around 30 kW. of power.

Rotor: What information do we need to find the "best match motor"?
We know that we sold 75.000 motors in 2007 and 77.000 motors in 2008.
How can we categorize these motors?

Paragraph 5.4: Bottom-up: Perceptual mapping via a classification scheme

The starting point of the meeting with the purchaser and the logistics manager is a list of different motors kept on stock on the 1st of September 2008. The number of SKUs on stock is a little over 1300 (whenever we mention motors in this paragraph we mean SKUs or configurations) and the number of motors with prescribed safety stock is 1437. The main reason this list is used is that this list consist of all motors with a safety stock and it was developed over the three years that MS Axapta 3.0 was in use. It incorporates the knowledge and experience with the electric motors of Rotor of both the purchasing and logistic managers and by starting from this list and working together with these employees, that knowledge can be put to use once more.

To give an idea of the information provided on the list of motors that is used as starting point, a sample of the list is presented in Table 6. Our goal is to figure out which motors should be kept on stock and which motors could be omitted. Furthermore, we aim at not more than 200 SKUs on stock. This would mean a significant reduction but it is a fictive number to stimulate us to be very strict in the reduction process. Due to their expertise, the purchase manager and the logistics manager are key employees to help with this exercise.

The following steps are taken during the meetings with the purchase manager and the logistics manager as part of the bottom-up approach:

- Categorization of motors into classes using the classification scheme;
- Reviewing each class per motor group and determining standard motors based on average demand per month and the possibilities for reconfiguration;
- Reviewing the motors that are difficult to classify;
- Defining the standard stock list and specific stock list;

Categorization of motors into classes

The first step is to create insight in the list of over 1300 motors. In order to create this insight we develop a classification scheme to categorize the motors into classes based on area of application and some inherent motor characteristics. The complete list of classes is depicted in Table 5. The classification scheme reflects the differences in the motors as is commonly used by the company and in the line of business. Of course, the category “Not from main supplier” is inherent to Rotor since it purchases most motor form this supplier and the percentage of motors purchased elsewhere is very small.

Classes
5RN (efficiency 2)
5RE (ATEX)
5RB (without cooling)
5RC, 5RCC (Single phase)
Not from main supplier
Other
Pole changing
Brake
2nd shaft end
Longer shaft
Universal mounting

Table 5: Classes defined to categorize motors

The classification scheme is a two stage process. First, we classify motors based on their area of application into one of the first six classes from Table 5. We review the largest and most common classes first. In this way, the classification process can swiftly identify an appropriate class for a motor. Next, we determine whether a motor has specific characteristics and, if so, remove the motor from the original class and classify it as a different class. Again, we review the largest and most common classes first. The diagram of the division of classes can be found in the appendix, Figure 24.

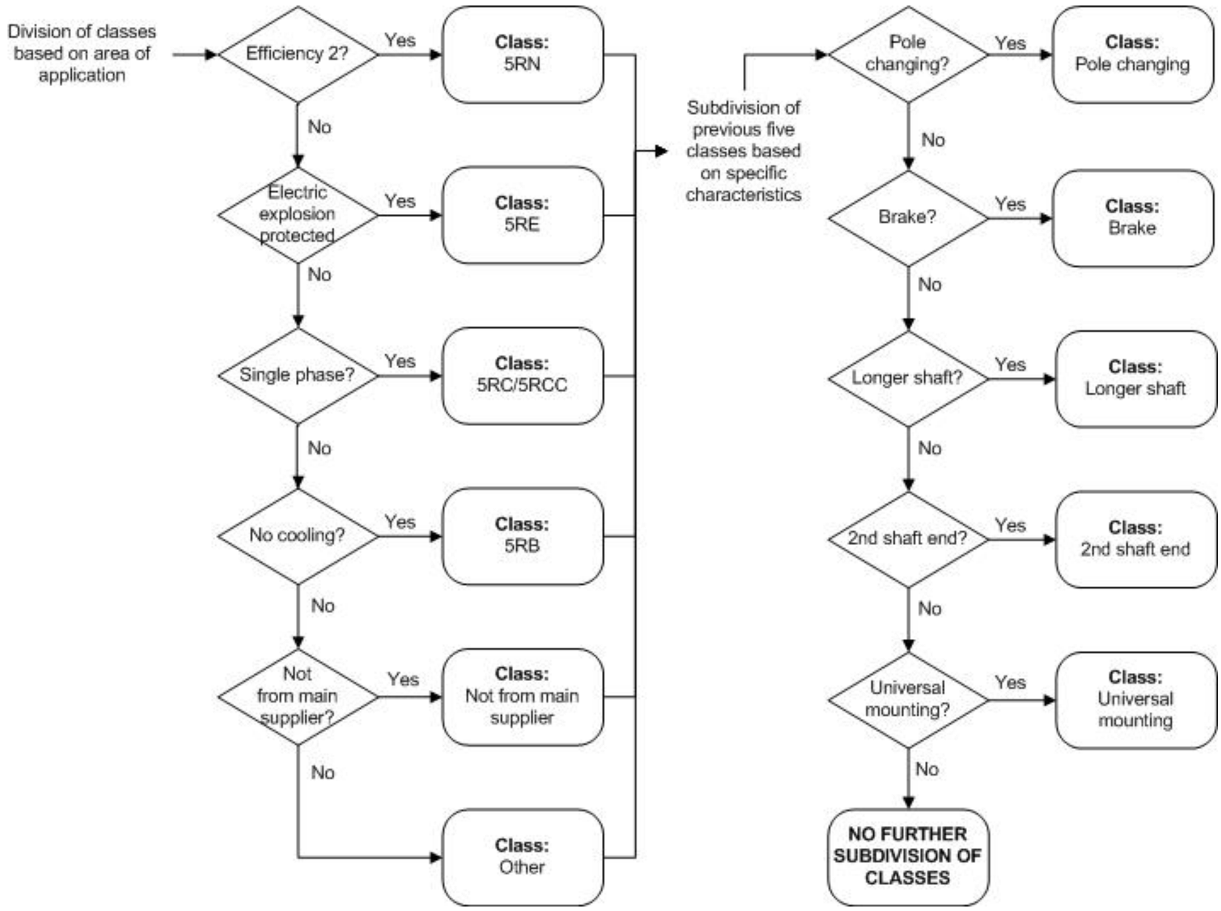

Figure 24: Division of motors into classes

Example 1.1:

Customer: I would like a motor for my ship. It will be used to bring in the anchor and needs to have around 30 kW. of power.

Rotor: By categorizing the motors in ten classes we can easily determine in which class the motor the customer wants can be found. In this case the customer wants an efficiency 2, 5RN motor. Most motors sold by Rotor are 5RN.

Reviewing the classes per motor group

The following step in the bottom-up approach is to review the classes of motors per “motor group”. This “motor group” is used in the ERP system even before this research commenced and is an amalgamation of other characteristics of the motor, namely the area of application, the IEC house size (including stator package length) and the pole number (including torque). In Table 6 a part of the motor list is shown for Class “5RN”, “motor group” “5RN180L04A6” (area of application: 5RN; IEC house size: 180L; pole number 04A6) and IEC mounting “IM1041”.

Art. number	Min. stock	Motor group	IEC Moun-ting	Average demand (per month)
A000020***	2	5RN180L04A6	IM1041	0,5
A000020***	1	5RN180L04A6	IM1041	0,33
A000020***	0	5RN180L04A6	IM1041	0,08
A000020***	60	5RN180L04A6	IM1041	15,83
A000020***	1	5RN180L04A6	IM1041	0,33
A000020***	2	5RN180L04A6	IM1041	0,17
A000032***	1	5RN180L04A6	IM1041	0,08
A000047***	0	5RN180L04A6	IM1041	0,5
A000061***	1	5RN180L04A6	IM1041	
A000283***	0	5RN180L04A6	IM1041	
A000292***	0	5RN180L04A6	IM1041	
A000308***	0	5RN180L04A6	IM1041	0,67
A000308***	0	5RN180L04A6	IM1041	1,83
A000309***	0	5RN180L04A6	IM1041	0,08

Table 6: Sample of article list (MOT B, IEC house size 180)

According to our expert meetings, the most important attributes with respect to the motors and whether or not they should be kept on stock are the following:

- Average demand per month of the motor
- Possibilities for reconfiguration of the motor

Each “motor group” within each class is consequently reviewed based on these two attributes and per motor it is decided whether it would be a “standard motor” or not. Within each “motor group” at least one motor is selected. That way, all others can be made by reconfiguring the selected motor. With this choice, it is important to recognize that some mounting positions cannot be made from other positions. This means that within a “motor group” multiple motors where selected if the mounting position was different and the average demand per month and the possibilities for reconfiguration supported this decision. Figure 29 is a detailed overview of the IEC mounting positions. This figure is placed in the Appendix.

If there is uncertainty about a motor we place the motor on a separate list to be reviewed later on with the help of the Sales department.

The result of this exercise is a total number of 536 SKUs divided among the earlier defined classes as shown in Table 7. It is important to realize that this is not the number of motors to keep on stock, but merely the number of SKUs to keep on stock. Within certain “motor groups” more than one motor is selected as a “standard motor”. This decision is based on the average demand per month and the possibilities for reconfiguration. No motors where selected in the class “other”.

Classes	Proposed number of SKUs
5RN (efficiency 2)	295
5RE (ATEX)	54
5RC/5RCC (single phase)	50
5RB (without cooling)	1
Not from main supplier	39
Pole changing	46
Brake	14
2^{nd} shaft end	7

Longer shaft	15
Universal mounting	15
Total number of SKUs	**536**

Table 7: Defined classes and proposed number of SKUs

Example 1.2:

Customer: I would like a motor for my ship. It will be used to bring in the anchor and needs to have around 30 kW. of power.

Rotor: If the customer knows how much power he needs we can use the motor class and "motor group" to find the available motors on stock. Any deviations from these motors can be reconfigured in the competence centre.

Reviewing the motors that are difficult to classify

As explained, some motors are difficult to classify because in the "motor group" there was not one motor with a distinctly high average demand per month or the motor has so much options and was put on stock in the first place because Sales once requested this.

To come to a decision on these motors we ask the senior manager Business Development and Sales to address these customer specific motors. In Table 8 a part of the questionnaire is given which is handed to this senior manager. His expert opinion is asked for a total of 89 motors.

Article number:	Purchase: Yes/No
A000023***	…
A000041***	…
A000042***	…
A000043***	…
etcetera	…

Table 8: Part of questionnaire about customer specific motors for the senior manager sales and business development

Finally, the competence centre requested some additional motors to be kept on stock based on the reconfiguration possibilities of certain difficult classes such as 2nd shaft end and longer shaft. This would greatly benefit the quality of the end product as well as reduce the production (reconfiguration) time needed. These motors are added to the "specific motors list" and can be sold as such but can also be used to reconfigure to create a customer specific motor.

Example 1.3:

Customer: I would like a motor for my ship. It will be used to bring in the anchor and needs to have around 30 kW. of power.

Rotor: We can check whether or not the motor is on stock. If not we can select a motor from the same "motorgroup" and perform reconfigurations at the competence centre. And if the requested delivery time by the customer allows it, we can always order the motor from our supplier.

Defining the standard stock list and the specific stock list
The result of this bottom-up approach is a list of 546 standard stock motors (SKUs). This is a reduction of 58% compared to the number of motors which had a minimum stock level at the start of September 2008. Moreover, the selected motors and reconfiguration possibilities offered by the competence centre, enable Rotor to supply 93% of all motors sold in 2008.

Next to this list there is a list of special stock motors (again: SKUs) on which some customer specific motors are placed together with specialized motors requested by the competence centre. This list contains 59 motors.

It is important to realize that these two different kinds of stock require different methods of management. The standard motors can be managed with the safety stock while the specific motors should be managed on a case-to-case basis, in cooperation with sales and the competence centre.

The “standard motors list” and “specific motors list” can be used to find the appropriate motor for a customer whenever the requested delivery lead time is shorter than the production lead time and thus the motor has to be provided by either the warehouse or the competence centre in Eibergen.

The first approach of our method is finished. We found an acceptable number of standard motors that cover 93% of sales over 2008. In the next paragraph we continue with the ERP analysis to uncover the unique elements of a motor and to see whether it is possible to standardize the stock even more.

Paragraph 5.5: Top-down: ERP analysis

For this approach we team up with the general director and the IT developer. Both have experience with the electric motors of Rotor. Furthermore, the IT developer has a profound knowledge of the ERP system and has personally developed several add-on’s for the system.

In the top-down approach we take the following steps:

- Determining unique elements that define a motor (on a higher level of abstraction)
- Voltage analysis
- Data cleaning in the ERP system
- Clustering IEC mounting positions
- Defining Configure Bases and Motor Bases

Determining unique elements that define a motor
Firstly, to start the search for unique elements, the current situation regarding motors is given an in-depth view in Table 9. As a short explanation: MA stands for a motor without an additional bill of material (BOM). MSA stands for a Motor with additional BOM (options added at the competence centre of Rotor). These abbreviations have been used for years within Rotor.

	Including MSA	Excluding MSA
Number of **articles** in the Article File (Dutch: artikelbestand)	20830	
Number of motors in the supply program	7435	6314
Number of SKUs (motors)	1479	1437

Table 9: Current situation regarding motors

Now we know how many motors there are in the supply program and how many of these motors are SKUs for Rotor. We do have to realize that the number of motors in the supply program is not the maximum number of motors possible. For this we would like to refer to Paragraph 3.3 on product variants and modularity.

For the Top-down approach we want to know what uniquely defines a motor. To answer this, the first thing we have to realize is what Rotor buys from its supplier and what Rotor reconfigures itself. As described in Chapter 3, Rotor can purchase any motor from its supplier(s). Figure 25 shows a simplified supply chain of electric motors.

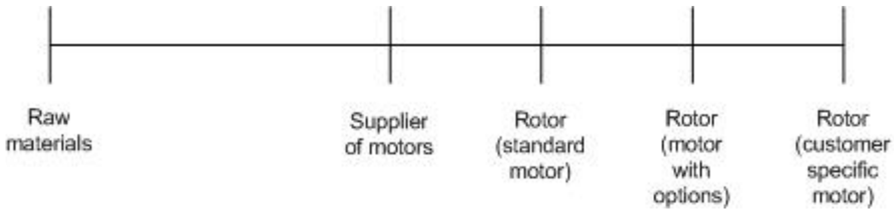

Figure 25: Simplified supply chain ranging from raw materials to a customer specific motor

At the Competence Center of Rotor no electric characteristics of a motor are changed. The reconfiguration pertains merely to mechanical characteristics. For example the stator package length, the winding, the pole number and the power of a motor are not changed. Reconfiguration can change the IEC mounting position, the protective coating of a motor, the number of PTC's (positive temperature coefficient) used in the motor, the presence of brake or a heating and so on. So, back to Figure 25, we want to know what characteristics of a motor are inherent to the motor as soon as it is transferred from the supplier to Rotor and never changed by Rotor and can consequently be used to uniquely define a motor.

Example 2.1

Customer: I would like a motor for my ship. It will be used to bring in the anchor and needs to have around 30 kW. of power.

Rotor: Well, we have infinite possible motors for you to choose from. Last year alone we sold around 77.000 motors. What kind of motor should we select for the customer. How do we find the "best match motor"?

What elements of a motor are not changeable by us? If we know this, we can determine whether we can reconfigure the motor at Eibergen or we need to order the motor from the supplier.

In Table 10 the characteristics of electric squirrel cage motors are listed along with some examples. It is from these characteristics that we work out the elements that uniquely define a motor.

Characteristic	Examples
Material of house	Iron, aluminum
Area of application	5RN (efficiency 2), 5RE (ATEX), 5RC (single phase), 5RCC (single phase), 5RF (efficiency 1), 4RD (explosion proof)
Duty	S1 (continuous operation), S2 (brief operation), S3 (periodic operation)
IEC house size + stator package	56, 132M, 180L, 280S, 315M
Pole + winding package	02A6 (2-pole), 04 (4-pole), 21 (4/2 pole

	changing)
Power	2,2 kW, 4 kW, 36kW
Voltage and frequency	400V 50 Hz, 440V 60 Hz,
Flange /shield	FF 265, FT 115
Mounting positions	IM1081, IM3041
Protection class	IP55, IP56
Options	Cooling, brake, PTC Thermistor, RAL number
Marine & offshore	Bureau Veritas, Det Norske Veritas, Lloyd's Register of shipping

Table 10: Motor characteristics (Rotor, 2005)

As we determined in the previous paragraph, Rotor has already defined an attribute of the motor named "motor group". The characteristics amalgamated in this attribute are the area of application, the IEC house size and the pole and they are used for this attribute with good reason. Our search for unique elements or characteristics of the products came up with four elements that are not changed by Rotor. These four unique elements form a base from which other elements follow.

- The model of the motor (area of application)
- The frame of the motor (IEC house size with length of stator package)
- The stack of the motor (number of poles, length of the tin package, torque)
- IEC mounting number

The first three elements correspond to the elements of "motor group".

The reconfiguration or rework that is carried out in the competence centre only changes the mechanical characteristics of the motor. The electrical characteristics remain unchanged. It is this knowledge that led to the conclusion that there are a few aspects that uniquely define a motor. For the point of view of Rotor, it is on these aspects that motors can be compared.

Example 2.2

Customer: I would like a motor for my ship. It will be used to bring in the anchor and needs to have around 30 kW. of power.

Rotor: The customer needs a motor that delivers 30 kW. This is common for a motor with frame size 132M, with 4 poles. Furthermore, the motor will be placed on deck so it would be an foot-motor, but it is not yet clear how it will be mounted. Last but not least, the area of application is normal efficiency 2, so a 5RN motor will do fine.

Voltage analysis

To be sure to capture all the necessary unique elements that define a motor, we also research the voltage (and frequency) of motors. The reason to do this is that Rotor (the Competence Center) cannot change this characteristic. The result of this research is that most motors are sold with 230V 50 Hz (or 400V Y, star) and 400V 50Hz (or 400V D, triangle). To ensure a limited number of unique elements the decision is taken to consider 230V 50Hz and 400V 50Hz standard and all other voltages and frequencies as an option.

Voltage (U)	Number of transactions	Percentage
0	191	0,2%

110	54	0,1%
200	1050	1,3%
220	299	0,4%
230	49891	62,8%
360	6	0,0%
367	908	1,1%
380	674	0,8%
400	25486	32,1%
440	81	0,1%
500	559	0,7%
690	271	0,3%
Total	**79470**	**100%**

Table 11: Analysis over 2008 over all models of different Voltages

Besides the voltages mentioned in Table 11 the following voltages are found in the Article File: 42, 56, 115, 120, 127, 208, 240, 254, 265, 266, 277, 288, 290, 332, 415, 450, 460, 480, 525, 550, 575 and 600 volt. But for all these voltages applies that there were no transactions during 2008. According to the purchaser and the logistics manager these where created for certain customers in the past and served as single orders without repetition.

Of all motors with transactions in 2008 only 5,1% of all transactions are for motors with a different voltage than 230V of 400V. Further analysis has led to the conclusion that of the 49891 230 volt motors, only 398 (0,8%) had a power > 2,2 kW. Of the 25486 motors with 400 volt, only 632 (2,5%) had a power =< 2,2 kW. This is however no surprise, the 230 and 400 voltages are the default voltages and the turning point is at 2,2 kW (Rotor, 2005).

With this result from the voltage analysis we decide not to use voltage as the fifth unique element but rather opt for the default voltages, being 230V 50 Hz for motors with power =< 2,2 kW and 400V 50 Hz for motors with power > 2,2 kW.

Data cleaning in the ERP system

A problem we encountered is the data contamination in the ERP system, which was already mentioned in Chapter 1 as part of the origin of the problem.

To resolve this problem we perform data cleaning in the ERP system. Our attention is focused on two types of data, namely the IEC house sizes and the poles. In Table 12 a sample is given of the data cleaning we perform on the poles of motors. As can be seen, there are several styles of denoting the number of poles and we make sure we eliminated all the “doubles” and end up with a uniformly described number of poles for each motor. A similar exercise is carried out for the IEC house sizes.

Old	New	Old	New
2	02	08	08
02	02	8	08
2D	02	B8	08
2T5	02T5	-8	08
B2T5	02T5	23	23
02A3	02A3	8/4	23
02A6	02A6	B8/4	23

Table 12: Sample of data cleaning in poles

Clustering the IEC mounting positions

To further cluster the motors based on unique elements we opt to cluster the mounting positions. This choice is motivated by the fact that all foot motors (including foot – flange motors) can be reconfigured into one another. The same holds for flange motors. By clustering the IEC mounting number to only accommodate the fact whether a motor has a foot (with or without a flange) or just a flange reduces the IEC mounting number to one digit. Next to foot motors and flange motors we choose to classify universal motors (of which the terminal box can be moved from the top the either side or from which the feet are screwed on instead of welded on). This clustering thus results in the following IM numbers:

- IM1: foot (or foot-flange)
- IM3: flange
- IMU: universal

We now have the following four unique elements:

- The model of the motor (area of application)
- The frame of the motor (IEC house size with length of the stator package)
- The stack of the motor (length of the tin package, number of poles, torque)
- IM number (either IM1, IM3 or IMU)

Example 2.3

Customer: I would like a motor for my ship. It will be used to bring in the anchor and needs to have around 30 kW. of power.

Rotor: Next to the 5RN, 132M and 4 poles, we now know enough to say it will be an IM1 motor. Depending on the delivery time requested by the customer, we can select the motor from stock and in case needed perform reconfigurations in the competence centre or order the motor from the supplier in the correct reconfiguration.

Configure Bases and Motor Bases

With the ERP analysis we intuitively adopt a higher level of abstraction and categorize SKUs based on a limited amount of characteristics instead of for instance on product number. To clarify the difference between the actual motors and the new higher abstraction level motors the term Base is from now on used. A Base is defined as the combination of the four unique elements (model, frame, stack and IM number). This is not a physical product because, as described before, we clustered the IEC mounting positions. A motor is thus defined as a Base with the IM number changed into a IEC mounting number. With that change, the Base becomes an actual product that can be touched. Of course, a motor can, and most often will, have more options, but the significant difference between a Base and a motor is the IM number or IEC mounting position.

We use the following definitions to classify the Base into two groups:

- Motor Bases: all combinations of the four unique elements
- Configure Bases: those combinations of the four unique elements that Rotor wants to be able to deliver from stock or use for reconfigurations at the competence centre in Eibergen.

Rotor cannot keep all motors available in the supply program on stock. This much was evident from the description of Rotor and the product characteristics in Chapter 3. So, to distinguish the Bases Rotor wants to be able to supply form Eibergen, we define the two different classes of Bases as just described.

The difference between Motor Bases (MB) and Configure Bases (CB) is based on subsets. This is visualized in Figure 26.

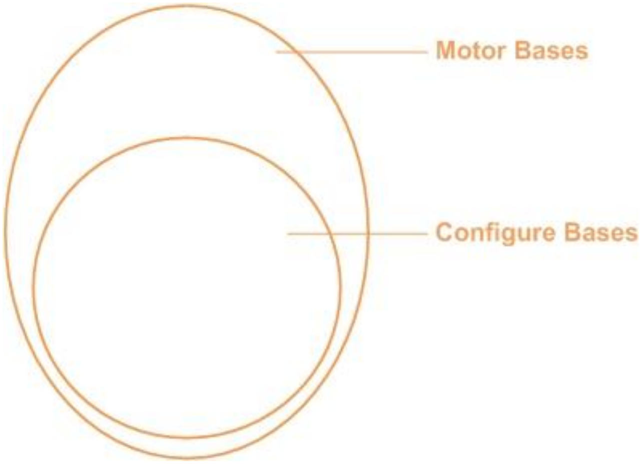

Figure 26: Visualization of the Motor Bases and its subset Configure Bases

The MBs describe all motors available in the supply program of Rotor whilst the CBs only describe those motors that Rotor wants to supply from Eibergen (either directly from stock or via reconfiguration in the competence centre). So all CBs are MBs but not all MBs have to be CBs.

We categorize all motors in the ERP system according to the four unique elements by adding four fields to the digital motor configuration that contain the appropriate information. We then make the choice whether an MB should be a CB on the basis of occurrence in sales order in 2008. A total of 380 MBs are selected as CB, in which the following number of unique elements were represented:

- Model of the motor: 5 models are selected (5RN/5RB, 5RE, 5RC, 5RCC, 4RD);
- Frame of the motor: 24 frames are selected;
- Stack of the motor: 38 stacks are selected;
- IM base: IM1, IM3 and IMU.

With the selected 380 CBs we cover 96% of all motors sold in 2008. To cover the remaining 4% of motors an additional 316 Configure Bases are needed. The coverage of sales by the Bases, split up for the model and the IM Base of a motor can be seen in Table 13.

Model Base	IM Base	# in Base	# Total	Sold Base	Sold Total
5RN	IM1	152	240	28229	28892
5RN	IM3	85	171	43106	44351
5RN	IMU	14	58	193	325
5RE	IM1	32	40	595	618
5RE	IM3	19	31	533	732
5RE	IMU	0	0	0	0
5RC	IM1	18	21	680	694
5RC	IM3	9	20	555	697
5RC	IMU	0	0	0	0
5RCC	IM1	14	21	490	549
5RCC	IM3	6	11	151	703
5RCC	IMU	0	0	0	0
4RD	IM1	31	54	640	680
4RD	IM3	0	28	0	80
4RD	IMU	0	1	0	1
Total		380	696	75172	78322
		54,6%		95,9%	

Table 13: Coverage of sold Bases and Motors in 2008 by Configure Bases

Paragraph 5.6: Combining the two approaches

We have now come to the point where the bottom-up and top-down approaches to the standardization of the stock are combined. But first the differences and similarities between the two approaches are clarified once more.

In the first approach, perceptual mapping via a classification scheme, we started with the motors that are currently kept on stock in Eibergen. Using the classification scheme we developed, we categorized the motors into one of eleven classes that are common in use by Rotor and in the line of business. Subsequently, we determined per class per "motorgroup" which motor(s) we want to keep on stock based on the average demand and the reconfiguration possibilities.

In our second approach, the ERP analysis, we determined four unique elements that together define a Motor Base. Three of these are similar to the "motorgroup" used in the first approach. Following this, we analyzed the sales data over 2008 and selected those Bases with the most occurrences as Configure Bases.

The two approaches thus determine which motors to keep on stock based on three similar elements. But, a major difference is that the first approach only takes current stock motors into account while the second approach review all motors (Bases, to be more precise) sold over the past year.

When we combine the standard motor list with the MBs and CBs we find that the 546 motors we want to keep on stock, relate to 386 CBs. With the 386 CBs we cover 95% of all motors sold in 2008. The selected 546 motors also provide 93% coverage. So despite the differences in the approach to the standardization, both methods are able to unearth the most important elements and motors. With this result Rotor can reduce the number of motors kept on stock while at the same time retaining the flexibility to supply a great deal of motors using the reconfigurations possibilities offered by the competence centre.

Besides this, we also found out that the difference between the two approaches was minimal. Almost all motors selected as standard stock motors in the bottom-up approach are covered by the CBs selected in the top-down approach. And for all the CBs selected in the top-down approach, at least one motor is selected in the bottom-up approach.

In Table 14 the number of MBs that we need to cover all know motors in the ERP system and the CBs that we want to be able to supply from Eibergen are depicted. Furthermore, the table shows that with 386 CBs 546 standard stock motors, Rotor is able to supply over 2600 motors from Eibergen.

Description	Amount
Number of Motor Bases	1684
Number of motors in these Motor Bases	7435
Number of Configure Bases	386
Number of motor which can be made with these Configure Bases	2649
Number of Standard Stock Motors	546

Table 14: Future situation with regard to Bases and motors

Within each CB only one configuration could be chosen and still all other motors with the same CB can be made. However, in cooperation with the purchase manager, the logistics manager and the operations manager the choice was made to keep more motors on stock, notwithstanding the double CBs on stock.

In Figure 27 the connection between the MBs, CBs and motors is visualized. With the motors kept on stock in Eibergen, Rotor is able to supply (by reconfiguration) all motors with the same CBs. All other motors, with MBs not part of the CBs, Rotor cannot supply directly from Eibergen and will have to order these from its supplier.

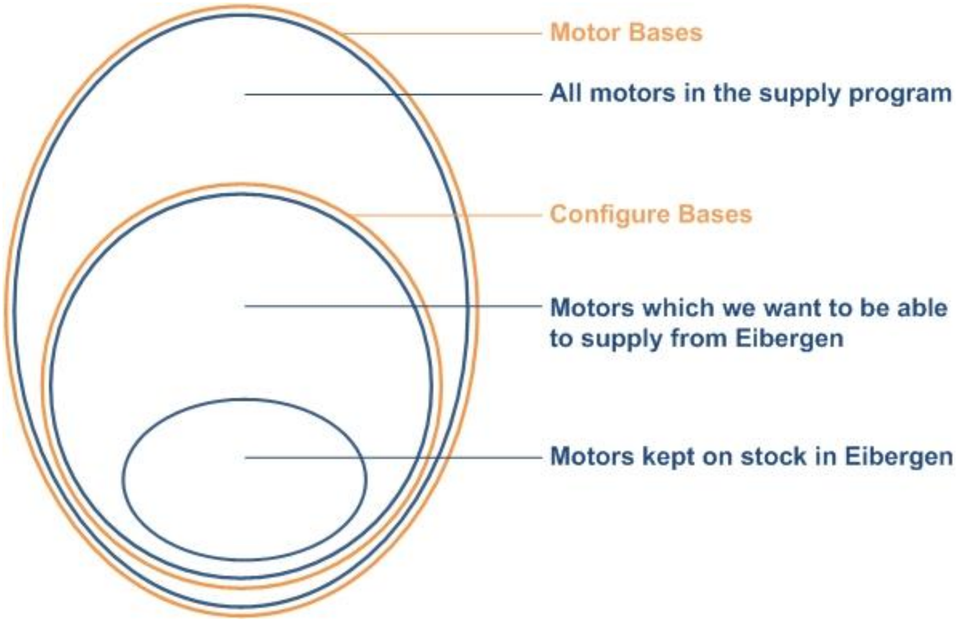

Figure 27: Visualization of the connection between the Bases and the motors

In addition to the standardization of the stock, our method (and the two approaches within) also contributes to increasing the understanding of Rotor's employees that the reconfiguration strategy provides the opportunity to decrease the number of SKUs on stock while at the same time increasing its versatility and flexibility. The Competence Center in Eibergen plays a central role because in the Competence Center all but four elements of a motor can be changed.

We split the stock of Rotor into two parts. One part is the standardized stock based on the Configure Bases. The other part is the special stock with motors that are reserved for customers and special motors that are not part of the Configure Bases. How this should be done and how Rotor can change over to the new standard stock is described in the Implementation plan for the standardization of Rotor's stock. This implementation plan is added to the Appendix.

Example 3: Conclusion

Customer: I would like a motor for my ship. It will be used to bring in the anchor and needs to have around 30 kW. of power.

Rotor: We can use the standard stock motor list to see whether or not the motor is already on stock. This is the case, so we can deliver directly from stock.

If it were not the case, we can use the appropriate CB to see if we can reconfigure the requested motor from a stock motor. If this is also not the case, we have no alternative but the order the motor from our supplier.

Paragraph 5.7: Conclusion

In this final paragraph we clearly present the results of our method to standardize the stock.

By adopting a higher level of abstraction and defining the unique elements of a motor we are able to cluster motors in categories such that we can limit the number to 386 categories to be kept on stock whilst still being able to cover 96% of all motors sold in 2008. Furthermore, we have a list of 546 motors that should be kept on stock to do this. This is a reduction of 58% compared to the number of motors on stock at the start of this research.

As we have showed, this categorization also provides the discernment to forecast with greater accuracy while at the same time limiting the risk of obsolescence products, inherent with keeping stock.

By using the idea of time postponement and the continuum of strategies described by Lampel and Mintzberg we were able to use the reconfigurations possibilities of Rotor to an advantage and develop an standard stock. Combining this standard stock with the reconfiguration possibilities offered by the Competence Center offers Rotor the customization opportunities towards its customers and at the same time organizes this internally in a cost efficient way. Though not with final products but with semi-finished products and modular parts, the same combination of standardization and customization has occurred in the automotive and personal computer industries. The standard stock can be used with the DFS CODP determined in Chapter 4. Furthermore, we have shown in this chapter that the RTO strategy is important for Rotor in combination with the DFS strategy. The standard stock is determined as such that it reflects the most sold motors over the past year and furthermore that it, in combination with the reconfiguration possibilities, offers the flexibility needed to be able to offer a great deal of motors to the customer, all with short delivery lead times. The sales department of Rotor (Contact Center) can offer short delivery times for more motors but the sales department should realize that the reconfiguration possibilities and the Competence Center play an major role.

A final contribution of the categorization is the increased understanding among employees of Rotor, that the Competence Center in Eibergen can reconfigure numerous elements of a motor and that, by realizing there are only four distinct and unchangeable elements in a motor, the stock of Rotor this way becomes more versatile and the flexibility of Rotor is hence improved.

To link the conclusions of this chapter to those made in Chapter 4, Figure 28 shows the product-delivery strategies of Rotor adjusted for the standard stock. The RTO PD strategy is based on the CB's. Of course, with the PTO PD strategy, every motor of every MB can be ordered.

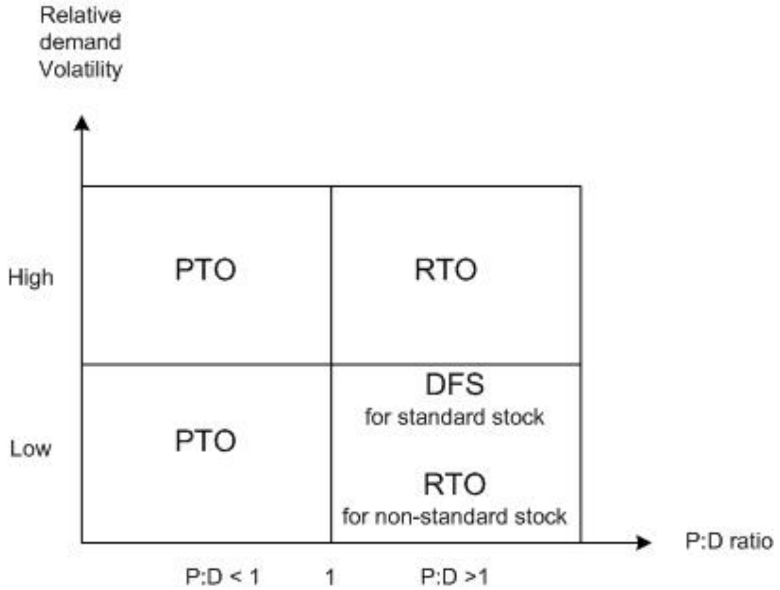

Figure 28: The product-delivery strategies and CODP positions for Rotor

Chapter 6: Application of the combined concepts at Rotor

Paragraph 6.1: Introduction and method

In the previous chapters we described different concepts to improve the. We determined the CODP positioning in Chapter 4 and we enabled mass customization in a cost efficient way with the standardization of the stock of Rotor in Chapter 5. In this chapter we answer the third and final research question:

3. *What information does the purchaser use that can be put into rules of thumb and what rules can be programmed into the ERP system (automating purchasing of standard motors)?*

In answering the third research question we have assessed the (daily) activities of the purchase manager and the manager logistics on their repetitive nature and the possible automation (computerization) of these activities in the ERP system. The repetitive nature makes the rules actually straightforward and furthermore, some of them were previously mentioned in Chapter 6. By interviewing and observing the purchase manager and the manager logistics we have assessed their (daily) activities and consequently deducted several rules of thumb.

After we answer this last research question we have described a total of three concepts that we use to tackle the problem of Rotor as described in Paragraph 2.3. In this chapter we will elaborate on the application of these concepts at Rotor. First we describe the application of the knowledge and expertise, so called rules of thumb, we unearthed during our research into the ERP system. Following this we describe the application of the CODP positions and the Motor Bases and Configure Bases. Then we describe the standardization of stock with an implementation plan.

This chapter is built up as follows. In the next paragraph we list the rules of thumb unearthed during our research. In Paragraph 6.3 we review the possibilities of automating the rules of thumb. Furthermore, in Paragraph 6.3 we prioritize the implementation of the rules of thumb. In Paragraph 6.4 we discuss the application of the combined concepts at Rotor. Paragraph 6.5 contains the implementation plan for the standardization of the stock. The chapter ends with a concluding paragraph.

Paragraph 6.2: Rules of thumb based on the repetitive nature of activities

In this paragraph we review the rules of thumb discovered by observing both the purchase manager as well as the logistics manager.

The main rules of thumb we unearthed are described in Chapter 6. First of all there are the four elements that uniquely define a motor:

- The model of the motor (area of application);
- The frame of the motor (IEC house size with length of stator package);
- The stack of the motor (length of tin package, number of poles and torque);
- The IM Base (either IM1, IM3 or IMU).

These rules of thumb are already in use as part of the “motorgroup”, as we have seen in Chapter 6. During our research we unearthed that the purchase department also takes the IEC mounting number in account (as part of the reconfiguration possibilities of the motor). So, next to the three rules of thumb already presented, the following two rules are also found:

- Average sales per month;

- Reconfiguration possibilities (including the IEC mounting number).

These rules of thumb are used by the purchase and logistic managers when deciding whether or not a motor should be kept on stock. The rules give attention to the fact that both managers, as well as the MT and BoD, want the number of times the average stock is sold per year is at least some number around 10. Furthermore, the risk in stock is diminished by using the reconfiguration possibilities at the competence center.

Additional rules that we deducted during conversations with and observations of both the purchase manager as well as the general director are:

- Ordering full pallets or pallet layers instead of ordering individual motors;
- Adjusting ordering periods based on number of motors on a pallet;
- Most motors will have cooling AC411;
- Most motors have 2 or 4 poles (about 85%).

Although we have not dug into the safety stock settings of the ERP system the following rules of thumb became evident when talking to the purchase manager:

- In calculating the safety stock, transactions from:
    - Former customers;
    - Customer that have filed for bankruptcy;
    - Projects (one-time-only sales);
    - Customers with limited credit;
    - Customers with agreements to keep specific motors on stock.

  are excluded. This is done manually every the safety stock is recalculated.

Paragraph 6.3: Rules of thumb that can be or already are automated in the ERP system

After having taken a closer look at AX 4.0 and after consultation with the IT developer, we can now list the rules of thumb that can be or already are automated in the ERP system. All rules of thumb we came across can in fact be automated in one way or another. The order in which we discuss the rules of thumb denotes the priority of implementation.

As we have seen in Chapter 6, the rules of thumb concerning the unique elements of a motor are implemented in the new approach to stock management, with the Motor Bases and Configure Bases.

The first rule of thumb concerning stock replenishment, using average demand of a motor, will be implemented in the safety stock journal as well. The reconfiguration possibilities are accounted for in the new product structure (using the A, B, L and R levels). This way an R configuration can easily be reduced to a B or an A configurations. The standard stock motors are most A and B configurations.

The rules of thumb concerning safety stock can be implemented by the software engineer in the safety stock journal.

The rules about pallet layers can be implemented in the ERP system as minimum ordering amounts. The periods will follow this setup.

Finally, the rules of thumb concerning standard cooling and number of poles can be implemented as default values when selecting a motor. Furthermore, AX 4.0 will be able to review all sales and production transactions and this way the configurations that are sold most, and their type of cooling and pole number, will become evident.

The list of rules of thumb that can be automated in the ERP system and the priorities between them (from high to low) is as follows:

- The model of the motor (area of application);
- The frame of the motor (IEC house size with length of stator package);
- The stack of the motor (length of tin package, number of poles and torque);
- The IM Base (either IM1, IM3 or IMU);
- Average sales per month;
- Reconfiguration possibilities (including the IEC mounting number);
- In calculating the safety stock exclude transactions from:
    - Former customers;
    - Customer that have filed for bankruptcy;
    - Projects (one time only sales);
    - Customers with limited credit;
    - Customers with agreements to keep specific motors on stock;
- Ordering full pallets or pallet layers instead of ordering individual motors;
- Adjusting ordering periods based on number of motors on a pallet;
- Most motors will have cooling AC411;
- Most motors have 2 or 4 poles (about 85%).

Paragraph 6.4: Application of the combined concepts at Rotor

The concept of the CODPs is already applied at Rotor, as we described in Chapter 4. The DFS CODP is situated at the shipping department, the RTO CODP is situated at the production department and the PTO CODP is situated at the purchasing department. The sales department is responsible for entering all sales orders in the ERP system , which then determines how far the customer order penetrates the organization.

The Motor Bases and Configure Bases concept are partly in place. We categorized all motors in the supply program of Rotor with the four unique elements. We denoted our standard stock motors with a check box in the ERP system. Rotor is now able to use the CODP positions, the MBs and CBs and the rules of thumb implemented in the ERP system to better control the stock and thus create flexibility in a cost efficient way. With the application of the concepts, the CODP positioning and the setup of the supply chain around these CODPs, we have contributed to the research problem described in Chapter 2.

Following the application of the three concepts we want to make the transition from the current situation to the designed situation. For this purpose we describe an implementation plan in Paragraph 6.5.

Paragraph 6.5: Implementation plan for the standardization of Rotor's stock

The main conclusions of this research impose several changes to the organization and the ERP system. The Board of Directors has expressed their wish to implement the conclusion of this research. In order to do this, we describe in this paragraph an implementation plan that aims to reorganize the organization and the ERP system in such a way that they support the conclusions of this research.

The implementation plan consists of the following steps:

1. Improving visibility of standard stock motors in AX 4.0;
2. Improving visibility of customer specific stock (customer agreements);

3. Evaluating current motors on stock;
4. Reconfiguring the non-standard motors to standard motors where possible;
5. Repositioning (to the standard motors) and adjusting safety stock levels;
6. Clearing up the remaining stock in accordance with the wishes of the Board of Directors.
7. Maintenance of the Standard Stock Motors and customer agreements (and customer specific motors)

A more detailed explanation of the implementation steps follows.

1. Visibility of standard stock motors in AX 4.0

With the definition of standard stock motors and the acknowledgement that Rotor should only have these motors as standard stock, the ERP system is the logical place to record this. In AX 4.0, the configuration level is the most appropriate place to record the fact that a motor is a standard stock motor or not with a certain mark.

Besides the location of the mark it is important to consider the use of this mark. The following aspects are important to take into consideration. First of all it will be used for recognition. Secondly, a filter can be placed on the configurations table to get an overview of all standard motors. Cross sections can be made with current physical stock to see what motors are on stock that should not be and therefore require attention. A third aspect of the mark would be for recognition of standard motors in the planned orders screen when a purchaser is preparing the orders to be send to a supplier. The fourth and final use for the mark would be recognition in the article demand planning screen. It is on this screen that the minimum stock quantities are shown.

The best choice is to create a checkbox in the configurations screen on the tab “RotorData” which is filled (checked) if the motor under consideration is a standard stock motor and which is empty is the motor is not a standard stock motor. The check box covers the first and second aspects described above. Furthermore, configurations which have the box checked are given a noticeable colour as background in AX 4.0 screens. Normally all configurations have a white background in every window of AX 4.0. With this noticeable colour, the third and fourth aspects are dealt with.

2. Visibility of customer specific stock motors and customer agreements

With the visibility of the standard stock motors assured, the question arises what motors are kept on stock in accordance with customer agreements. To get proper insight in these agreements the agreements are stored in the ERP system in such a way that they can be easily found by everyone and that the influence on stock can be easily deducted. This also assures better stock management in the future.

Having considered the possibilities of the ERP package, we decide, after due deliberation with the purchase manager, the logistics manager and most importantly with the software engineer, that a new screen and underlying table is necessary. In this screen the following information is made visible:

- Customer ID
- Article ID and configuration (which together a motor)
- Quantity to be kept on stock
- Start and end date of agreement
- Rotor employee ID
- Prognoses
- Minimum stock amount
- External article description
- Deliveries on order (Dutch: afroep orders)

For this visibility, as with the visibility of the standard stock motors, the recognition of such motors is important.

The screen is accessible from both the customer screen as well as the article and configuration screens. Furthermore, we create links to easily check the prognoses, minimum stock amount, external article description and deliveries on order of this agreement.

It is conceivable that a certain motor is selected as a standard stock motor and that one or more customers have also agreements with Rotor to keep this motor on stock for them. This also is visible in the ERP system and particularly in the article demand planning screen, where as mentioned before, the minimum stock amounts are recorded.

3. Evaluate current motors on stock

After both the standard stock and the customer specific stock has become visible as such in the ERP system, we evaluate the current motors on stock. The aim here is not to evaluate the number of motors on stock but the number of different motors (configurations) on stock.

This can be easily done with a selection with information from the ERP system. We evaluate in MS Excel the current motors on stock with the appropriate filters:

- Physical stock: yes
- Standard stock motor: no
- Customer specific motor: no

Another filter should be:

- Orders in the system for this motor: no

This insures that motors that have arrived recently and will be shipped to the customer in a short amount of time are excluded. These motors do have a good reason to be kept on stock (for a short amount of time).

Following this filter, we evaluate the selection of motors. Questions that we answer in this evaluation include the following:

- Why is this is motor on stock (origin)?
- Are there agreements that are not recorded in the system for this motor?
- Using the average demand for this motor, what would be the estimated time before the motor is sold in its current configuration?
- Are there reconfiguration possibilities for this motor to a standard stock motor?

This step in the implementation plan is about creating insight in the motors currently kept on stock. It serves as preparation for the following steps, where decisions are taken to deal with excess stock.

4. Reconfiguring

The fourth step in this implementation plan is the reconfiguring of those motors that are on stock but that should not be. In particular, the motors that have the possibility to be reconfigured to a standard stock motor.

Internal production orders, in close cooperation between purchasing/logistics/planning and operations, are the best way to get rid of these motors and increase the number of standard stock motors without additional purchasing. The option of incorporating the motors into production orders for customers should also not be forgotten. This would still mean extra work but the motor would be handled in production anyway. Because it would take a long time to reconfigure all the motors that should not be on stock anymore by incorporating them motors in production orders for customers, we recommend internal production orders.

5. Repositioning and adjusting safety stock levels
With the reconfiguring of some of the motors that should not be on stock anymore we also have to adjust safety stock levels, where applicable. All safety stock levels for motors that we do not want to keep on stock are removed, but this is done simultaneously with the adjusting of the safety stock levels of the appropriate standard stock motors, the motors that are used in the future to reconfigure the old motor.

6. Clear up the rest (*"good riddance to bad rubbish"*)
Probably the most difficult step in this implementation plan.

The motors that should not be on stock anymore and cannot be reconfigured into a more suitable motor will have to be either devalued or converted into scrap. Firstly, there is the financial aspect that will figuratively hurt. Because one way or the other this will cost the company money. Secondly, there is the recognition that all this rubbish of unnecessary stock is created by employees of Rotor. We are solving the problem now but do not forget that we created this problem to begin with. It would not be a bad idea to emphasize this to Rotor's employees. This will, hopefully, prevent non essential stock to accrue in the future and create a sustainable awareness that some decisions will lead to unnecessary high amounts of stock and the associated costs.

7. Maintenance of the standard stock motors
This final step is without doubt the most important step in this implementation plan.

The responsibility of maintenance of the standard stock motors is in the hands of both the purchasing and the logistics manager. The responsibility of the maintenance of the customer specific stock and the customer agreements however, is in the hands of the sales department.

We advise periodically reviewing the status of the stock as well as clear communication about the actions taken to keep the stock manageable.

Paragraph 6.6: Conclusion

In this chapter we have listed the rules of thumb used by the purchase and logistic managers of Rotor. By acknowledging these rules of thumb and incorporating them into the ERP system, we are able to mobilize the local, implicit knowledge which they represent. This way, process inherent knowledge can be captured and the dependence on people is reduced. Furthermore, this exercise is a step in making the purchasing and logistic business processes lean. We also provided prioritization for the implementation of the rules of thumb.

Furthermore we applied the concepts of the CODP positions, Motor Bases and Configure Bases and the standardization of stock. For this last concept we described an implementation plan. All research questions have now been answered and we have contributed to the research problem described in Chapter 2.

Chapter 7: Conclusions and recommendations

Paragraph 7.1: Main conclusions

The main conclusions is split into three parts, analogous the three research questions.

Our first research question pertained to the Customer Order Decoupling Point for Rotor was:

1. *What is the best position of the Customer Order Decoupling Point for Rotor?*

We described in Chapter 4 that the CODP should be placed at the sales department of Rotor Eibergen. This way, the company is able to decouple the customer order from the production and delivery time of the manufacturer. As a result, the main order winner of delivery speed is secured. Furthermore, the position of the CODP at the sales department in Eibergen also contributes to the flexibility of Rotor. The main reason for this is that next to the warehouse of Rotor is the Competence Center in which numerous reconfigurations can be carried out to customize the product. So despite the fickleness of production lead times and the erratic movements of demand Rotor will be able combine mass customization, with competitive delivery times and cost efficient logistic processes.

Our second research question concerned the standardization of stock upstream of the CODP:

2. *What is the best way of creating standard stock so that Rotor can combine internal standardization with customization towards customers?*

We answered this question with a two-way method in Chapter 5. On the one hand we adopted a higher level of abstraction and defined the unique elements of a motor. By doing this we are able to cluster motors in categories such that we can limit the number to 386 categories, Configure Bases, to be kept on stock. This enables us to cover 96% of all motors sold in 2008. On the other hand, we designed a list of 546 motors that should be kept on stock reflecting the knowledge of both the purchase manager as well as the logistics manager. This is a reduction of 58% in different SKUs. Also, the "motorgroups" reflect some unique elements already used by Rotor prior to this research.

Our third and final research question relates to the rules of thumb used by the purchase and logistic managers:

3. *What information does the purchaser use that can be put into rules of thumb and what rules can be programmed into the ERP system (automating purchasing of standard motors)?*

In Chapter 6 we listed the rules of thumb used by the purchase and logistic managers of Rotor. An important step we took by acknowledging these rules of thumb and incorporating them into the ERP system, is to be able to mobilize the local, implicit knowledge which they represent. This way, we can capture process inherent knowledge and the dependence on people is reduced. Furthermore, as we already mentioned, this exercise is a step in making the purchasing and logistic business processes lean. Furthermore, we applied the combined concepts of the CODP positions, the MBs and CBs and the standardization of stock at Rotor. With this application we have contributed to the research problem.

So, after having answered our three research questions we now come back to our research goal. This was formulated in Chapter 2 as follows:

The goal of this research is to clearly position the CODP in the organization of Rotor and create a standard stock with which Rotor is able to continue offering flexibility and short

delivery times to their customers while at the same time reducing risk and being able to determine stock with more accuracy.
A further step is the deduction of rules of thumb concerning purchasing and implementing these as good as possible in the ERP system. This way the standard tasks of the purchasing department can be automated.

With the results from this research we can now conclude that the goal of our research has been met. The ground has been laid for Rotor to reduce risk in their stock, retain the flexibility required to serve their customer and continuously improve their business processes.

Paragraph 7.2: Discussion

Concerning the dual approach
In answering the second research question we were unable to find a good standardization method in related literature. The dual approach which we designed gave us the opportunity the use the knowledge and expertise of Rotor's employees. Though useful for this research, the dual approach is difficult to use in other research projects, although the principles behind it would still be viable. On one hand evaluating actual products and sales while on the other hand taking a higher level of abstraction and evaluating unique aspects and finally combining these two approaches.

Concerning the Configure Bases
In the analysis of the motors sold in 2008 and the subdivision into Configure Bases we have to take into account that in this analysis only the four unique elements are considered. It is conceivable that the subdivision would be different because different voltages for example cannot be reconfigured into one another. However, the voltage analysis showed that only a small portion of motors has a different voltage than the default voltage, so the discrepancy would not be that big.

Concerning the data
When we perform data analysis with data provided by the ERP system, it is striking that almost every approach results in a (slightly) different value (for example the number of motors sold in 2008). The precise nature and origin of this unusual phenomenon can unfortunately not be traced. It is due to the different approaches inherent to the different modules of the ERP system. However, despite the differences in certain data, the percentages do not fluctuate that much and the overall conclusion that working with Configure Bases and Motor Bases improves the stock and the forecasting does remain uncompromised.

Paragraph 7.3: Future Research

As future research we would recommend research into the similarities and differences between production companies and wholesalers concerning stock management, CODP positioning and standardization. As became evident in both Chapter 4 and Chapter 5, the position of Rotor is unique in the way that Rotor is a wholesales with more than 10.000 motors on stock and in addition to this also reconfigures finished products to the customers wishes. Future research could focus on the differences between manufacturers and wholesalers and the influence on stock management and standardization.

Paragraph 7.4: Further Recommendations

Evaluation of Configure Bases and Standard Stock Motors
Rotor and in particular the purchasing and logistics departments should on a regular basis, for example quarterly, shed light on the Configure Bases as well as on the Standard Stock Motors. Are the correct motors kept on stock and can we still supply (either deliver or reconfigure) all the motors

we want from our warehouse in Eibergen? The last question defines whether or not the Configure Bases are chosen correctly, i.e. chosen such that the Configure Bases reflect almost all motors supplied from the warehouse in Eibergen. The first question in its turn reflects whether within the Configure Bases the right motors are chosen to directly deliver or use in reconfiguration purposes.

Standardization downstream of the CODP
Another recommendation that we would like to make is to continue standardization downstream of the CODP. In close cooperation with (some) service partners in the Netherlands, Rotor should strive to align the stocks so that the total stock in the supply chain can be reduced. Vendor Managed Inventory (VMI) is an interesting collaborative planning initiative to do this. With VMI the supplier has sole responsibility for managing the customer's inventory policy, including the replenishment process (Cooke, 1998).

Alignment Rotor UK with Rotor NL
We would recommend further research into the differences and similarities between Rotor NL and Rotor UK in order to discern the possibilities for further standardization of the stock in the supply chain.
At this point, not only the ERP systems used differs but more importantly the versatility of the personnel is quite different. At Rotor NL, all employees are trained for specific tasks, there is division of labour. There are sales employees, order entry employees, purchasers and employees responsible for shipping the product. The personnel at Rotor UK on the other hand have multiple tasks and handle almost the entire process from customer request , via purchasing to shipping. This is partly due to the fact that Rotor UK has around ten employees.
Another difference is the product portfolio. While the efficiency 2 and efficiency 1 motors are similar, Rotor UK offers a lot more products (motors and other).
With the alignment of both branches of Rotor, and for instance the deployment of VMI, purchasing and stock management for Rotor UK could be done by the purchase manager at Rotor NL.
As stated, there are possible gains with the alignment of Rotor NL and Rotor UK, but further research is needed.

Performance measurement
Finally, we would like to stipulate the importance of the link between high-level organizational aspirations and day-to-day operational objectives. Several departments are working with performance indicators but the relation with the company goals and the mission, vision and strategy are not directly evident. Our advice is to re-evaluate, unambiguously describe and communicate the following:

- Mission, Vision, Strategy and company goals;
- Company values;
- Mid- and short term departmental objectives.

Subsequently the following steps could be taken to assure performance measurement is accurate:

- Determining Key success factors (KSF);
- Determining Key Performance Indicators (KPI);
- Measuring, reporting and steering towards performance improvement based on KPI's.

An example for the purchasing and logistic departments, concerning stock:

- ✓ Percentage of Configure Base on stock;
- ✓ Percentage of motor versions sold in the past 12 months covered by standard stock.

The commitment of the employees in this project will be of great importance. This can be created and boosted by involving them in the determination of the company values and the performance indicators. Without stating the obvious, communication throughout the described steps is a key notion that should not be taken lightly.

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II: Appendix

Appendix A: Figures

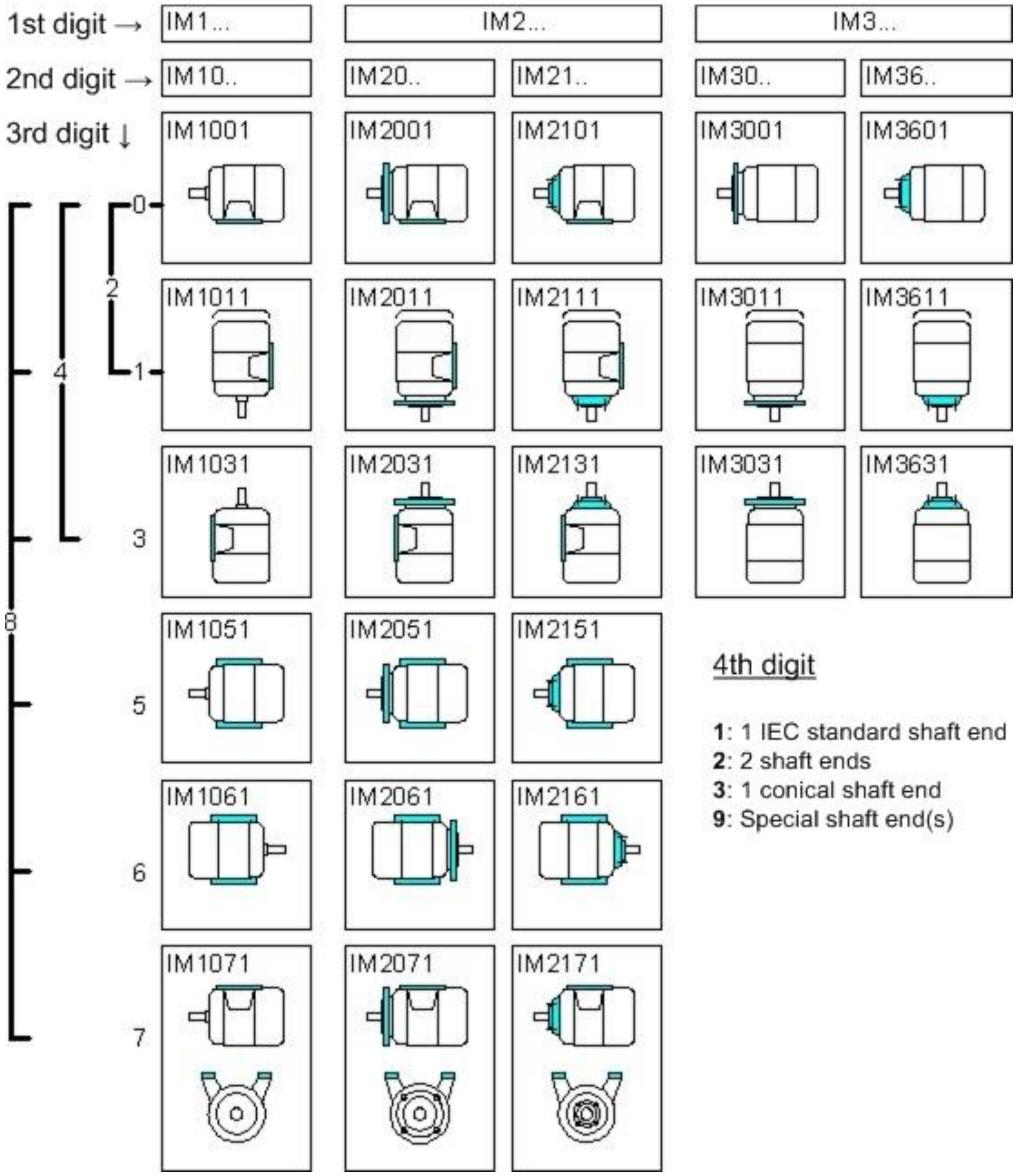

Figure 29: IM coding of mounting positions (Rotor, 2005)

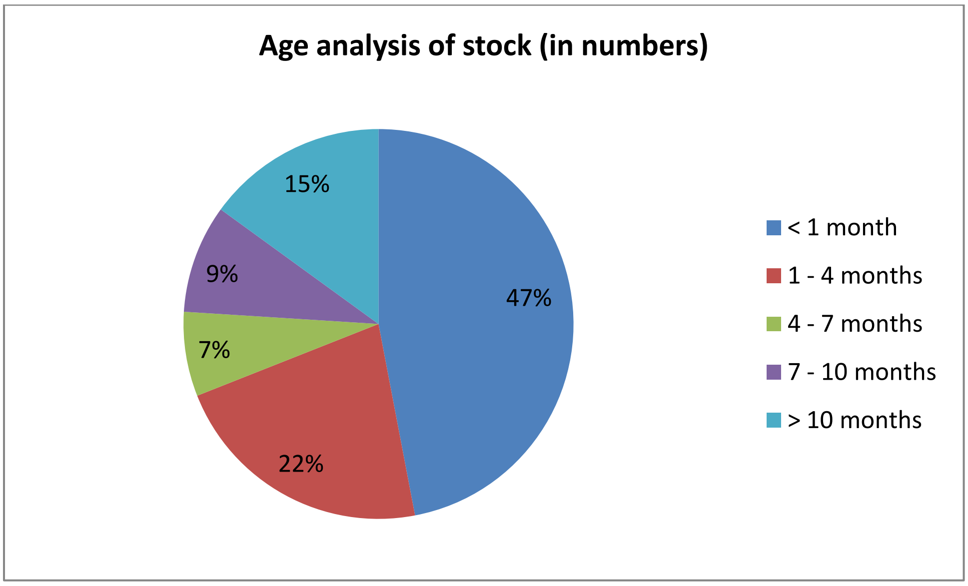

Figure 30: Age analysis of stock (in numbers). Adapted from (van Alten, Leijen et al., 2008)

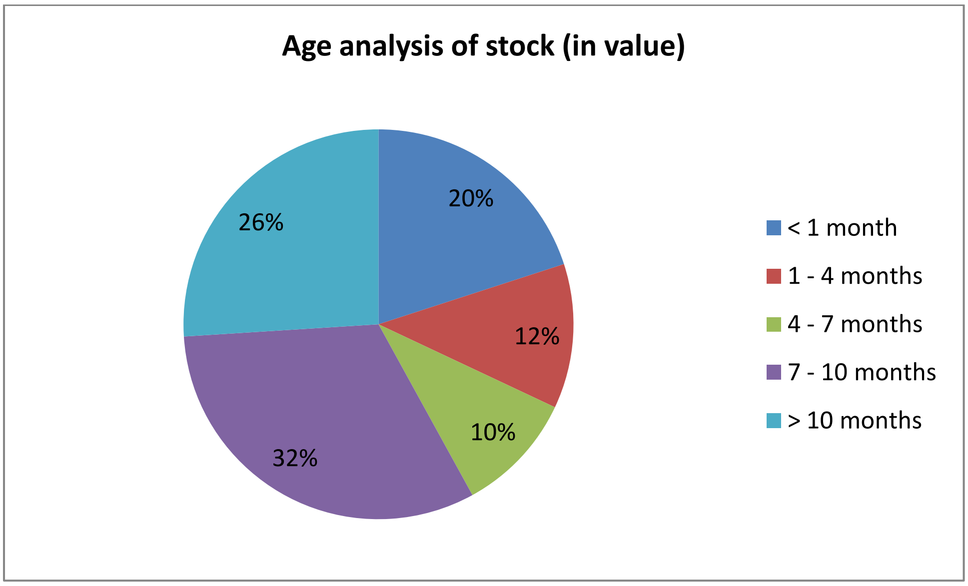

Figure 31: Age analysis of stock (in value). Adapted from (van Alten, Leijen et al., 2008)

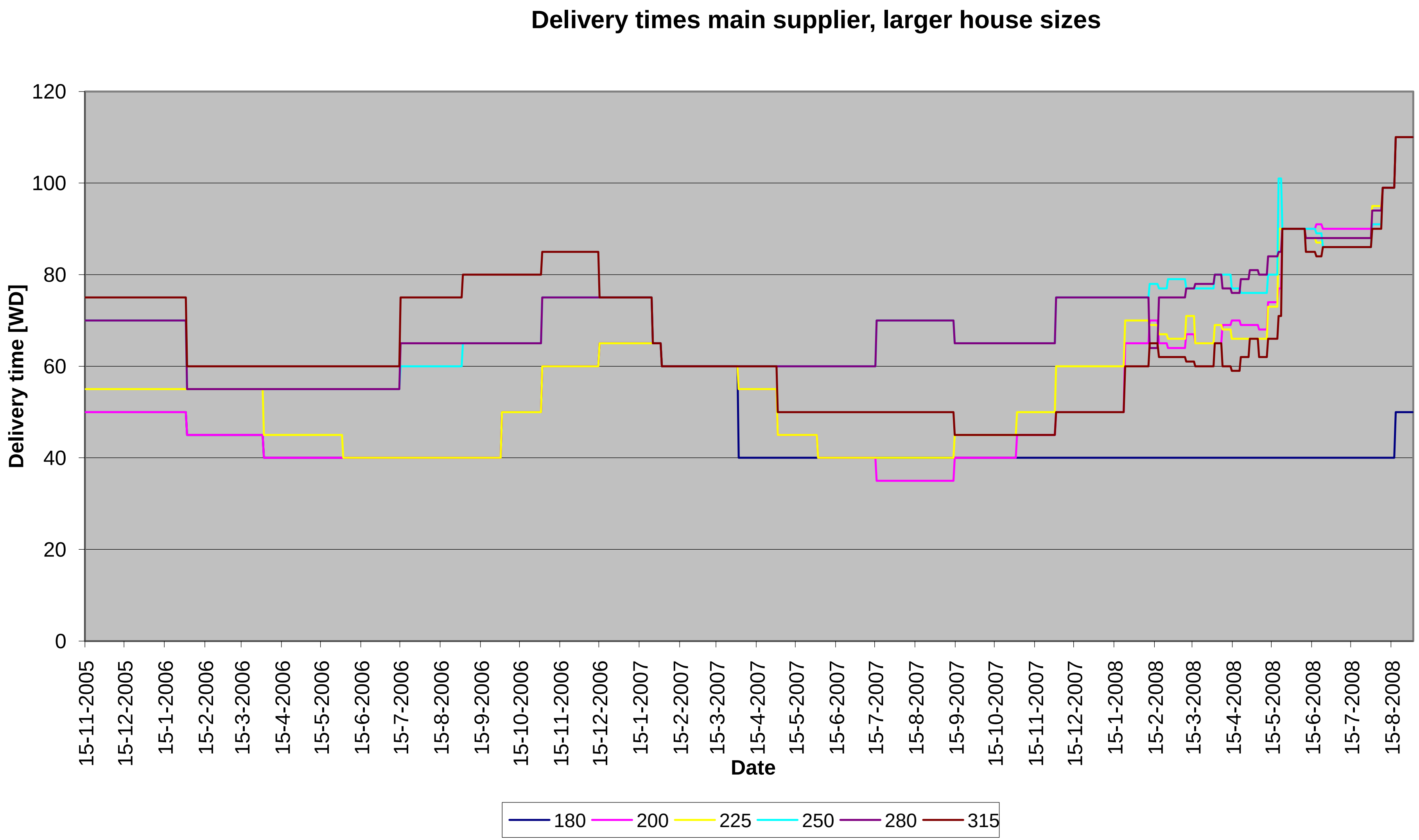

Figure 32: Development of delivery times of MOT B over the past three years

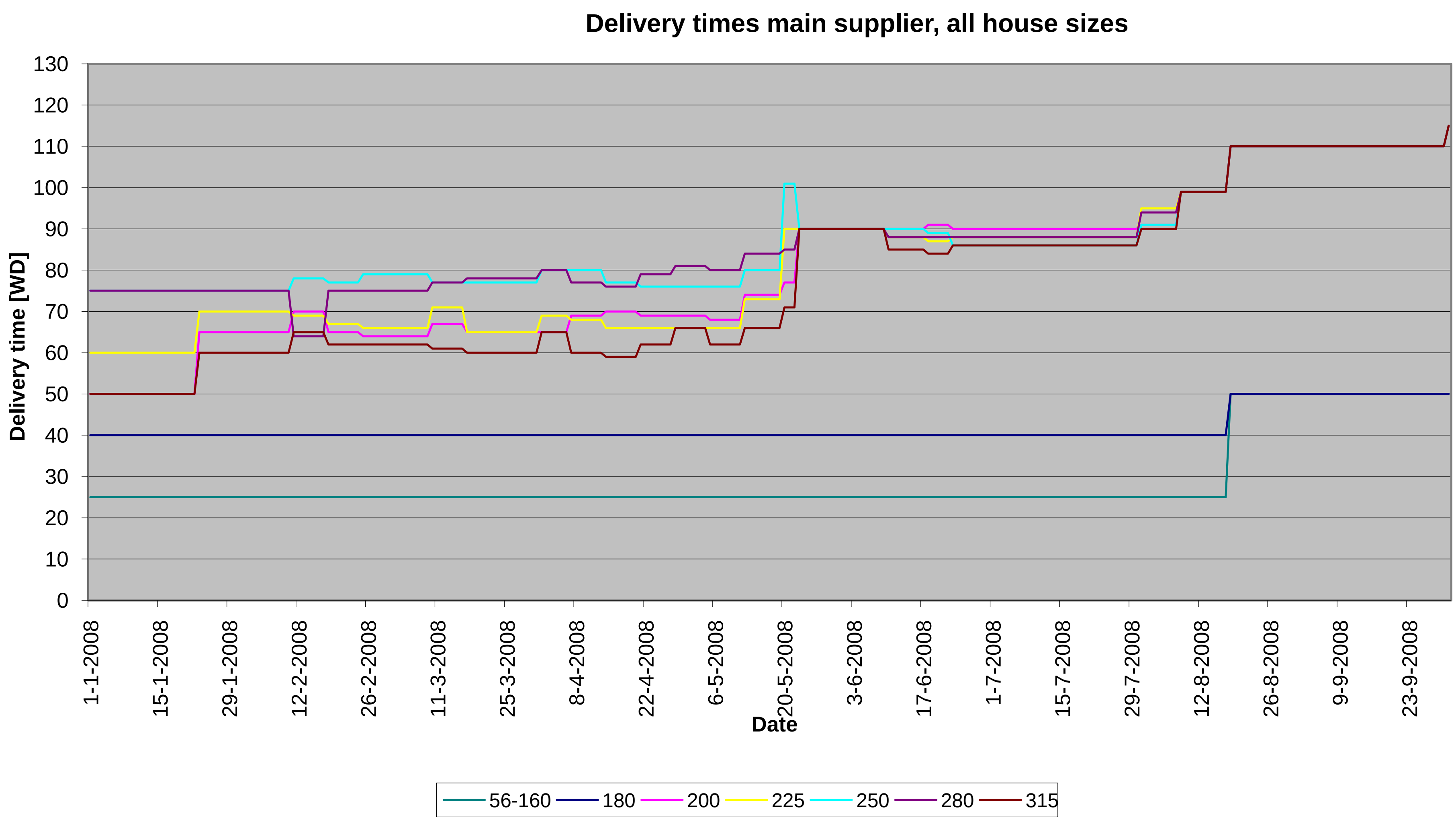

Figure 33: Developement of delivery times of MOT A and MOT B over the past nine months

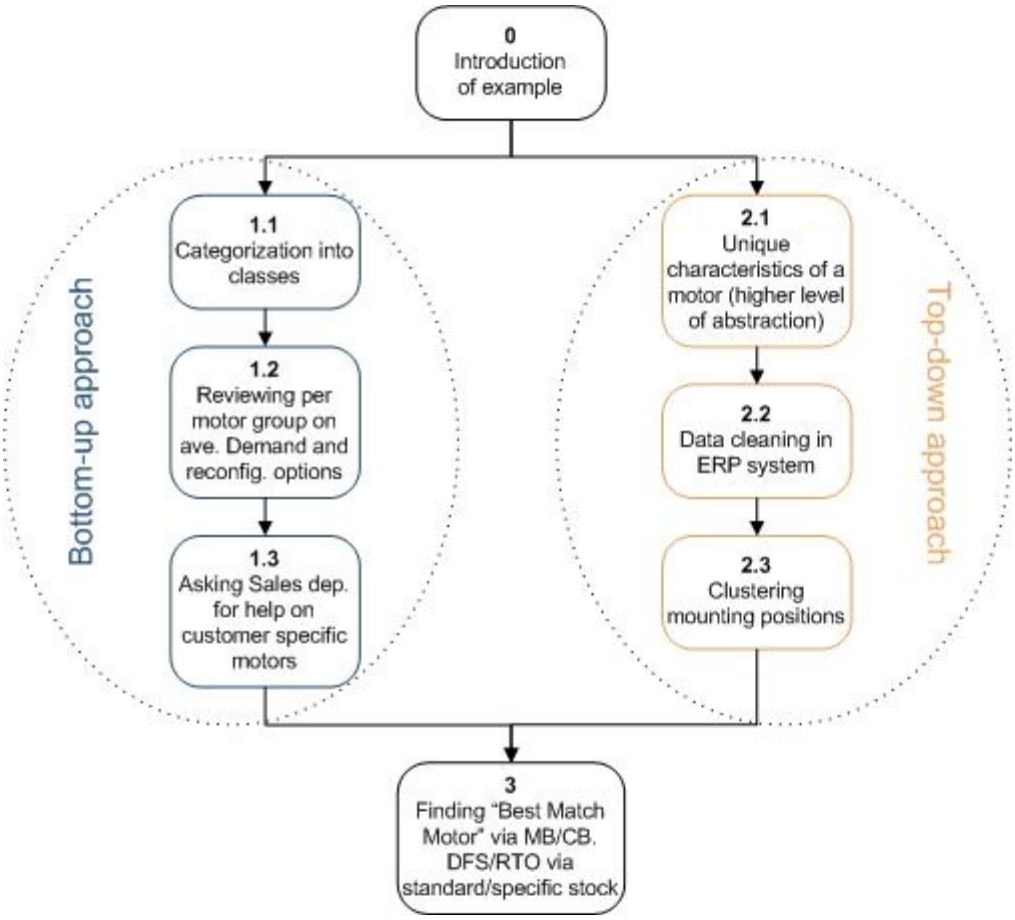

Figure 34: Structure of the running example.

Appendix B: Explanation of the title

The squirrel cage mentioned in the title of this thesis refers to the way electricity is converted to motion using magnetic fields. These magnetic fields are created using a setup of copper windings around the stator and tin package.

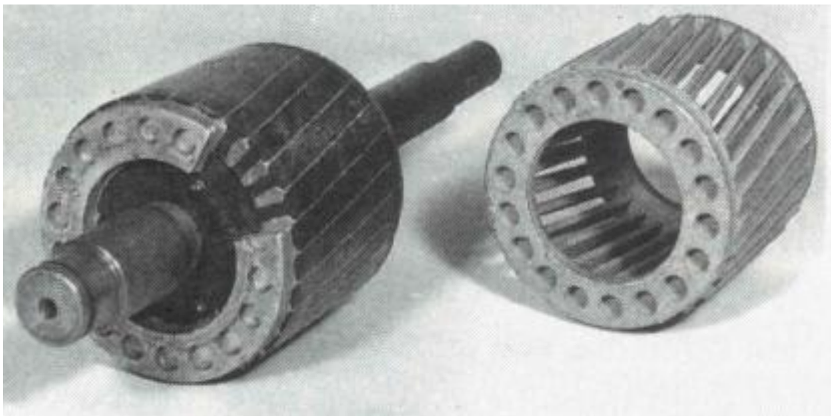

Figure 35: Squirrel cage with (left) and without (right) tin package and rotor (Hamels, 1992).

In Figure 35 the stator package is depicted on the right. When the stator and the tin package are removed, the cage on the right becomes visible. This cage resembles a squirrel cage, hence its name.