MASTERTHESIS

2011

Lead-time Reduction within an MTO-environment

A Case Study regarding Purchased Parts and their Suppliers

UNIVERSITY OF TWENTE.

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Lead-Time Reduction within an MTO-environment:

a Case Study regarding Purchased Parts and their Suppliers

May 29, 2012

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Public Version

This is the public version of a confidential Master Thesis, written for an organization in a MTO (Make-To-Order)-environment. Therefore some sections are deleted, and references to the name of the organization are replaced by the *Case Organization (CO).*

Summary

This research is conducted within CO, operating in the steel fabricating industry, and currently is one of the world's leading single source supplier of CNC-controlled machinery in this field. Extreme long delivery times and low delivery reliability of suppliers of purchased parts cause difficulties for CO restraining their preferred lead-time of 16 weeks.. From the *orientation and focus* phase, the *central question* and *problem definition* are derived. The *diagnosis* of the current situation, together with the *set of requirements* , results in a *solution design* which tries aim to improve the current situation.

The focus of this research is on the purchased parts and their suppliers because most difficulties are experienced in this field. It will aim for improvements with regard to the lead-time of suppliers, the variability in their delivery times, and also the internal processing of purchase orders within CO. Therefore the central question answered in this research is:

How can the lead-time of CO be decreased, by influencing the lead-time and variance of suppliers' delivery times and the processing of purchase orders within the organization?

Diagnosis

The diagnosis phase describes the current situation within CO, and aims to find and address the causes of the difficulties experienced, in order to answer the first research question: *How can the current situation within CO and at their suppliers be analyzed, and what are the causes of high lead-times and their variability in this situation?* For the first part of this question, a method is proposed in order to choose suitable Value Stream Mapping Tools, used to analyze the current situation. The second part of the diagnosis is the actual measurement of these factors with the use of data from CO's administrative (MRP-) system, documents and interviews.

The diagnosis illustrated several possible causes of experienced long delivery times and high delivery variability. The main topics derived from this are; (1) a lack of order release mechanisms; (2) imprecise forecasting; (3) the absence of supplier or supply chain monitoring techniques, and; (4) a low significance for strategic suppliers.

Solution Design and Managerial Implications

The Solution Design phase answered Research Question *3: What solutions can be derived based on the analysis, the researchers' knowledge and creativity, the set of requirements and theory, in order to decrease supplier lead-time and its variability with regard to purchased parts?*
With the methods described in the question, several strategies were derived in order to decrease supplier lead-time and increase reliability, based on the causes found in the analysis.

With the intention to *implement order release mechanisms*, several purchasing- and replenishment strategies for categorized purchased parts should be introduced. Categorizing is done on the base of costs, delivery time and the FAS (Final Assembly Schedule: time available at the buyer between ordering the item, and latter being needed in assembly) for which maintenance in the MRP-system is needed. Several strategies are applied including Vendor Managed Inventories (VMI) in the form of a two-bin-system, an Re-Order Point (ROP), ordering on demand with the use of the MRP-system, and an extension of the current forecasting method.

The second implication involves *the refinement of the currently used forecasting method*. To make this more precise and reliable, (forecasted) demand of critical (long lead-time) items should be communicated and shared with their corresponding suppliers. These can discuss and anticipate on this information with regard to maintain stocks or ordering in advance. When a frozen period is added to the shared forecast (within this period CO is required to purchase on the agreed date) stability in demand is created. The sharing of information with (important) suppliers requires a close relationship and both buyer and supplier acting for good customer service.

The *introduction of supplier or supply chain monitoring and measurement* involves the design of the desired situation with regard to delivery times and variability, and communicating this towards the suppliers. Within CO, the performance of the suppliers can be measured upon entry of the ordered goods (on-time delivery, delivery time variance etc.). These criteria can also be used when selecting new (potential) suppliers, rather than selection on the basis of lowest costs. When performance of suppliers is below the agreed level, this will be noticed timely and subsequent actions can be taken.

Finally, in order for CO to *increase significance towards strategic suppliers* to gain preferential resources with regard to availability of items, several steps can be taken. The increasing of perceived expected value and trust are the main implications resulting from this (strategic) method.

Concluding, several, relatively new methods can be applied in order to decrease long delivery times and their high variability with regard to purchased parts. These include; the categorizing of purchase part in order to implement order release mechanisms; information sharing with

suppliers to refine the currently used forecasting method; the introduction of supplier or supply chain monitoring and measurement to assure long-term success, and; gaining preferential resources by increasing the significance of CO towards strategic suppliers. These implications concern both the processes within CO as well as their entire supply base and the contact and cooperation with them.

Table of Content

Figures and Tables

Table of Abbreviations

ADU	Average Dollar Usage
AHP	Analytic Hierarchy Process
ANN	Artificial Neural Networks
ATO	Assemble-To-Order
AUC	Average Unit Cost
BOM	Bill of Materials
CPFR	Collaborative Planning, Forecasting and Replenishment
CQ	Central Question
DEA	Data Envelopment Analysis
ESI	Early Supplier Involvement
et. al	et alii [and others]
FAS	Finally Assembly Schedule
GA	Generetic Algorithm
i.e.	id est [that is]
JIT	Just In Time
LT	Lead-Time
MCIC	Multi Criteria Inventory classification
MRP	Materials Requirement Planning
MTO	Make-To-Order
no.	numéro
NPD	New Product Development
NVA	Non Value-Adding
OEM	Original Equipment Manufacturer
OMC	Order Management Cycle
p.	Page
pp.	Pages
POS	Point-of-Sale
R&D	Research and Development
ROP	Re-Order-Point
RQ	Research Question
SC	Supply Chain
TPS	Toyota Production System
VALSAT	Value Stream Analysis Tool
VMI	Vendor-Managed Inventories
vs.	versus
VSMM	Value Stream Macro Mapping
WIP	Work-In-Progress

1. Introduction, Research Approach and -Questions

Lead-time is an often-discussed topic, in classic, but also increasingly in recent operations literature. It is mostly associated with mass production and lean manufacturing. But also organizations that use a Make-to-Order (MTO) strategy are more and more interested in lead- or turnaround time reduction. CO is one of those organizations. They believe that their lead-time is negatively influenced (increased) by several internal and external causes. A practical example of this can be derived from the assembling workshop; assembling personnel often has to wait (in some cases up to 2 or 3 weeks) on critical parts before the product can be shipped to a customer. This is due to extreme delivery times (and their variance) of several purchased parts, and this happens approximately on 40% of the projects.

Using a case study, this thesis diagnoses lead-time problems within CO. Also it provided solutions and recommendations towards solving these problems. This thesis aims to apply both (1) existing literature about lead-time reduction to project-based production systems, and (2) to specify it towards purchased parts and their suppliers. In order to accomplish this, this research also discusses and applies (relatively) new tools that can be used to map, describe, and analyze a supply chain.

1.1. Introduction to the Case Organization

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The main issue that lead to this research is that several suppliers of purchased parts maintain delivery times that are problematic for CO. CO aims for a delivery time of their machines of 16 weeks. With internal order processing and engineering included, 10 weeks maintain from the moment of ordering parts to final assembly of the machine. Often, the delivery time of a purchased part is longer than those 10 weeks, and the lead-time of a CO-machine will increase. In this chapter, the approach of this study will be clarified, as well as the central, and research question(s) which will be answered in this research.

1.2. Overall Research Approach

Focus is very important, and therefore the first phase of this research will be orientation. A deeper understanding of several key elements of this study will be created, in order to define the problem and current situation; what exactly is lead-time, what are the internal processes of CO, and what is the real problem to be addressed within this research? This will lead to a specific problem definition, from which the central- and research question(s) can be derived. The research questions are corresponding to the following sequential phases: the diagnosis phase, the phase for the set of requirements, and the design phase. These steps, and their sequence are discussed by De Leeuw (2003, p. 90) and Van Aken et al. (2007, pp. 4,24) as being a business problem solving and design project.

The diagnosis phase has two purposes: First, describing the current situation, and second, reviewing this situation in order to derive the causes or effects occurring at CO: the actual diagnosis. This will be done with the use of value stream (or process) mapping tools to identify the current situation, in line with George (2003, p. 3) and Roberts (2003) who argue that before a certain process can be managed well, it first has to be visualized. Other authors discuss the same aspect, and also provide several value stream mapping tools in order to visualize the value stream and -chain, and propose procedures to choose an appropriate and useful tool (Hines & Rich, 1997; Hines et al., 1998a; Rother & Shook, 1998). After this phase, a set of requirements will be constructed. This will give a direction for the prerequisites of (a) possible solution(s); it contains the factors that should be taken into account and reflects on how CO would like to change from the current to the desired situation. The final step is the design phase. In this phase possible solutions will be designed, while taking both the diagnosis- and requirements phase into account. The phases discussed in this chapter are summarized in Figure 1-1, and Chapter 2 elaborates on the above discussed strategies, in order to answer the research questions. Each phase will be supported by a theoretical framework and literature study. The next section discusses lead-time in general.

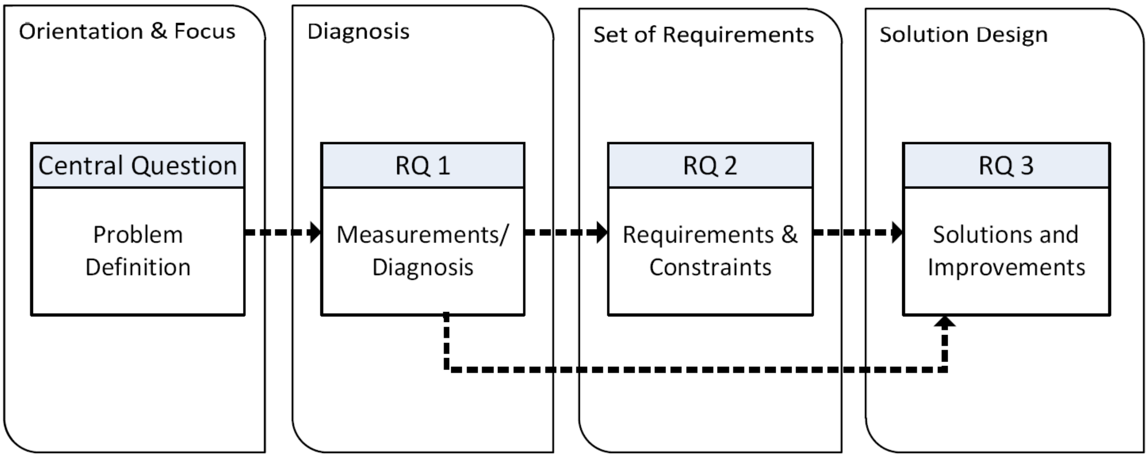


Figure 1-1: Research Approach

1.3. Causes of Lead-Time and -variance influencing Factors regarding purchased Parts and their Suppliers

This section introduces the concept of lead-time, in order to create an understanding of this theme, the factors that influence this, and the occurrence of these factors. In this research, lead-time is defined as: *"…the time elapsed in between the receipt of customer order until the delivery of finished goods to the customer."* (Gunasekaran et al., 2004, p. 336). According to Hariga (2000), lead-time is made up of several components besides the fabricating itself: (information) moving time, waiting time, setup time, lot size, and rework time. Furthermore , Tersine (1994) states that lead-time normally also includes the following elements: order transit, supplier lead-time, order preparation, delivery time and set-up time. Hopp et. al (1990) adds queue time to this. Table 1-1 summarizes the factors from current literature, and provides definitions of the discussed concepts.

Factor	Definition
1. (Information) Moving time	The time needed for moving products, goods or assemblies or information within or between organizations, departments and processes. *"…the movement of materials or information."* (George, 2003, p. 10).
2. Order transit/ Conveyance	Transit time occurs between manufacturers and retailers (Jain & Moinzadeh, 2005). According to Hines and Rich (1997) conveyance is *"…goods being moved about."* (p. 48).
3. Set-up time	*"…the sum total of all of the internal setups involved in processing the job."* (Hopp, Spearman, & Woodruff, 1990)
4. **Waiting time**	Ohno (1988) and Tommelein (1998) define waiting as: *"Inventories of goods waiting further processing or consumption"* (p. 2). Furthermore, Hopp and Spearman (1993) use the following definition: *"…the time between the arrival of the part and the time it is needed for assembly."* (p. 4).
5. Supplier lead time / delivery time	Former is defined as *"the time that lapses between the time an order is received by a supplier and his shipment of the items"* (Liao & Shyu, 1991). Latter has the same definition, but includes transport time (order transit) from supplier to the customer organization.
6. Queue time	One of the few authors who quote queuing time are Hopp et al (1990) who state that "*Queue time is the time spent waiting in line for work centers to become available."* (p. 80).
7. Order preparation	The time that is needed between receiving a customer order and starting the processing of that specific order (Boone & Ganeshan, 2007).

Table 1-1: Lead-time influencing factors

In order to discuss where these factors (could) occur, Figure 1-2 illustrates the supply chain of CO, together with the before-mentioned factors. As can be seen, lead-time of CO depends on the lead-time of the suppliers. Therefore this concept can be discussed both internally and externally.

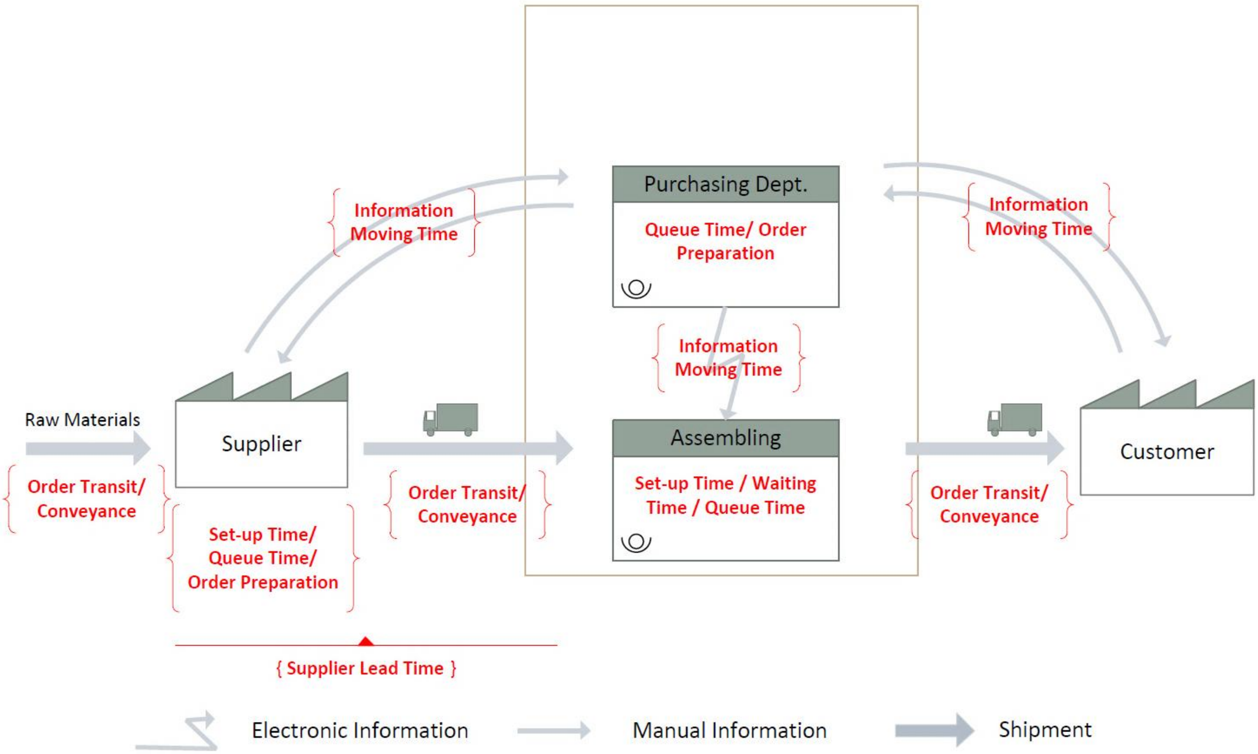


Figure 1-2: Lead-time influencing factors in the supply chain of CO

1.4. Focus and Problem Definition

Lead-time can be discussed internally (within the company) as well as externally (within the supply chain, as discussed above), and its reduction and stabilization can be realized with many different methods, in different fields and scopes, and with different constraints. Therefore focus is needed to derive a good problem definition and research goal.

CO usually aims for a lead-time of 16 weeks or less, without a stock of complete or semi-finished products. Currently this is difficult because of the fact that some suppliers (discussed in Chapter 3.1) maintain (too) long delivery times, which on top of that, also have a high variability. The variability of the lead-time is the difference in lead-time between two similar deliveries, in other words; low delivery reliability. From a sample of 29 projects, almost 41% was delayed due to waiting on delivery of purchased parts. The average delay was 2.9 weeks, with a variance of 3.88 weeks. In most of the cases, waiting occurred when parts where delivered later than agreed. Sometimes an unannounced increase in delivery time of purchased parts was experienced. A delivery time of, for example, 6 weeks was known at the purchasing department, and after ordering the order confirmation showed 10 weeks.

First part of creating focus in this research is the choice for purchased parts only. Bottlenecks in the delays discussed above are the delivery times of purchased parts in particular. There are two main differences between purchased and manufactured parts; the purchased parts that CO processes are all parts that are ordered at a supplier, and can directly be added to an assembly. Manufactured parts are produced custom-made using drawings by machining companies. Delivery times of manufactured parts (from machining suppliers) are not lead-time increasing for CO because they mostly are delivered within 6 weeks and therefore do not exceed the "critical" 10 weeks mentioned before. Obtaining of purchased parts account for approximately 62% of CO's turnover, which illustrates their importance.

As illustrated by Table 1-1 and Figure 1-2, the lead-time can be influenced both internally as externally. In other words, lead-time can be increased by the supplier, but also the processing of orders within CO has an effect on this time. The second part of focusing will therefore discuss the suppliers. CO recognizes the delivery time of the purchased parts as one of the main lead-time increasing factors. They even started a forecasting procedure to cope with this problem (further discussed in Chapter 3.2.4.). But supplier lead-time cannot be seen apart from its variance (Hopp et al., 1990); basically the reliability of the supplier. In other words, how much does lead-time differ between two similar orders, as well as between order confirmation and reality? Therefore, the focus to decrease lead-time is specified to the purchased parts and their suppliers.

The third point resulting in more a specific research is (as introduced above) the processing of purchasing orders within CO. This can be specified towards the purchased parts and their suppliers. A separation can be made between the moment of ordering (influences *when* suppliers receive order-information), and the methods of ordering (influences *how* suppliers receive order-information).

Concluding, this research will focus on the decrease of long delivery times (and their variance) of purchased parts, by influencing the lead-time of suppliers and the processing of purchasing orders towards these suppliers by CO. The aim of this study is to reduce and control the lead-time of CO.

1.4.1. Currently ongoing Changes within the Organization

The second reason for the choice of purchased parts and their suppliers is partly based on the fact that CO is currently implementing several new methods, which also could have influence on the lead-time within the organization. Therefore these methods will be discussed below, as they could act as constraining or reinforcing factors for this study.

The first change within CO is the production of modules, instead of an entire machine. Modules (somewhat the building blocks of the machines) consist of purchased parts or manufactured parts, but mostly a combination of those two. Now, a machine of CO consists of a set of fixed, standard modules, with additional modules, configurable by the customer as can be seen in Figure 1-3. The configurable modules are "standard" as well, but for these the customer can decide whether or not to add them to his machine. Before, the entire machine was re-engineered for every project following the configuration of the customer before the Bill Of Materials (BOM) was known, so that parts could be ordered. In the new situation, only the configurable modules chosen by the customer have to be added by engineering. This results in a BOM that is known (almost) directly after sales or configuration, and therefore ordering needed parts in an earlier stage than before. The implementation of this method is within CO referred to as "plan A".

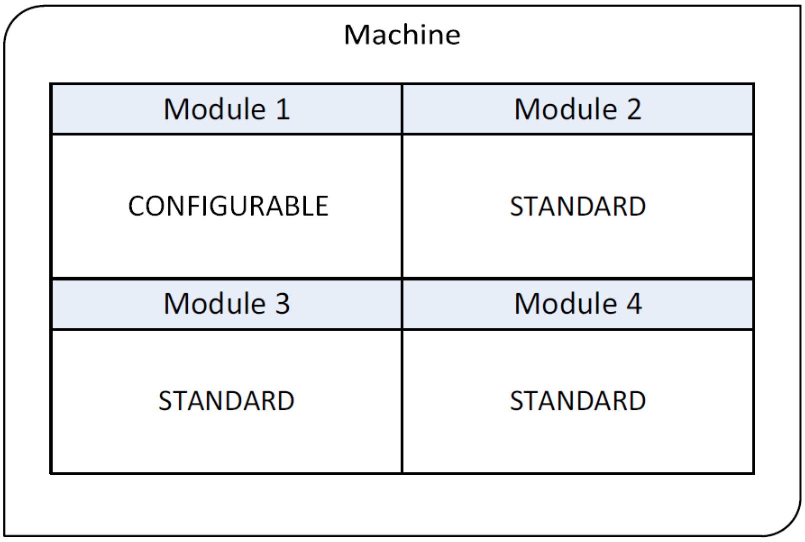


Figure 1-3: A machine divided into standard and configurable modules

The second change can be seen as a consequence of "Plan A"; the assembly shop has to be rearranged in order to effectively produce in modules, instead of whole machines, as discussed above as one of the advantages of "Plan A". Currently, research is done within CO on how to increase the effectiveness and efficiency of the assembly process output, in combination with a 25% reduction of the used surface of this assembly shop. The main result will only be recognized within one or two years, but known is that the process needs a decrease in variance of part delivery time, in order to create a Just-In-Time (JIT)-environment. This fact makes this study more applicable in practice within CO, and therefore the variance of delivery time of the purchased parts will also be studied in this research.

1.5. Central Question

The goal of this research is to reduce the lead-time of the machines of CO, while focusing on the delivery time and -variance of the purchased parts and their suppliers, even as the processing of purchase orders by CO. In most literature, lead-time reduction is applied within mass production; to create a lead-time reduction of for example a few hours, minutes, or even seconds per product. Because CO's production system is mainly on project basis, this study is different. The desired lead-time of a machine within CO is 16 weeks, and this research aims to maintain this time unrelated to (variations in) supplier delivery- and lead- times. The recommendations will not only focus on the current situation, but also on the long term, and the ongoing changes discussed before.
Taking the above-mentioned factors and focus into account, the following central question can be derived:

How can the lead-time of CO be decreased, by influencing the lead-time and variance of suppliers' delivery times and the processing of purchase orders within the organization?

This central question will be answered using several research questions, as discussed in the research approach; Chapter 1.2.

1.6. Research Questions

The first research step in this study is the diagnosis phase, which reviews the current situation and aims both to demonstrate the occurring (expected) issues and to trace their causes. The factors that can increase lead-time are discussed earlier. These factors have to be uncovered and quantified in practice, so that the current situation within CO is known together with the factors that actually increase the lead-time. Therefore this research question is needed:

1: How can the current situation within CO and at their suppliers be analyzed, and what are the causes of high lead-times and their variability in this situation?

Second, when the current situation is described, a set of requirements for future solutions has to be constructed, in cooperation with involved employees of the purchasing department and the management of CO. This would give direction to future solutions or improvements. The answer to this question should act as a framework for the design phase of this study.

2: What are the requirements for a future solution for reducing the lead-time and its variance, with regard to the analyzed causes and effects, according to the purchasing department and the management of CO?

The final phase for this research is the design phase, in which possible solutions for reducing lead-time within CO are being suggested. The researchers' creativity and knowledge supported with theory, offers several strategies and methods to decrease supplier lead-time and –variability. Based on the set of requirements the most suitable solutions should be selected.

3: What solutions can be derived based on the analysis, the researchers' knowledge and creativity, the set of requirements and theory, in order to decrease supplier lead-time and its variability with regard to purchased parts?

2. Methodology, Data Collection and Analysis

This chapter elaborates on methodological issues and the data collection needed for this study. For the first part of this research a literature study is needed in order to discuss tools that can describe the current situation at CO. The second research question regarding the set of requirements will be answered with information of employees and staff within CO. This is done with focus groups, as discussed in Section 2.2. Finally, applicable solutions will be discussed using a literature review, the researchers' creativity and knowledge, and the diagnosis (Figure 2-1).

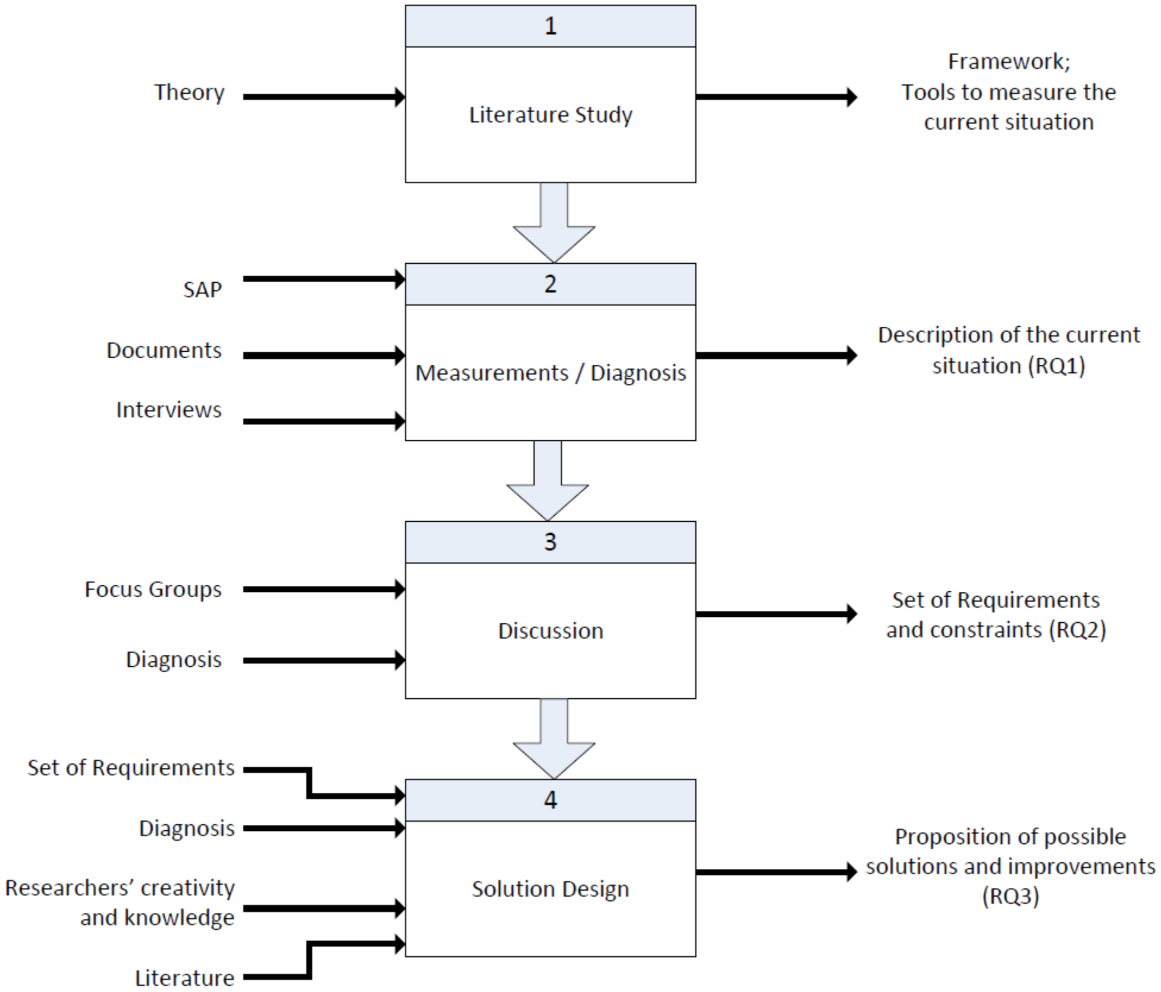


Figure 2-1: Research Methodology

2.1. Analysis: Using different Sources of Data within CO in Order to describe the Current Situation.

In order to describe and analyze the current situation and the causes of occurring issues within CO, different types of data will be used including literature, written procedures, database information (from CO's administrative system; SAP) and of course employees of CO. These methods will be discussed in this chapter with regard to the methodological implications.

The first method, which forms the basis for this research, and acting as background is the literature review. The aim of this research is to apply theory from different fields as supply chain management, lean management and purchasing in the supply chain of CO. Literature also provides several lead-time reduction strategies, which will be discussed in the final part; the proposition of possible improvements. Some theories or papers are highly applicable towards this case, others are only slightly generalizable. This should be taken into account with regard to external validity (Shadish et al., 2002). In the past 15-20 years supply chain management became popular at both scholars as managers and therefore much literature with regard to this topic is available. With the use of the literature review, a framework is created which provides tools for measuring the current situation.

The administrative system of CO is SAP. All relevant information with regard to production orders, machines, purchase orders, delivery dates etcetera can be found in this system. A complication is that CO currently is in a transition phase from the old system to SAP. Therefore only information from 2011 is available, and longitudinal measurements are difficult. This causes the analyses to only act as examples in order to reveal occurring problems and their (possible) causes.

CO has a relatively flat organizational structure and an informal atmosphere. Therefore not all procedures are written down, as this simply does not fit the company. This study mainly will use written information: organization charts, the so-called "swimming lanes" (fixed information streams), and the flowcharts of the different departments. These written procedures are used to create an overview on how an order runs through the organization and which actors (both internal and external) are involved.

Particularly in the first phase of this research, employees of CO are the most important source of information (also see Section 2.2). Personnel whose daily activities include planning and procurement can extensively explain occurring problems and procedures. These employees could be biased in their information, and therefore asking as many and divers as possible would increase validity (Shadish et al., 2002).

As a final part, the creativity and knowledge of the researcher are used. Not all topics and strategies can be included in one single study, and therefore choices have to be made. These choices will be based on the researchers' interests, knowledge and possible biases.

As can be seen, no information is used from suppliers, which has two main reasons. The first reason is that there is a very big supply base, and in order to gain consistent information almost every supplier should be interviewed regarding their processes, current situation and mindsets. The second reason is that most information is treated as confidential, and therefore not available for CO.

2.2. Focus Groups: deriving a Set of Requirements from CO

As mentioned before, the set of requirements for future solutions will be discussed with the management of CO, and the involved employees of the purchasing department. This is a total of 6 people, all having different interests and disciplines. Normally in a business problem solving project, a set of requirements is also derived from the strategy of the organization. Many organizations do not have a strategy written down, and this is also the case within CO; therefore this method includes deriving opinions and experiences from staff and employees. A common tool for collecting this sort of information is the focus group (Hyden & Bulow, 2003). A focus group is a qualitative method and described as a *"carefully planned discussion designed to obtain perceptions on a defined area of interest…"* (Krueger, 1994, p. 6). According to Fern (1982) individual interviews generate more ideas than a focus group, but on the other hand focus groups can derive the same sort of answers, but in social context (Watson & Robertson, 1996; Massey, 2011). Another advantage of group discussions over individual interviews is discussed by Morgan (1997), who states that *"Group discussions provide direct evidence about similarities and differences in the participants' opinions and experiences…"* (p. 10). Massey (2011) cites several authors who discuss focus groups as being useful in the process of understanding stakeholders in the case of specific experiences or incidents (Krueger, 1994; Wibeck, Dahlgren, & Oberg, 2007).

Focus groups have several strengths and limitations, which are important in a methodological context. First, in a focus group the participants can interact with each other in order to generate data (McLafferty, 2004) without a contextual framework, in order to uncover the various perspectives present (Massey, 2011). Second, the evaluator is able to understand the problem from the participants point of view (Kress & Shoffner, 2007), which is particularly useful when, as in most cases, the researcher is not involved in the problem, or even not employed in the organization that owns the problem. Third, a focus group can help creating support for possible changes within an organization; the purpose and aim(s) of the research is shared with the

participants (McLafferty, 2004), and therefore the reliability of the data is enhanced (Thayer & Fine, 2001).
One of the limitations of focus groups is provided by Massey (2011) as he states that the relevancy of the data is dependent on relevancy of the questions asked by the evaluator: *"If questions are confusing or irrelevant, or if the moderator fails to provide useful and meaningful prompts, the focus group may fail to capture the participants' meanings."* (p. 24). Another limitation is the reliance on manifest content. While in most interviews, researchers count data on the frequency of arising topics, or a certain opinion is expressed (Basit, 2003; Flick et al., 2004) several authors state that this is not desirable within data analysis of focus groups (Carey, 1995; Webb & Kevern, 2001).

Although focus groups are widely used in health care studies (Watson & Robertson, 1996; Devers, 1999; Webb & Kevern, 2001; McLafferty, 2004), this method is also used in more recent studies regarding social sciences (Bloor et al., 2001; Hyden & Bulow, 2003; Hollander, 2004), and applicable for this research as discussed above. The aim with regard to this study is to gain both long-term as short-term requirements. Therefore there are two groups, as can be seen in Table 2-1. The former is conducted on a strategic level, while the latter is used to gain information on an operational level.

Group		**Activities**
1	A	Financial Controller, Mentor of this research
	B	Technical Director
2	C	Procurement of purchased parts
	D	Purchasing Strategies, Communication towards suppliers
	E	Procurement and outsourcing of manufactured parts
	F	Overall project- and production planning

Table 2-1: Focus group participants

3. Diagnosis: Describing the Current Situation

The actual diagnosis is conducted in this chapter. First, the suppliers and purchased parts are discussed in order to create an understanding of the organizations and items interesting for this research. Second, a choice is made for several time-based tools in order to describe the current situation and the problems that occur. After discussing the results of these tools, this chapter aims to find the causes that should be overcome. The tools are applied in order to analyze the processing of purchase orders (of purchased parts) at both the suppliers and CO itself. Where possible, information from the administrative system is used in order to illustrate the situation.

3.1. An Analysis of the Suppliers of Purchased Parts

First, an overall analysis is conducted in order to create a good overview of the purchased parts and their suppliers. Many authors discuss portfolio models in order to map suppliers (or purchased parts) and discuss strategies for each specific position (Nellore & Soderquist, 2000; Gelderman & Van Weele, 2002; Wagner & Johnson, 2004). The basis for this, according to Caniëls and Gelderman (2005), lies in the research of Kraljic (1983). He proposed two factors through which suppliers (or purchased items) can be categorized: *"…(1) the strategic importance of purchasing in terms of the value added by product line, the percentage of raw materials in total costs and their impact on profitability, and so on; and (2) the complexity of the supply market gauged by supply scarcity, pace of technology and/or materials substitution, entry barriers, logistics cost or complexity, and monopoly or oligopoly conditions…"* (p. 110).

The so-called *Kraljic-Matrix* by Kraljic (1983) and later modified by Caniëls and Gelderman (2005) – which is used here - has four quadrants (based on supply risk and profit impact, as discussed before). Figure 3-1 shows the Kraljic-Matrix applied to CO, which is filled in for the suppliers of the purchased parts. The supply risk of the total of CO's 162 suppliers of purchased parts is determined by the purchasing department of CO. Suppliers which maintain very long delivery times, and deliver scarce products or are scarce themselves, are stated to be "high risk". Categorizing on costs is done with the Pareto method: suppliers were sorted on CO's purchasing volume. The top suppliers that together accounted for 80 percent of CO's purchasing volume, were classified as high with regard to costs. As can be seen, most (144) suppliers deliver items low costs and low supply risk; *non-critical* or commodity items like bolts and other items needed on a regular basis. *Leverage Items* are items with low supply risk (multiple possible suppliers, and often therefore no delivery problems), and a high yearly turnover. Small percentages of savings involving these items often result in high costs savings, and suppliers are mostly dedicated because of high competition; supply risk is low, so suppliers can be substituted if needed.

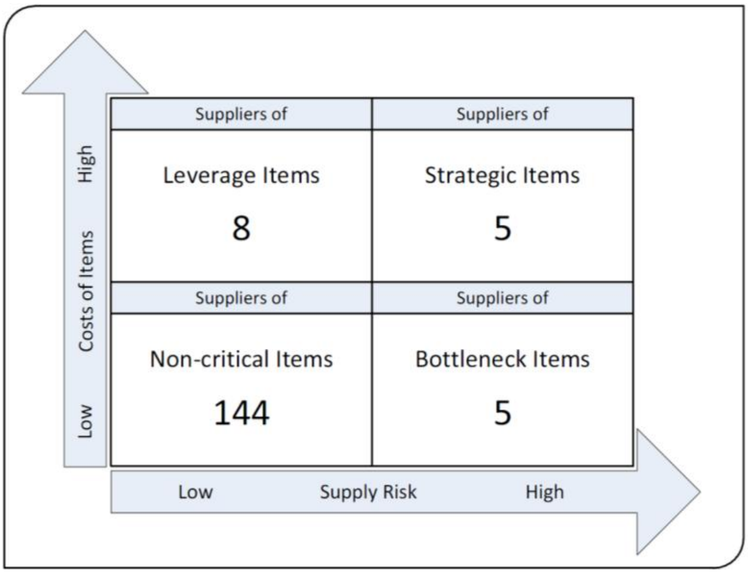


Figure 3-1: The Kraljic-Matrix filled in for the suppliers of purchased parts

Most interesting categories with regard to the studied topic are the suppliers of *strategic* and *bottleneck items*. These suppliers offer items with a high supply risk: not only the items or materials are scarce but often also the suppliers themselves. This results in availability problems or delivery errors. *Strategic* items are necessary as they are a (relatively) large part of turnover. *Bottleneck items* should be avoided as much as possible because of the dominant power position of the supplier(s). *Non-critical* and *leverage* items are items with a low supply risk, and respectively low and high yearly turnover. From discussions with the purchasing department it appears that extreme long delivery times mostly only occur at items with a high supply risk (because of the scarcity of items or the suppliers themselves, as discussed before). Problems with high variability of delivery times (unreliability of the suppliers), on the other hand, occur at all categories. This research will therefore focus on all groups of suppliers.

Kraljic (1983) and Caniëls and Gelderman (2005) propose strategies and main tasks for each quadrant in the matrix. For strategic items, the authors propose cooperation and partnership-strategies. For the suppliers of these items in particular, the only actions currently undertaken by the purchasing department are pressurizing suppliers by phone and a minimum number of agreements. The absence of supplier cooperation could result in longer lead-times or lower supplier reliability. The possibility for successful cooperation also depends on CO's importance to a specific supplier. CONFIDENTIAL
Table 3-1 shows the yearly turnover of the 5 strategic suppliers (with which CO should cooperate according to literature), and the sales volume of CO as a percentage of this turnover.

CONFIDENTIAL

Table 3-1: Turnover of strategic suppliers and CO sales volume (2011)

Above standing table illustrates that CO sometimes is not a highly important customer for strategic suppliers, with regard to turnover. Cooperating with suppliers therefore, will be more difficult. While all suppliers are taken into account in this research, the following statement with regard to long lead-times and high variability concerning strategic suppliers can be derived from this analysis:

Cooperations in order to reduce lead-time and increase delivery reliability are more difficult to enter because CO is a too small market player for several strategic suppliers.

3.2. Identifying and Quantifying Lead-Time and-Variance influencing Factors

This section aims to identify and quantify (where possible) the factors that influence and increase the lead-time of CO. As discussed in Chapter 2.2, this will focus on the suppliers' delivery time (and delivery time variance) of purchased parts and the processing of purchase orders within CO.

A well-known method for analyzing time-wastes in a supply chain is known as Value Stream Macro Mapping (VSMM), a relatively new term introduced and applied by Womack and Jones (2002), and later on discussed by Fontanini and Picchi (2004), but the concept itself (in another form) is used before by several authors (Hines & Rich, 1997; Holweg & Bicheno, 2002). Romero and Chávez (2011) address that VSMM can be used to eliminate supply flow wastes, and that it is *"…aiming the entire flow improvement and not isolated tools application or isolated initiatives with limited results"* (p. 2). Hines and Rich (1997) discuss seven different value stream mapping tools, and use a simplified version of the Value Stream Analysis Tool (VALSAT) to choose a useful mapping tool. The fact that these authors use a case example which is about supplier lead-time reduction makes this paper highly applicable, even as the fact that Hines et al. (1998a) put this strategy into practice for creating a JIT supplier network. Lee (2001, p. 2) concludes that VALSAT is *"a dynamic analysis, prioritisation and focusing tool, which if possible should be capable of using both tacit and subjective information as well as explicit or quantifiable information…"*.

3.2.1. Using the VALSAT-Method in Order to select Value Stream Mapping Tools

For discussing the current situation in the value stream of CO, value stream mapping tools will be used, as discussed before. Table 3-2 is filled in with the use of the VALSAT approach. The left column contains the factors (who are originally based on the creation of a lean supply chain or to decrease supply chain lead-time) are tailored towards this specific case with the use of Table

1-1. An elaboration on this method can be found in Appendix I. The second column contains the weights. These weights are averages of the scores that are filled in by all (5) employees and staff within CO who's daily activities include purchased parts and their suppliers. These respondents (including a technical director and several purchasers), were asked to weight the different factors to their perceived importance; a total of 35 points was assigned, and a factor could not attract more than 9 points. The last column contains all the different value stream mapping tools. Hines and Rich (1997) scored each combination of tools and factors on correlation and usefulness (p. 50). A high (H) score results in a 9, medium (M) and low (L) scores result in respectively a 3 and 1 (Appendix II shows the original table). The weights in the columns are the product of the scores of and Hines and Rich (which should be considered as given) and the weights filled in by CO. The row "total weight" is the sum per tool, and with this row the most applicable and usable tool(s) will be chosen.

		Tools						
Wastes	**Weight**	Process activity mapping	Supply chain response matrix	Production variety funnel	Quality Filter mapping	Demand amplification mapping	Decision point analysis	Physical structure
Stocks of (semi-)finished products	4,20	4	13	0	4	13	13	0
Supplier delivery time/ supplier order cycle time	6,40	58	58	6	0	19	19	0
Conveyance	2,60	23	0	0	0	0	0	3
Inappropriate processing	4,20	38	0	13	4	0	4	0
Excess stock	6,40	19	58	19	0	58	19	6
Unnecessary information movement	4,60	41	5	0	0	0	0	0
Service defects (on-time delivery)	6,60	7	0	0	59	0	0	0
		190	132	38	68	89	55	9
		Total weight						

Table 3-2: Selection VSM tools with the use of the VALSAT-method

A methodological remark however is needed, because some VSMM-tools are more generally usable than others, and this will automatically result in a higher VALSAT-score, even with only the correlation scores filled in by Hines and Rich. Therefore, together with the intention to be as complete as possible, and the fact that a decision-point-analysis is already executed by CO, not a single but the four highest-scoring tools are selected: Process activity mapping, supply chain response matrix, demand amplification mapping, and quality filter mapping. In the rest of this chapter, these mapping tools will be used to describe the current situation within CO, and try to address the causes of currently experienced issues. In the future these methods can be used to analyze the effect of implemented solutions over time.

3.2.2. Process Activity Mapping

The origin of process activity mapping can be found in industrial engineering, and also known as *process analysis* (Practical Management Research Group, 1993). This tool is not only used to introduce lean management in an organization, but also in different (supply chain) waste-reducing projects, for example in construction by Lee et al. (1999), the white good industry (Alaca & Ceylan, 2011), engineering and manufacturing (Krishnamurthy & Yauch, 2007), and the forest products industry (Haartveit, Kozak, & Maness, 2004). In this research the following two steps are performed with regard to process activity mapping: studying the process- and information flow for an entire project and after that the identification of waste: non-value-adding activities (Hines & Rich, 1997). Each step within a project is analyzed for the time needed, as well as the department and the number of people involved. The steps are categorized in Operations and Activities, Transport of goods and information, Inspection, Storage, and Delays as can be seen in Table 3-3. Operations and Activities contain both the value-adding and necessary but non-value-adding activities (Monden, 1993). In this overview, single actions do not include time; the time for waiting on these actions on the other hand, is included. Furthermore, waiting on actions of customers is not taken into account: delays caused by customers who for example pay too late, are directly charged to the project.

The analyzed project (a drill/saw-combination) is relatively standard and therefore generalizable towards other (similar) projects; each month one or two of these projects are started, but still several wastes occur, as discussed hereafter. The waiting times measured in this example cannot be considered as averages for other projects, but there are no reasons to believe that this project is an exception.

		Project A (1000144)							
	Step	**Time (hr)**	**Department**	**People**	**Operat./ activity**	**(info)Transport**	**Inspect**	**Store**	**Delay**
	Customer order								
1	Send Invoice 1st Term					T			
2	Confirmation of order						I		
3	Waiting on 1st payment								D
4	1st Payment				O				
5	Creating sales order				O				
6	Kickoff Meeting					T			
7	Design Layout				O				
8	Send Layout & Customer check						I		
9	Waiting on customer to confirm layout								D
10	Layout confirmed					T			
11	Startup production order				O				
12	Waiting on planner								D
13	Production planning		**CONFIDENTIAL**			T			
14	Waiting on Work prep								D
15	Work prep. Purchased- and custom parts				O				
16	Determine handling				O				
17	Waiting on mech./electr. Engineering								D
18	Custom mech./ electr. Engineering				O				
19	Create BOMs				O				
20	Ordering purchased- and custom parts				O				
21	Awaiting arrival purch.- and custom parts								D
22	Arrival of parts					T			
23	Assembly				O				
24	Send invoice 2nd term					T			
25	Testing						I		
26	Packing							S	
27	Machine storage							S	
28	Awaiting 2nd payment								D
29	2nd payment				O				
30	Shipping					T			
	TOTAL 30	**810.1**	**hr**	**39**	**11**	**7**	**3**	**2**	**7**

Table 3-3: Process activity mapping

What can be noticed is the occurrence of waiting times, which are often caused by external factors from both sides of the supply chain (customers and suppliers). In the first phase of a project, the customer causes the main delays (not quantified as discussed before). The first payment is needed before a project can be started up, and after that the concept of the layout has to be checked and approved. This approval is important in order to prevent unnecessary mistakes and rework.

In the second phase of a project, delays are caused by the suppliers: Long and unreliable delivery times. After the assembly process, the machine is rigorously tested, again both to deliver a high-quality product, and to prevent rework. Furthermore, waiting can occur between departments due to fluctuations in workload, for example waiting on the planning as can be seen in this project.

This overview is only a starting point to describe the current situation. The main problem (with regard to processes) seems to be that the longest delays occur, or are caused by, external actors which will be discussed in the rest of this chapter. Within CO, the cause for long waiting time lies in the order of processes. After ordering parts for example (step 20), nothing can be done for a project except waiting for parts to arrive. When this step could be advanced in time, this would possibly decrease waiting time without decreasing the actual supplier lead-time. Nevertheless would this have a positive effect on the lead-time of CO. Taking above discussed into account, the following possible cause could be derived with the use of process activity mapping:

The relatively late moment (within a project) of ordering purchased parts causes longer (internal) waiting times for CO.

After implementing solutions, the waiting time on arrival of parts should be decreased. Table 3-3 describes the process and the general wastes that occur: the rest of this chapter will further illustrate these problems which are correlated to waiting time, using the mapping tools chosen before.

3.2.3. Supply Chain Response Matrix

The origin of the supply chain response matrix is logistics movement (Hines & Rich, 1997) and is used in many different fields including textile supply chains (New, 1993; Forza et al., 1993), in industrial sectors by Beesley (1994) known as “time-based process mapping”, and as Value Stream Process Modeling in a study of Jessop and Jones (1995) with regard to an electronics supply chain.

A supply chain response matrix can be used *“…to evaluate the inventory and lead times incurred by a supply chain in maintaining a given level of customer service.”* (Lehtinen & Torkko, 2005, p. 60). Practically for CO this means that for a specific part, it can be seen where in the supply chain inventory is held, together with the lead-time of that specific part. Figure 3-2 shows the supply chain response matrix of a single part (in this case a mounting roller; a leverage item, delivered by REPA. See Figure 3-1) and clearly illustrates CO's strategy to keep in-house inventories low. The horizontal axis shows the (cumulative) lead-time of the product, and the vertical axis shows the amount of inventory (in days) present within a certain process (inventory at certain point divided by average usage). Most interesting parts of the matrix according to Hines and Taylor (2000) are *"…lengthy delays (long horizontal lines within and between the elements of the chain) and high amounts of inventory storage (long vertical lines within each element of the chain)."* (p. 32).

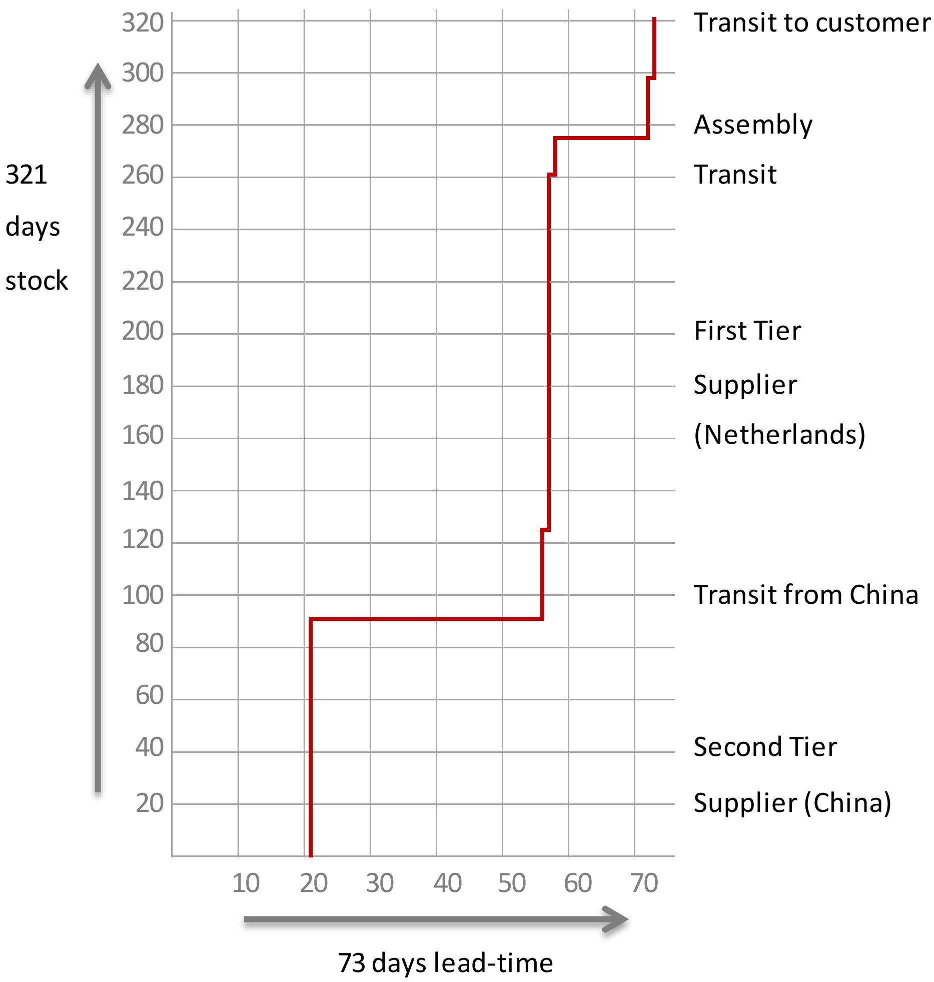


Figure 3-2: Supply Chain Response Matrix

Because of the relatively long supplier lead-times, (safety) inventories are needed to assure on-time starting of assembly at CO. With CO not accepting in-house inventories, the suppliers have to maintain these, as can be seen in Figure 3-2. CO has a considerable influence on this supplier through both substantial consumption and a good market position. Here, the effect and advantage of leverage items (Figure 3-1) is clearly visible: the first tier supplier is willing to take the risk of inventories for CO, instead of CO itself taking this risk (or the risk of too late delivery).

3.2.4. Demand Amplification Mapping

Demand amplification mapping is a tool which evaluates the consequences of poor decision making and information sharing in a supply chain (Hines & Rich, 1997). Several decades ago Forrester (1958) designed this method, and Burbidge (1984) increased the usefulness in that period. Theory states that demand amplification increases for each actor upstream in the supply chain: the Forrester Effect (Forrester, 1958), also known as the bullwhip effect (Metters, 1996; Lee et al., 1997).

Demand amplification mapping distinguishes all steps where products are ordered or sold, occurring from actual sales towards customers, to orders at upstream actors. Taking CO and their 1st tier suppliers into account, three steps can be determined: Actual sales (machine orders), orders towards suppliers and product shipments. Figure 3-3 illustrates the actual orders and shipments of projects in several weeks of 2011. As can be seen, demand fluctuation is relatively high when taking the scale of one single project into account. One shipment (or project) generally consists of multiple machines, for which numerous parts have to be ordered at suppliers. One single shipment therefore needs several hundreds of orders towards suppliers. This increases the fluctuations, as can be seen in Figure 3-3.

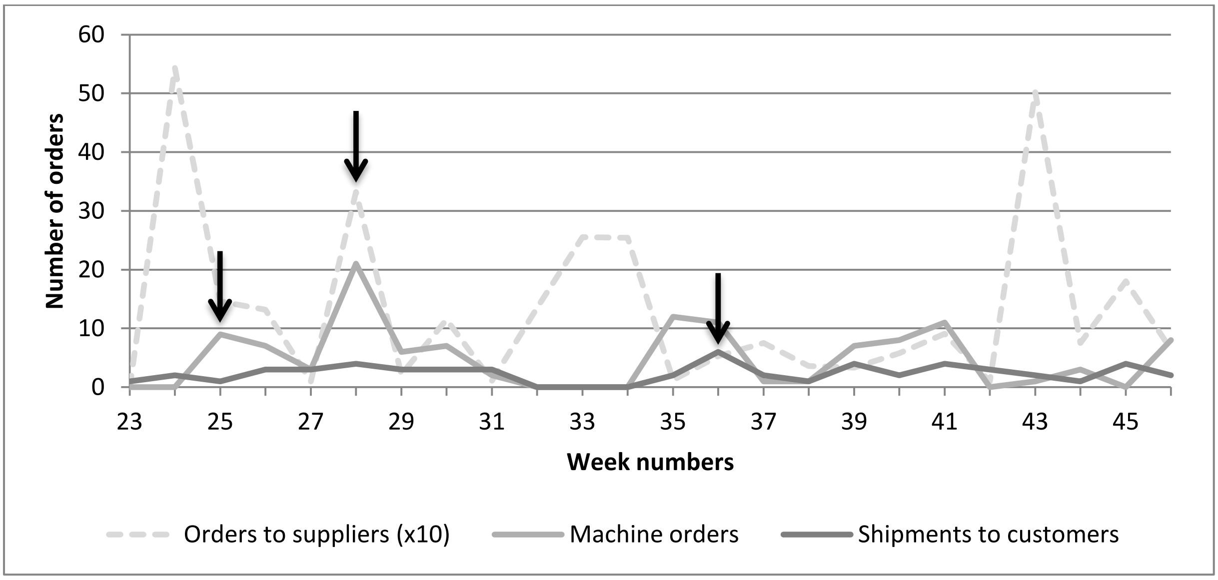


Figure 3-3: Order and demand variation

The arrows in this figure illustrate this sequence and fluctuation. The peak under the left arrow shows a peak in machine orders in week 25 (projects are started up). After starting up the orders, the purchasing department starts the ordering of parts (second arrow, week 28) and after the supplier lead-time and delivery of parts, assembling and shipping of the projects takes place, under the third arrow (in week 36). Because demand (particularly from CO towards suppliers) heavily fluctuates, it is difficult for suppliers (in particular *leverage* suppliers, where CO has high yearly turnover) to anticipate on the changing demand or schedule (CO's) demand in order to create stability in delivery planning. The high demand amplification (initially caused by the customers of CO) towards suppliers also depends on the ordering procedure of CO's purchasing department. This results in ordering all parts if the assembly date and the Bill of Materials (BOM) are known, instead of demand-driven ordering (order date = planned delivery date – delivery time) for every specific part. CO uses insufficient order release mechanisms: no difference in moment of ordering is made between parts with a long or short delivery time. The only distinction that is made, is for parts with extremely long delivery times, which are ordered far in advance (based on forecasts). This prevents CO itself to stabilize demand towards suppliers (Taylor, 2000).

Wrong or insufficient use of order release mechanisms causes high demand amplification towards suppliers, which prevents them from anticipating on demand changes and stabilizing their delivery schedules for CO.

This demand amplification also occurs in the forecast of CO's planning department. As stated in the introduction, CO uses a forecasting procedure in order to anticipate on demand of items with long delivery times. The planning department creates a rolling forecast for each specific type of machine in cooperation with the sales department. 25 Weeks before the forecasted starting date, a choice has to be made whether to start up the project (order the items with long delivery times), or to cancel the project and wait for the next forecasted machine. This is a relatively long period, which makes forecasting extremely difficult. An example of (part of) a rolling forecast can be found in Appendix III.

When reviewing the forecast of CO it is noticeable that often, projects did not start although they were forecasted. Only from the first week in Figure 3-3 (week 23) CO started to forecast projects, with a timeframe of 30 weeks in front (these machines will be built in 2012). Therefore it was not possible to create an overview of forecasted machines versus actual sales of those machines. However, with the use of reports from forecast meetings an overview is created on how many projects are started from forecast, and how many rescheduled to a later date. This can be seen in Figure 3-4, which shows that forecast currently is reasonably fluctuating and imprecise, and therefore could be improved.

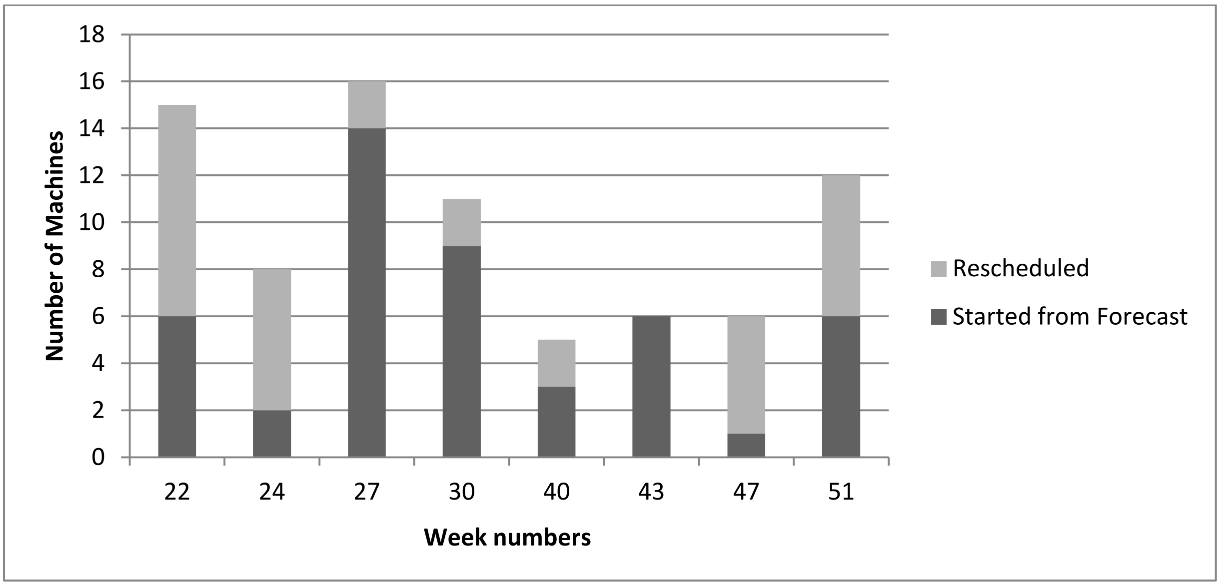


Figure 3-4: Forecast accuracy

Machines rescheduled from forecast cause rework: the planning department has to reschedule all manufacturing processes to a new date. Furthermore, the purchasing department have to change all purchase orders (Figure 3-3) and contact the suppliers to receive other delivery dates. This, besides even more demand amplification, could result in difficulties for suppliers; a new delivery date has to be found (whether or not in accordance with CO), and again all procedures with regard to order confirmation etcetera have to be gone through. This requires effort and resources (and therefore money). Apart from this, all irregularities could result in irritations, or even a decrease in the supplier's dedication towards CO. This could have painful consequences with regard to every category of supplier. With this reasoning, the following possible cause of long and variable supplier lead-times is identified:

Regular rescheduling of purchase orders due to relatively imprecise forecasting decreases the supplier's dedication and therefore CO's priority towards them.

As final remark of this chapter: Purchasing parts when the BOM is known (in other words; ordering parts when a customer order is received, no matter the planned delivery date), also could cause inappropriate delivery. On the long term, the starts of the assemblies are unsure. With demand-driven ordering (ordering on a more short term), the order dates and starts of assemblies are closer together.

3.2.5. Quality Filter Mapping

Quality filter mapping is a relatively new tool, and is used to detect supply chain quality problems. Hines and Rich (1997) state that there are three quality defects that can occur in a supply chain (p. 54). One of them is service defects:*"... such defects include any problems that customers experience which are not concerned with production faults."* (p. 54). This research focuses on the service defects within the supply chain of CO, which according to Hines and Rich (1997) consists of too late or too early delivery. In this context, a service defect occurs when there is a difference between the planned delivery date of an order confirmation (provided by the supplier), and the actual date of receipt at CO. An overview of the fluctuating delivery times (service defects) can be found in Figure 3-5. Here an overview is created for purchase orders, and their difference between the planned and actual delivery date. This is done for three random, independent, recent projects.

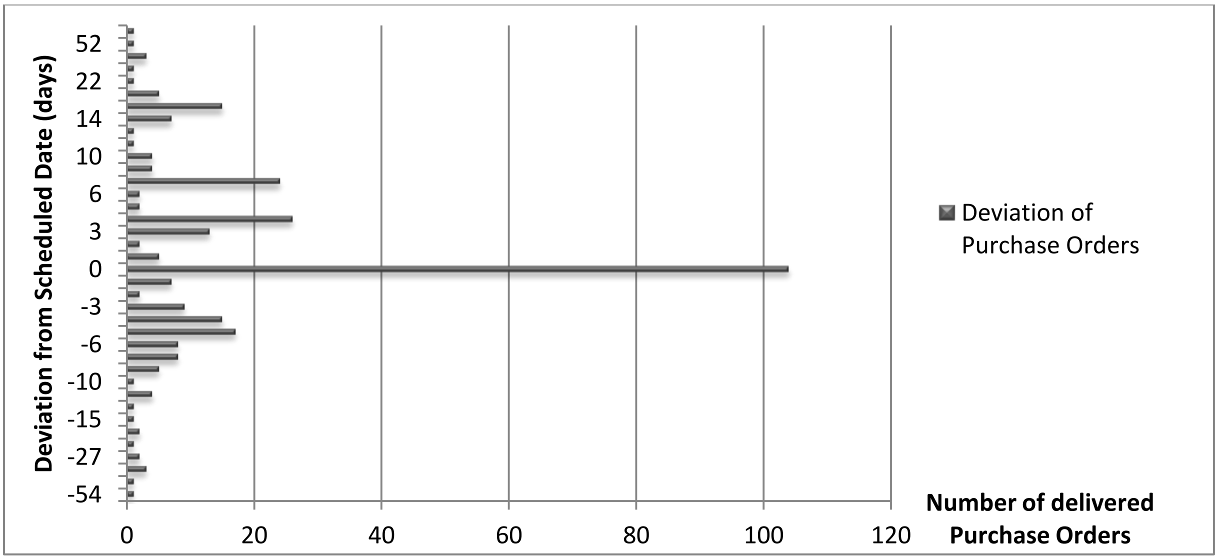


Figure 3-5: Deviation from scheduled delivery dates

In Table 3-4 these three projects are compared for exact on-time delivery and for a timeframe of two days. A comparison within this timeframe is added because on the one hand manufacturing most of the time can start with some parts not being present for a small amount of days, and on the other hand parts are not always registered the exact same day they are delivered at CO.

Order-no.	Total purchase Orders	On scheduled date		+/- 2 days	
		27	(27 %)	37	(37 %)
CONFIDENTIAL		5	(8 %)	13	(20 %)
		72	(48 %)	81	(54 %)

Table 3-4: Orders and on-time delivery

The high unreliability of deliveries is not only caused by suppliers: the differences between the modules in Table 3-4 is that the first and third were standard projects, and the second was rescheduled by CO. Parts were already ordered long before needed (when a project is started up and the BOM is known, all parts are ordered all at once), but afterwards the delivery date was rescheduled where possible. Therefore the purchased parts arrived over a long period of time, and had to be held as inventories at CO or its suppliers, or caused projects to be delayed. This clearly illustrates the effects of rescheduling by CO, in combination with purchasing regardless delivery times (ordering when the BOM is known) which causes orders to be fixed over a too long period. Therefore the following statement can be derived:

The combination of orders that are placed regardless of delivery times, and regular rescheduling causes service defects: too late or too early delivery of purchased parts and unnecessary inventories.

In Figure 3-6a-c overviews for the same projects as discussed above are given. The darker lines illustrate the agreed date and number of deliveries of goods, the lighter lines do the same for the actual numbers. This figure demonstrates again that many purchase orders are delivered later than planned or agreed. In other words, the timeframe in which orders actually are delivered at CO is much longer than planned. In reality, planning and purchasing personnel of CO exchanges incoming or ordered parts between started up and rescheduled projects so that actual waiting time is not as long as these figures show.

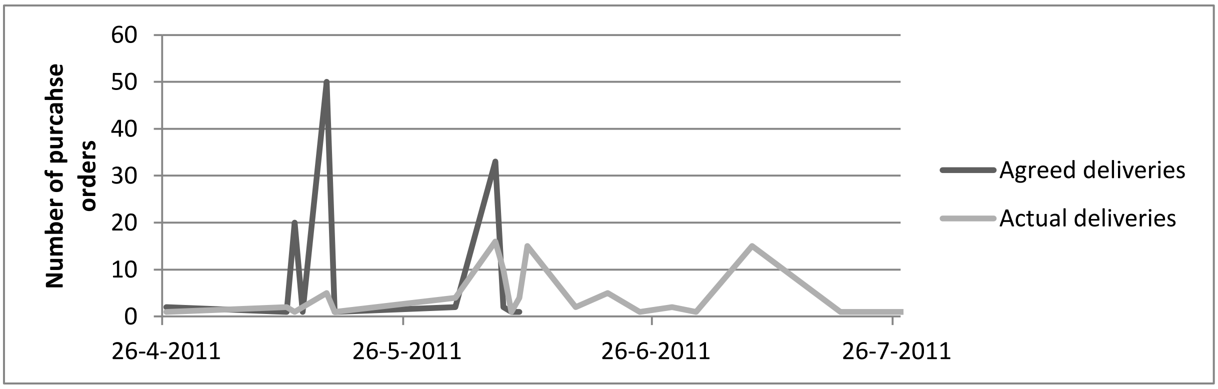


Figure 3-6a: Planned vs. Actual Deliveries for Project A

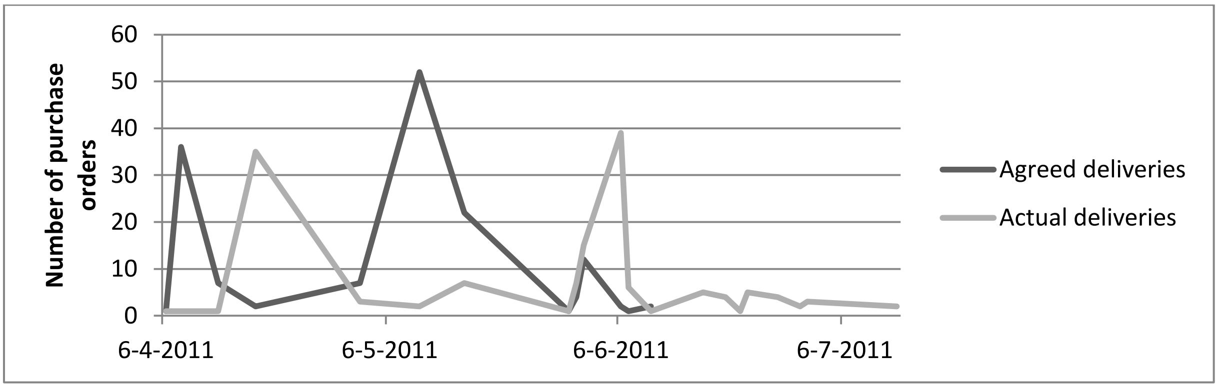


Figure 3-6b: Planned vs. Actual Deliveries for Project B

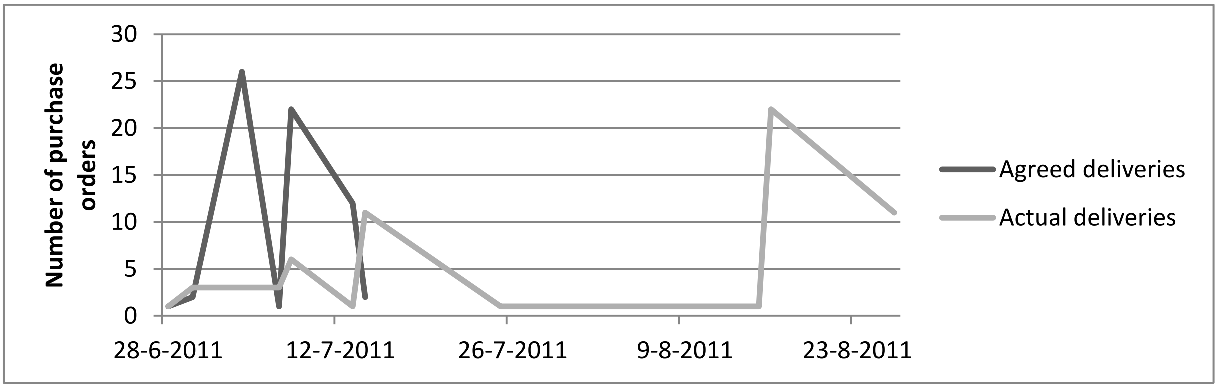


Figure 3-6c: Planned vs. Actual Deliveries for Project C

To create a statistically valid overview, a longitudinal measurement or information from multiple projects is needed, but currently this is not possible with CO's accounting software. Therefore Figure 3-5 and Figure 3-6a-c as well as Table 3-4 are only examples that illustrate the current situation. The fact that this information currently is not obtained by CO is an issue according to Hines and Taylor (2000). These authors discuss that if this sort of supplier- and supply chain information is not present within an organization, they are not able to make improvements in this field. The reason that this currently is not monitored is the transition to a new administration system. Therefore not all data is present at this moment. In the future on the other hand, monitoring techniques could prevent (obvious) problems to maintain unnoticed (Jahnukainen & Lahti, 1999). This leads to the following statement:

The absence of supplier monitoring techniques could cause problems and irregularities to maintain unnoticed and prevent them from being solved.

3.3. Analyzing the Observations

The analyses of the current situation provide a better overview of the current situation within CO, and a better understanding of the occurring issues and their causes. To precisely discuss and analyze the current situation, a longitudinal study has to be conducted. But because of the limited time, and the limitations as a result of the transition to a new accounting system this was not possible in this research. On the other hand, the currently available results clearly indicate and illustrate both the problem and the causes.

Analyzing and categorizing CO's suppliers showed that most suppliers are those of commodity (non-critical) items, for example bolts and screws. But several suppliers are difficult to replace or provide very specific items; suppliers of *strategic* and *bottleneck* items. Conversations with the purchasing department reveal that long delivery times mostly occur at these two types of suppliers, while high delivery time variance occurs at all four types of suppliers. A comparison of the yearly turnover of strategic suppliers, and CO's sales volume shows that the latter is not very important for these suppliers. This causes collaborating-difficulties which prevents CO from increasing their priority for these vendors.

The process activity mapping shows that long waiting times are caused by both sides of the supply chain (customers and suppliers), as well as internally in CO. Some waiting times occurred by waiting on the customer to pay, or to confirm the order and the layout of the machine. This is to prevent rework and therefore necessary but non-value-adding. Within CO waiting times (or queue-times) are caused by waiting on departments to become available for the project. Furthermore, when products are ordered, waiting time again occurs for the arrival of the purchased and custom parts This is because of the relatively late moment of the start of purchasing within a project of CO.

Using a supply chain response matrix, CO's strategy to keep in-house inventories low, even for products with a long supplier lead-time, was illustrated. For products with long lead-times a buffer has to be made, somewhere in the supply chain. Several suppliers are willing to cooperate by maintaining inventories, as discussed before. But other suppliers, where CO only consumes a small proportion of annual turnover, will not collaborate this easy. Furthermore; their inventory is also used for other customers (in the case of purchased parts), thus mapping inventory especially for CO was not possible. Examples of this are several suppliers of regulators and actuators which maintain both long delivery times and low in-house inventories. This currently forces CO to forecast demand and establish a buffer.

Furthermore, demand amplification mapping showed the major fluctuations of demand and orders over time, caused both by customers and by the lack of order release mechanisms within CO. Customer demand mainly fluctuates because of the magnitude of the projects. These machines are not sold on a regular basis, and no project is the same with regard to size: This differs from one single machine to a complete production hall layout as stated in the introduction. The purchasing strategy of CO also contributes to the amplification of demand towards suppliers. Parts are ordered for a specific project, so it can occur that two similar parts are delivered in the same week but not on the same day because this results in two different purchase orders. This causes unnecessary activities for both the purchasing department of CO and the suppliers.

Finally, with the use of quality filter mapping focused on service defects, the deviation in supplier delivery precision is visualized: Too early or too late delivery often occurs due to reasons from both CO and their suppliers. The rescheduling of projects (with parts already ordered when the BOM is known) within CO is a major reason this happens. The absence of monitoring techniques prevents CO from recognizing this sort of upcoming problems. Here, a dilemma arises: As stated, demand for parts with long delivery times should be known in an as early stage as possible, but the ordering itself as late as possible with regard to enable rescheduling without contacting the suppliers.

Summarizing, the issues derived from the diagnosis could result in long supplier lead-times and high lead-time variability (unreliability). An overview of the causes discussed in this chapter and their effects are given in Figure 3-7. On the left side of the Figure the causes extracted from the analysis are given. These causes are combined towards the right as they have the same effect. Rightmost, where all causes and their effects lead to is the issue that CO experiences: long lead-times.

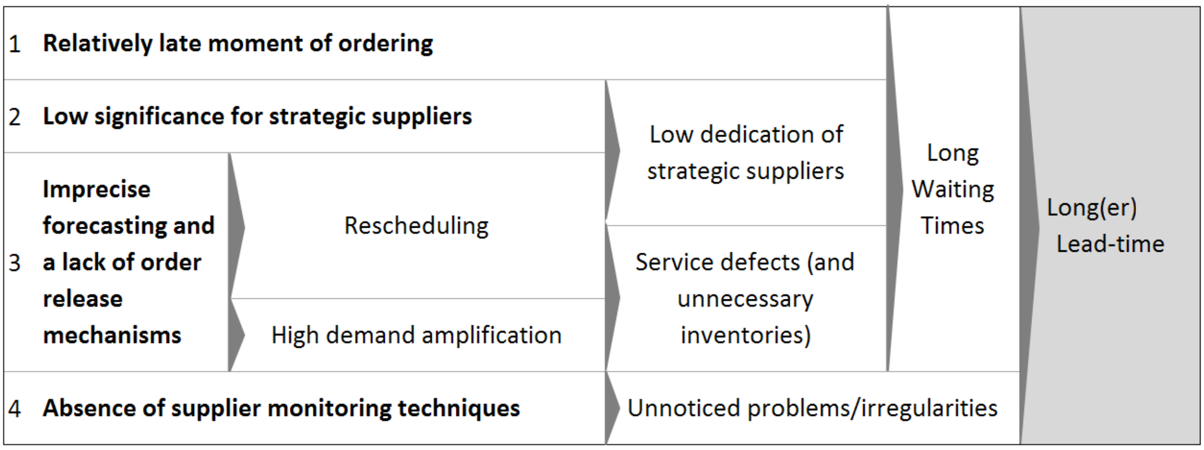


Figure 3-7: Cause-Effect relations

Many processes within CO are executed very well, and the purchasing employees are professionals. Some procedures are simply not grown along with the company over the years. The next section will discuss the set of requirements for future solutions, in order to solve these issues with the aim to reduce lead-time and their variability.

4. Set of Requirements

This section aims to create a set of requirements for possible future solutions and their implementation. The data will be derived from the management of CO, as well as the involved employees whose daily activities are related to purchased parts and their suppliers as can be seen in Table 2-1. This will be done using two focus groups as discussed in the methodological chapter, in order to answer the second research question of this study: *What are the requirements for a future solution for reducing the lead-time and its variance, with regard to the analyzed causes and effects, according to the purchasing department and the management of CO?* Literature also provides several prerequisites and constraints for problems occurring in a value- or supply chain, and these will be supplemented with the researcher's observations and knowledge regarding the studied topic.

The first focus group includes the staff of CO, in order to create and fill in the set of requirements. The second focus group was conducted with the employees whose daily activities involve purchased parts and their suppliers; they also filled in the created set of requirements. Topics were extracted from both the analysis and conversations with the respondents. The results are categorized in the most suitable situation (Table 4-1) and limitations and constraints from the current situation and the ongoing changes (Table 4-2). The requirements in Table 4-1 are derived from the effects resulting from the previous chapter: the analysis, and Figure 3-7 in particular. These requirements should be met by both changes towards the suppliers, or the processing of purchase orders within CO, in accordance with the central question.

	Causes/Effects					
Topic	**Long waiting times**	**Service Defects**	**Unnecessary inventories**			
CO Delivery Time	x			Max.	*16-18*	Weeks
Supplier delivery time	x			Max.	*6*	Weeks
Variance in supplier delivery time between two similar orders on different moments		x		Max.	*0-1*	Days
Variance compared to agreed delivery date		x		Max.	*1-2*	Day(s)
In-house stock (CO) compared to current situation			x	Max.	*+10*	% (with constant costs)

Table 4-1: The most suitable situation

Limitations and constraints from the current situation	Causes/Effects: Late moment of ordering	Imprecise forecasting	Rescheduling	Low supplier dedication
CONFIDENTIAL	x			
	x	x	x	
			x	
		x		x

Table 4-2: Limitations and constraints from the current situation together with the desired modifications.

The proposed improvements with regard to lead-time reduction will be judged with the use of this set of requirements. In particular Table 4-1 is important, because it describes the situation CO would like of reach.

5. Solution Design: Lead-time Reduction Strategies from Literature

In order to gain insight in the field of supplier lead-time and –variance reduction, a literature review is conducted. This chapter will discuss the methods and strategies proposed by literature. Once the set of requirements is used to filter the appropriate solutions, these methods will be critically assessed on applicability, and implications for implementation within CO's supply- and value chain will be discussed.

The first part (Chapter 5.1) will discuss the classification of inventories and parts in order to create specific procurement strategies including forecasting and MRP-driven ordering, with regard to the lack of order release mechanisms. Second, an improvement with regard to imprecise forecasting is proposed using information sharing with regard to demand and forecast (Chapter 5.2). After that, the absence of supplier- and supply chain monitoring techniques is discussed (Chapter 5.3), and several implementations are proposed. The fourth part will introduce methods to become an interesting buyer (Chapter 5.4). Each section, divided in subsections, discusses a (or several) specific paper(s) with regard to the topic. These concepts are supplemented or criticized with the use of similar literature and the set of requirements. The result of each section is a proposal for implementation of the methods in order to improve the situation with regard to above the main causes derived from the analysis. The late moment of ordering (within the process of CO) will not be discussed, because the results of the introduction of module-based production should be awaited as discussed in Table 4-2. The end of this chapter provides an overview with the proposed implementations, the causes they affect, feedback to the set of requirements, and the proposed order of implementation together with their estimated change of succeeded implementation.

5.1. Lack of Order Release Mechanisms

This first section discusses possible improvements with regard to the purchasing procedures and replenishment strategies of purchased parts: there is a lack of order release mechanisms. As stated before, the purchasing strategy of CO is one of the causes of long(er) lead-time. Within a project, the parts with a longer delivery time then CO's lead-time should be ordered as soon as possible, while on the other hand ordering in an as late as possible stage allows rescheduling without the need of contacting suppliers. First, two methods which discuss classification and different types of ordering are proposed in order to create specific strategies for categories of items. Classification will allow CO tot structurally determine different purchasing strategies for different types of items. Second, ordering with MRP (demand-driven) is discussed, which allows different moments of ordering within the different parts needed for a project.

5.1.1. Classification of Purchased Parts using Multi-Criteria Inventory Classification based on the ABC-analysis

Not every single item or part needs a purchasing strategy, but on the other hand a differentiation is needed with regard to several criteria in order to distinguish at least a few categories to make the purchasing process more efficient. One can imagine for example, that bolts and screws need less attention and strategy than gear units or motors of high value and a long delivery time.

In order to separate and categorize the different parts, often the ABC-analysis is used (Ramanathan, 2006; Zhou & Fan, 2007). This (inventory) classification method, using the Pareto principle, categorizes in three groups: *“Class A items are relatively few in number but constitute a relatively large amount of annual use value, while class C items are relatively large in number but constitute a relatively small amount of annual use value. Items between the above two classes constitute class B…”* (Ramanathan, 2006, p. 695). Items in category A are parts that *“…have to be controlled tightly and monitored closely.”* (Ramanathan, 2006, p. 696). These items are in need of an appropriate balance between low inventories and high service due to their value (Hautaniemi & Pirttilä, 1999). To successfully apply this method, the parts in the portfolio should be relatively homogeneous -and with the main difference being annual use value- which is mostly not the case in practice. Furthermore, often annual turnover of a specific part is not the only or most important factor. Therefore, several methods appear from literature which use multiple criteria in order to categorize inventories or parts: multi-criteria inventory classification (MCIC) (Flores & Whybark, 1987; Flores et al., 1992; Hautaniemi & Pirttilä, 1999; Ramanathan, 2006; Zhou & Fan, 2007; Hadi-Vencheh, 2010). Most commonly used criteria are; Average Dollar -or any other currency- Usage (ADU); Average Unit Cost (AUC); Lead-time (LT, which in case of CO would the most important criterion); and criticality, but other factors also can be used, even as many as 40 criteria (Cohen & Ernst, 1988). Ng (2007) proposes a simple, easy to use model based on the ABC-analysis and data envelopment analysis (DEA) in order to categorize parts with the use of multiple criteria. A detailed example of this can be found in Appendix IV.

There are several advantages of using multiple criteria, instead of a single one as used in the regular ABC-analysis. Except for the fact that multiple criteria can be used to illustrate the importance of an item, this method is less complicated than other decision tools as the analytic hierarchy process (AHP), genetic algorithm (GA), and artificial neural networks (ANN) proposed by literature (Saaty, 1990; Guvenir & Erel, 1998; Partovi & Anandarajan, 2002; Saaty, 2005) according to Ng (2007). These statements justify the choice for this method, instead of other, before discussed methods. A minor disadvantage using (part of) the ABC-analysis that could remain is the subjectivity; the choice where to establish the borders between the categories A, B and C.

Once the analysis is conducted, the organization is aware of the parts or items that need special attention and monitoring in fields regarding the chosen criteria. It also forces them to prioritize the most important factors concerning their purchasing and inventory strategies. When for example lead-time and criticality (with regard to availability or the amount of suppliers) are chosen as the most important factors, besides others, items that need specific attention will classified as high. Purchasing strategies have to be developed for the different categories with this method, while the method discussed in the next section might have some advantages by proposing strategies on the basis of lead-time and the type of demand.

5.1.2. Replenishment Policies for Purchased Parts in Combination with MRP

Another, complementary paper from the end of the past century also discusses the categorizing of purchased parts or inventories (Hautaniemi & Pirttilä, 1999). It mainly categorizes on lead-time and demand regularity. Therefore it could be very applicable in this case, in particular in combination with an MRP-system as present within CO.

"Materials requirement planning (MRP) and simpler methods, such as re-order-point (ROP) or visual review systems such as two-bin system are usually considered as mutually exclusive. (…) some manufacturing companies, especially assemble-to-order (ATO) companies, have found it necessary to use re-order-point (ROP) or (…) two-bin, in addition to their MRP systems." (Hautaniemi& Pirttilä, 1999, p. 85; cited according to Spencer (1995)). In other words, a combination of MRP and other inventory- (or procurement-) methods can have a positive effect on purchasing performance. The authors also use the ABC (Pareto) analysis in order to distinguish the categories, but only use the A and C-classes in line with Nicol (1989) and Willis and Shields (1990). Figure 5-1 illustrates the classification process and as can be seen, this results in five separate groups (I-V).

The first group consists of the C-class items; parts with high yearly demand, but low yearly turnover as discussed before. Hautaniemi and Pirttilä (1999) do not further discuss replenishment strategies and methods for this category; items in group 1 only used 5% of value in their particular case study. Most common method according to these authors is introducing a re-order-point in a warehouse, and a two-bin system in workcenters in order *"…to reduce procurement, material handling and order inspection costs."* (Hautaniemi & Pirttilä, 1999, p. 88). Remaining items are in the A-class and have a high(er) value, and therefore the replenishment method should aim for *"…a proper balance between high service level and a low inventory level."* (p. 89).

In order to further categorize, supplier lead-time is compared with the final assembly schedule (FAS) of the purchasing organization. FAS basically is the time needed for the purchasing organization in an ATO-environment between receiving a customer order and the start of assembly; the moment the parts are needed. In the case of CO, the FAS is approximately the 10 weeks mentioned earlier (CO delivery time minus the time needed for assembly).

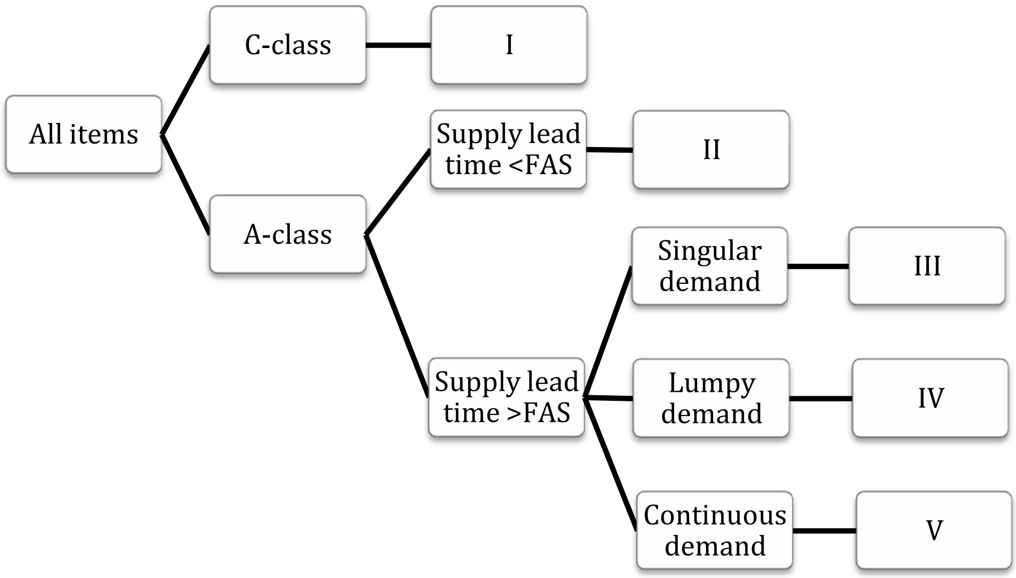


Figure 5-1: The classification process. Source: based on Hautaniemi & Pirttilä (1999, p. 88).

In the past years, many organizations and scholars used the comparison between FAS and supplier lead-time in order to distinguish material groups and replenishment strategies in combination with MRP (Miltenburg, 2001; Bilczo et al., 2003). For an organization to use purchase on order, lead-time of those items should be shorter than, or equal to the FAS. These items together form the second group, which can be purchased on demand with MRP. This will further be discussed in Chapter 5.1.3.

Items with a lead-time longer than FAS clearly need another strategy than being purchased to order, as illustrated above. Hautaniemi & Pirttilä (1999) use the distribution pattern of demand in order to categorize the last three groups. *"We can classify the demand distribution of items roughly into three classes: singular, lumpy and continuous demand."* (p. 89). Categorizing or prioritizing on demand (pattern) is later used by Lee et al. (2011) and proves to be a useful method.

Items with singular demand (group 3) are needed sometimes, mostly one item per order. In the example case of Hautaniemi & Pirttilä (1999)*"…items with demand lower than five units/week were classified as singular demand items…"* (p. 89), and ordered with the use of a Re-Order-Point (ROP) because forecast (for singular items) can have significant errors (Jacobs & Whybark, 1992; Xie et al., 2004). Parts that have a lumpy demand, the fourth group, are basically the same as previous, with the difference that these usually are demanded in batches of various sizes. This is a very difficult group, as even theory states that a possible solution should be to lengthen the organizations lead-time, to be longer as the delivery time. This would place the items in group 2. Since the aim of this study is to reduce lead-time, other methods for this group should be applied. For this category, theory seems to rely back on neural networks (although very difficult to apply by purchase managers as discussed in Chapter 5.1.1) (Gutierrez et al., 2008) and other forecasting techniques (Bartezzaghi et al., 1999; Johnston & Boylan, 1996; Willemain et al., 2004). The latter is a logical consequence of the criterion of the FAS-transcending lead-time. Methods in order to improve forecasting precision is discussed in Chapter 5.2 and these can be used for this group. Other options for critical component-management are proposed by Jahnukainen and Lahti (1999); modularization or standardization in order to enable buffering; supplier development to cut their lead-times, and; the focusing of orders.

The final and fifth group has a relatively steady and continuous demand. Hautaniem & Pirttilä (1999) also propose forecasting for this group. While these items can be found within a large part of the orders, the items can be ordered based on sales forecasts. Over-planning is needed *"... to ensure some safety stock against fluctuations in sales…."* (p. 90, also see; Verganti, 1997), because forecasting methods that use historical data lead to relatively imprecise performances (Bartezzaghi & Verganti, 1995). Table 5-1 summarizes above discussed methods per group. Before categorizing, some problematic items could be excluded from this process for example due to extreme lead-times, high variability or high risk of obsolescence (Hautaniemi & Pirttilä, 1999).

Group		**Method**
I	C-Class	ROP in combination with a two-bin system
II	Shorter than FAS	MRP, purchase on order
III	Longer than FAS, Singular Demand	ROP
IV	Longer than FAS, Lumpy Demand	Forecasting, lengthen organization's lead-time
V	Longer than FAS, Steady Demand	MRP, forecasting in combination with over-planning

Table 5-1: Item-groups and their proposed replenishment method. Source: partially based on Hautaniemi & Pirttilä (1999, p. 91).

A disadvantage for CO of this proposed method with regard to the set of requirements is that it solely aims for assuring item availability on the time it is needed, and does not take (inventory-) costs into account. Items in class A are expensive, or at least use a high annual value. Using ROP for items with a longer lead-time than FAS, together with over-planning, both would cause relatively high inventories for costly items.

5.1.3. Demand-driven purchasing, MRP-driven ordering and Vendor Managed Inventories

As discussed before, and shown in the analysis, the lack of order release mechanisms (for example, ordering parts without considering their delivery times, when the BOM is known) can lead to difficulties with regard to rescheduling in combination with long and unreliable delivery times. Furthermore is ordering items with the use of MRP (ordering demand-driven) discussed in the previous section as being an important purchasing method. Release mechanisms mostly are discussed with regard to the question *"…when to release material into a manufacturing line? That is, when should workcentres be authorized to produce or, conversely, be authorized to remain idle."* (Chan et al., 2001). But this question can also be asked within a supply chain, in other words; when to release a material order into a supply chain towards suppliers? The source of rescheduling from the side of CO will not be discussed in this research, and therefore the solution should be sought in the process of ordering which could influence the suppliers' behavior. Yücesan and De Groote (2000) discuss order release mechanisms with regard to push and pull. CO uses a pull-mechanism for most parts, *"…where order releases are triggered by the consumption of downstream inventory…"* (p. 120); parts are ordered when needed. Parts with an extremely long delivery time are ordered on forecast (in accordance with the theory as stated in Chapter 5.1.2), thus using a push-mechanism which "*…releases orders to meet some anticipated requirement in the future…"* (p. 120).

While in the current situation, there is (mostly) no difference between high, and low lead-time parts and their moment of ordering (every part of a certain project is ordered at the same time, with exception of parts with an extreme delivery time), there are several methods in order distinguish order dates, and therefore reduce the effect of rescheduling towards suppliers. Demand-driven ordering with an MRP-system will cause parts to only be ordered a certain time (an amount of days equal to their delivery time) earlier than the assembly date (with possibly a safety time). As can be seen in Figure 5-2, when rescheduling takes place, this affects fewer parts: in the current situation, all parts are ordered at the same time. When rescheduling has to take place, all these purchasing orders should be rescheduled, which has to be communicated and discussed with the suppliers. When ordering on demand with an MRP-system, items with shorter delivery times will be ordered much later. Therefore they do not have an agreed delivery time on the moment of rescheduling.

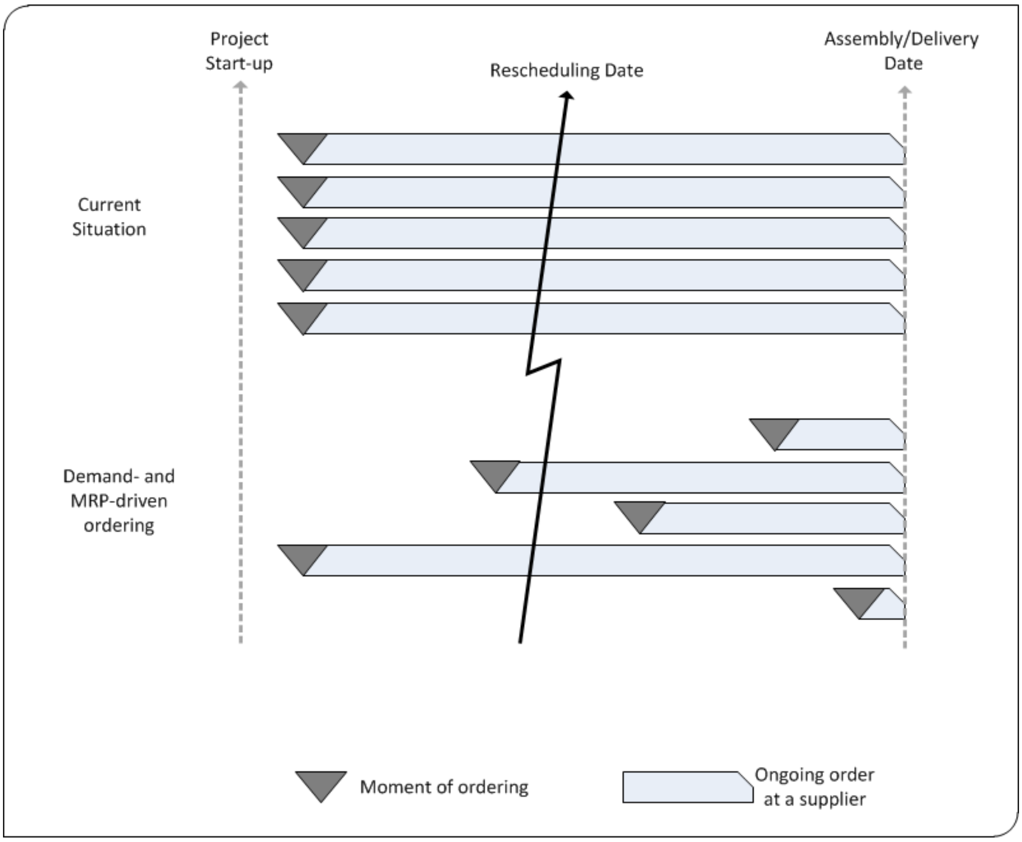


Figure 5-2: The current situation vs. demand- and MRP-driven ordering

Another method for replenishing, for parts with short lead-times in particular, is connected with the principle of information sharing: Vendor Managed Inventories (VMI). This method *"…involves the vendor making the replenishment decision for products supplied to a customer based on specific inventory and supply chain policies."* (Angulo et al., 2004, p. 101, also see; Lee & Whang, 1998, Simchi-Levi et al., 2002). An example of VMI is a two-bin-system, as proposed in Chapter 5.1.2. VMI has benefits for both the buyer and supplier namely; reduction of demand amplification for the supplier (and therefore less safety stocks which means cost reduction) and reliability of the supplier (Waller et al., 1999). On the long term though, it could increase the supplier's profit, and costs towards the buyer (Dong & Xu, 2002).

5.1.4. Implications and Recommendations concerning the lack of order release mechanisms

Preceding sections discussed three topics with regard to a lack of order release mechanisms within CO. Two methods were discussed in order to categorize the existing items currently used in machines. Demand-driven ordering with the use of MRP and VMI are proposed by the second method (Chapter 5.1.2) and Chapter 5.1.3 elaborated further on their advantages. This section will provide implications and reccomendations for improvements regarding the lack of order release mechanisms.

From conversations within CO it appears that classification based on supplier lead-time and demand type (the FAS-based method) is the most suitable. The main reason for this is the relative simplicity and high level of applicability in the case of CO. Currently, some items are in a two-bin-system (an example of VMI) and an MRP-system is present and used for tracking or processing customer- and purchase orders, while extended use of this system could provide substantial advantages as discussed before.

The FAS-based method basically uses four different order release mechanisms namely; VMI, ROP, MRP and Forecast. Each of the five groups has their own (combination of) mechanisms. Following the steps below, CO can divide the parts in the groups according to FAS and demand type:

Items with a delivery time shorter than the FAS

- Group I: Investigate the lowest 20% of the purchasing volume on parts suitable for a two-bin-system. These items have low costs, small size, are regularly needed in considerable amounts and are easily available (bolts, nuts, electrical components etc.). These will mostly be *non-critical* items from the Kraljic-matrix in Figure 3-1.
- Group II: These items are not suitable for a two-bin system due to higher costs, large(r) in size. Low-cost items that are not suitable for two-bin are also added to this group.

Items with a delivery time longer than the FAS

- Group III: items with a delivery time longer than the FAS and used once or twice in only a minimal number of machines. This creates a unstable and unpredictable demand of one or two items once in a while.
- Group IV: items with again a delivery time longer than the FAS and occurs more than twice in different types of machines. When a certain machine should be build, several of these items are needed, which creates a relatively large fluctuation in demand.
- Group V: These items are ordered on a relatively regular basis; they occur in different types of machines so create more or less a continuous demand.

When the groups are established, the different order release mechanisms can be implemented, according to Table 5-1. The rest of this section shortly discusses these methods, except for forecasting, which is discussed in an separate chapter: 5.2.

First VMI, in the form of a two-bin-system. Two-bin is already used within CO for fasteners, and therefore easily extendable towards all components that are suitable for this system. Agreements with suppliers have to be made with regard to minimum stocks and replenish-quantities and -dates.

Second, the use of an ROP consists of setting a target quantity in the warehouse; a minimum amount of available items in order to guarantee fast internal delivery. When the amount of in-stock items is lower than the target quantity, a new purchase order should be generated in order to replenish stock. Each item for which an ROP is used can have other minimum quantities, depending on costs, size and demand, but in this case a maximum of three is advisable (otherwise these items should be in another group).

Third, MRP-driven ordering as discussed before, has several advantages as an overall strategy, in particular with regard to rescheduling. Also will it flatten out the workload for the purchasing department. This leads to a major implication for CO, namely that all exact delivery- or lead-times of the purchased parts should be inserted in the MRP-system. The system then will calculate the order-date using the assembly date and possible safety-times. A prerequisite for this system to work is high reliability of suppliers; them, delivering on the day that is scheduled and agreed. Clear agreements have to be made within the supply chain of CO, and maintenance of the delivery times in the MRP-system is needed.

	Task	Responsibility	Estimated % of parts
Categorize items	Categorize the purchased parts according to above discussed groups	Purchasing	
Implement order release mechanisms	Group I: Two-bin-system	Purchasing	15%
	Group II: Order on demand via the MRP-system	Purchasing	60%
	Group III: Set a Re-Order Point and order via the MRP-system when stock is below minimum	Purchasing	15%
	Group IV: Include in the current forecasting procedures	Purchasing, Planning	5%
	Group V: Use forecasting and order on demand (MRP)	Purchasing, Planning	5%

Table 5-2: Implications with regard to the categorization of purchased parts

5.2. Imprecise Forecasting

Chapter 5.1.2 discussed forecasting as an inevitable strategy for certain purchased parts. From the analysis it appeared that the forecasting within CO should become more precise. As an increasing amount of organizations become aware of the importance of collaborating with their suppliers and buyers, information sharing in the supply chain is more well-known. Information about demand and forecast in specific, could improve (on-time) availability of items from suppliers towards buyers (Simatupang & Sridharan, 2002). Collaborative Planning, Forecasting and Replenishment (CPFR) is successfully used in order to reduce response times and unnecessary stock (Simatupang & Sridharan, 2002; Min & Yu, 2004). *"CPFR attempts to lessen the problems associated with traditional anticipatory demand forecasts by co-operating with trading partners to better match supply and demand."* (Stank et al., 1999, p. 75, also see: Skjoett-Larsen et al., 2003). This method includes the buyer (electronically) providing point-of-sale (POS) data and inventory levels together with the buyer's forecast towards the manufacturer, and latter comparing this information with their own forecast while identifying and discussing exceptions (Stank et al., 1999): this needs both trust and technology (Barrat & Oliveira, 2001). This method is basically an extended version of the before-mentioned VMI, and can be used for more complex situations. Although CPFR usually is adapted by retailers in the consumer business, the sharing of (demand) information in a buyer-supplier relationship in a business to business environment is discussed by several authors. Sahin and Robinson Jr. (2005) discuss information sharing and physical flow coordination. These authors prove that combinations of partial or full information sharing and partial or full (supplier) coordination provide significant advantages over traditional replenishment processes (Fry et al., 2001). Lee et al. (2000) suggest and prove that information sharing (with regard to inventory level information) is specifically useful for high-tech supply chains where *"...the demand variance within each time period is high; or ... the lead times are long."* (p. 627).

In order to create certainty towards suppliers, a "frozen period" in forecast can be introduced. This is a certain time period prior to delivery, where forecast (shared with suppliers), should not be changed (Johnson, 1999). For items in the frozen period, the buyer is obligated to purchase; forecasts for items outside this period could also have a purchasing obligation but can be moved in time. Therefore, often a longer frozen period results in lower prices (Lian et al., 2006), but also limited flexibility (Johnson, 1999). Furthermore, when used for a single item it could lead to a higher inventory due to safety stocks (Sridharan & Laforge, 1994), and increasing forecast errors when a rolling horizon is used (Sridharan & Berry, 1990).

Sharing information has several advantages for both buyers and suppliers as discussed above. This needs all parties to cooperate and act towards the information provided. It creates certainty for the suppliers of CO, and a frozen period in the forecast prevents CO itself from regular rescheduling. Although collaboration in the supply chain can be discussed in many different forms focusing *"…on joint planning, coordination, and process integration between suppliers, customers, and other partners in a supply chain."* (McLaren et al., 2002, p.348), the sharing of information is one of the main concepts. It brings benefits for both buyer and supplier with regard to *"…process, inventory, and product cost …cycle times, service levels, and market intelligence."* (p. 348). It also brings additional advantages for the supply chain with regard to the bullwhip effect: "*The bullwhip effect is the phenomenon whereby the size of inventory overages and shortages increases the further a firm is from final consumer demand in a supply chain.*" (Yao et al., 2007, p. 664). This effect is minimized by information sharing within a supply chain (Cachon & Fisher, 2000; Chen et al., 2000). Collaboration can also be used in order to increase the buyer's significance for a specific supplier, which is discussed in Chapter 5.4.

5.2.1. Implications and Recommendations Concerning Imprecise Forecasting

External collaboration is considerably complicated, because interests of various organizations should be taken into account. For a long-term collaboration to succeed, there should be substantial benefits for both buyer and supplier. This needs trust and technology, as stated in a previous chapter. Trust for example also depends on the not (often) changing the supply specifications, i.e. the rescheduling of order dates or quantities (a cause discussed in this research). External collaboration can be discussed in many forms but the sharing of information is the most applicable in this situation. Information sharing with regard to demand and forecast towards suppliers can give several advantages for both parties. CO could share anticipated future demand of specific parts to corresponding suppliers. This information should be available real-time (for example on the web or intranet), or at least be updated together with the forecast of CO (weekly). This needs the suppliers to act on the received information in order to assure on-time deliveries, but on the other hand creates certainty and a direction for future sales. Because of the impact and the amount of work needed for shared (forecast) information, not all suppliers are suitable for this.

In several cases this method could be improved with the introduction of a frozen period in the forecast. Furthermore should there be a distinction in long- short- and mid-term forecasting (Wagner, 2005). As can be seen in Figure 5-1, the frozen period obliges the buyer to purchase, but also the buyer to deliver, the forecasted items on the agreed date.

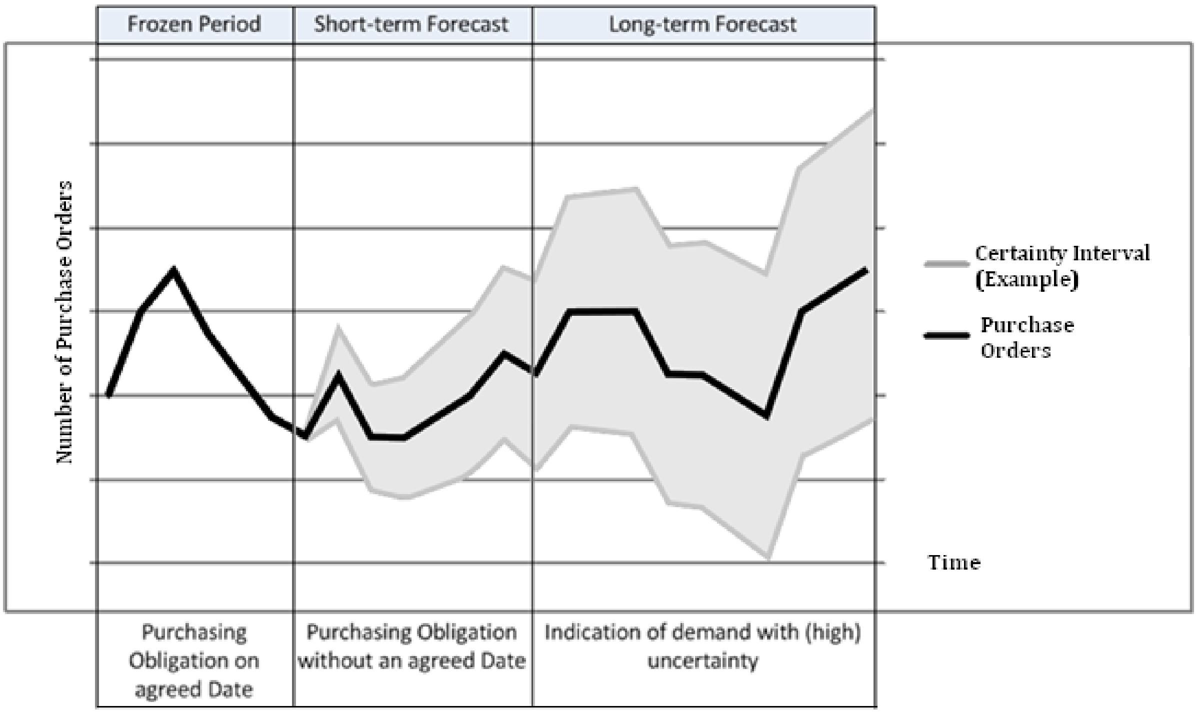


Figure 5-3: Shared forecast information

Items entering the short-term forecast also have a purchase guarantee, but can be rescheduled by CO. This, on the one hand is an advantage for suppliers, but on the other hand increases their risk of maintaining stock if dates are rescheduled. Finally, long-term forecast could indicate already sold machines (or parts) or anticipated demand, but with the fluctuating sales of CO this would be very difficult. The length of scope of these categories should differ per item or supplier, because an optimum has to be found with regard to delivery times and inventories. Updating the forecast could be done by applying a rolling forecast; every week, the forecast basically shifts a week in time. Sharing the forecast can be done for example using a portal; suppliers can log into the system of CO and download the newest version of the forecast, only with regard to their own products.

In practice, first has to be decided which items, and towards which suppliers to forecast. As discussed before, several items are already forecasted, in particular due to long delivery times (longer than FAS). This forecast is on machine-level, and should be maintained. But for each machine, the critical parts are known, and can be forecasted with them. Other criteria can be whether or not the item is suitable for keeping on stock (in particular costs and size play a role in this). Choosing suitable suppliers for this depends mostly on the criticality of the items, together with the height of CO's turnover with these suppliers. Most important group should be *strategic* suppliers and after that *leverage* suppliers (see the Kraljic Matrix, Figure 3-1). Furthermore, a fundamental decision has to be made on the length of the different periods (frozen period, short-term forecast and long-term forecast). For CO, a long frozen period will assure on-time delivery, but limits the flexibility of the organization. Therefore, a best practice has to be found. The delivery time of the part should in any case fall within the short-term forecast; the supplier can order the part and keep it on stock until it enters the frozen period, in which it can be sent CO. Also, agreements should be made with the suppliers about acting towards the forecast. They should download the forecast on regular periods in time (weekly, or when they are about to order specific parts).

In short, the following actions should be prepared in order to share forecasting information with suppliers:

	Task	Responsibility
Share forecasting information with suppliers	Decide which items to highlight from the current machine forecast (based on supplier delivery time, costs and size) and their suppliers (criticality and CO purchasing volume)	Purchasing, Planning
	Make sure that there are benefits for both parties, and that the suppliers are aware of this	Purchasing, Suppliers
	Agree on the lengths of the periods (frozen period, short-, and long-term forecast), based on delivery times, criticality and costs of stock and the way of sharing the information of the forecast	Purchasing, Suppliers
	Weekly update the forecast, and assure availability towards suppliers for their specific items	Planning
	Download or receive the forecast from CO, and process this when new items are ordered	Supplier

Table 5-3: Steps in order to share forecast information with suppliers

5.3. Absence of Supplier Monitoring Techniques

In the current situation, problems or difficulties on both long- and short-term could remain unnoticed because suppliers and the supply chain are not monitored, and their performance is not measured. In order to observe, monitor and measure the supply chain (the suppliers in particular), several techniques can be used. This could prevent future, long-term developments and problems with regard to longer delivery times and higher variability, to occur unnoticed.
First, a buyer itself could monitor their suppliers. From a survey of Hendrick et al. (1996), the most implemented activity was *"Just-On-Time Goals and Measurement (Suppliers Meeting Scheduled Due Dates/Times for Purchased Materials)."* (p. 7). Having clear agreements with suppliers regarding timely and consistent delivery and monitoring this, creates a longitudinal overview for the buyer of the supplier's performance. Confronting, on top of this, the specific suppliers with their performance creates awareness. This technique is closely related to frequent on-time delivery measurement, and reporting procedures for suppliers (Hendrick et al., 1996): the buyer measures deliveries to monitor the long-term reliability and consistence of a supplier in order to detect flaws with specific suppliers or items. Gunasekaran et al. (2004) discuss several measures in order to evaluate delivery performance namely; on-time delivery (Stewart, 1995), on time order fill (Christopher, 1992), number of faultless invoices, and flexibility to meet the buyer's needs (Novich, 1990). Suppliers themselves also could (be given the ability and freedom to) report delivery or availability difficulties in an as early stage as possible. This would assure a faster response of the buyer's purchasing department on oncoming problems.

Talluri and Sarkis (2002) propose a model to monitor supplier performance with both multiple criteria and measures. In combination with providing feedback to suppliers, this method is improving supply chain performance. Furthermore, Brewer and Speh (2000) propose an extended balanced scorecard (BSC) and link this to supply chain performance measurement. As can be seen, many different forms of supplier and supply chain monitoring are known in literature. Handfield and Nichols (1999) propose three criteria in order to effectively measure supply chain performance, regardless the method used:

- Measuring the performance of the overall supply chain, rather than the individual members
- There should be one focus in the entire supply chain; improvement of customer service
- Managers should be allowed to eliminate possible identified causes of problems.

Taking above criteria in account, performance measurement has multiple functions. From the case studies of Schmitz and Platts (2004), these functions appear. The most important are mentioned in Table 5-4.

Category	Function
Communication with suppliers	- Communicate dissatisfaction with supplier's performance - Provide basis for rational argumentation between OEM and suppliers - Increase authority/power of OEM's employees in their dealings with suppliers
Communication between departments	- Communicate supply base performance to purchasing department
Co-ordination and alignment	- Increase the overall importance of logistics for purchasing decisions
Motivation of suppliers	- Instrument to threaten supplier in order to catch their attention or initiate action
Other	- Provide documental evidence on historical performance for negotiations and discussion

Table 5-4: Functions of supplier logistics performance measurement. Source: Based on Schmitz & Platts, 2004, p. 241

Another technique to prevent certain problems with suppliers in advance lies in the selection of new suppliers. Often, purchasing selects (new) suppliers on basis of lowest costs (Monczka et al., 2010), but *"Commodity partnerships that are exclusively based on price are no longer acceptable for suppliers of critical inputs and resources…"* (Talluri & Sarkis, 2002, p. 4257). With additional supplier selection criteria, buyers can identify vendors that are for example likely to provide high product availability, consistent delivery, short delivery times or high flexibility (Fawcett & Fawcett, 1995; Vonderembse & Tracey, 1999; Gosling et al., 2010).

5.3.1. Implications and Recommendations concerning the Absence of Supplier Monitoring Techniques

In order to prevent developments and possible problems to occur unnoticed, in particular on the long-term, the supply chain should be monitored, and the suppliers' performance be measured. Clear agreements have to be made, so that CO's expectations are known to their (potential) suppliers. Therefore CO has to design a workable (optimal) situation for itself (see the set of requirements, Chapter 4). Confronting suppliers with these requirements can be done on two ways: through power or through collaboration. Buyers at which CO has a high yearly turnover are more likely to accept demands that are more favorable for CO. Suppliers with a strategic position should be approached with collaboration.

Evaluating delivery performance can be done on different criteria. In order to create the desired effect, suppliers should be confronted with their performance according to the criteria, with or without the use of formal contracts. Giving the suppliers themselves the ability and freedom to report delivery or availability difficulties in an as early stage as possible, would guarantee a faster response on future problems. To successfully implement this, a high degree of information sharing, trust and openness are needed, together with suppliers who think and act for, and in the favor of, the supply chain. The continuous evaluation of suppliers is usually referred to as "vendor rating". The optimal situation (described in Table 4-1) discussed supplier delivery time, and variance with regard to both two similar orders and the agreed delivery date. These factors can be measured when orders are checked in at CO's warehouse, and analyzed monthly or quarterly by the strategic purchaser and used for feedback towards suppliers. CO should establish a limit for incorrect deliveries (outside the criteria discussed and agreed yearly with the specific suppliers). This could be for example 5%, and when a supplier exceeds this percentage, further steps should be taken. A further benefit from supplier performance measurement on the long term is that the delivery times and availability of items can be monitored. Therefore, changes in the supply chain and/or market can be noticed and evaluated. In practice, foregoing would result in the following steps:

	Task	Responsibility
Supply chain monitoring and performance measurement	Establish the optimal situation, and the way this will be measured	Purchasing
	Communicate the requirements of deliveries towards the suppliers	Purchasing, Suppliers
	Establish fixed times, percentages etc. with regard to the measured factors, together with the suppliers. These should be updated yearly	Purchasing, Suppliers
	Monthly or quarterly (depending on the amount of orders) evaluation of the criteria, and feedback towards suppliers	Purchasing
	Subsequent actions (to be determined) in the case of too many incorrect deliveries	Purchasing
	Use criteria derived from step 1 and 3 when selecting new (potential) suppliers	Purchasing

Table 5-5: Steps in order to monitor the supply chain and measure supplier performance

Within the selection of new or potential suppliers, (strategic) purchasers could use additional criteria like flexibility, openness, trustworthiness, and possibilities for supplier development. Often purchasers or organizations use costs as the main criterion, but in order to create a supply base consistent with, and aligned to, the organizational strategy other criteria should be introduced.

5.4. Low Significance for Strategic Suppliers

Particular organizations receive preferential resource allocation from (strategic) suppliers when for example scarcity occurs, or with regard to innovation efforts (Williamson, 1991; Steinle & Schiele, 2008). To achieve this, an organization could apply techniques in order to become a more significant partner for their strategic suppliers, and therefore gain a preferential treatment with regard to delivery times and product availability.

The collaboration in a buyer-supplier relationship and the performance of a supply chain are directly linked by theory: *"Strategic partnerships between suppliers and manufacturers may have a significant impact on SC performance."* (Simchi-Levi et al., 2002, p. 5). Partnerships within supply chains are proven to decrease cycle time (Hendrick et al. 1996), and furthermore will these collaborations make the buyer more important for the supplier. This is needed in order to be allocated more resources, and Ellegaard et al. (2003) introduce this as reverse marketing: not the suppliers seeking for a buyer, but the other way around because suppliers allocate (scarce) resources to specific buyers only. Collaboration mainly consists of three parts: "*…information sharing, decision synchronisation, and incentive alignment.*" (Simatupang & Sridharan, 2005). A more intensive form of collaboration is the integration of buyer and supplier: the combination of processes of the two parties (for example sharing of demand information as proposed before), with mutual benefits, or as Fawcett and Magnan (2002) indicate: "*…cross-functional process integration…"* (p. 334). Increasingly used by organizations engaging in supply chain management and -integration is early supplier involvement (ESI) in new product development (NPD) (Ragatz et al., 1997; Handfield et al., 1999; Schiele, 2010).

Many buyers are willing to collaborate or integrate with a supplier in order to receive preferential resource allocation (in the case of CO, with regard to favorable delivery times and reliability) and therefore are searching for a strategic partnership (Handfield et al., 1999; Primo & Amundson, 2002; Tracey, 2004; Schiele, 2006). Furthermore, these suppliers are highly selective in dedicating resources (Schiele et al., 2010). In order to enter a relationship with a strategic supplier, the buyer should therefore be attractive, or as recent literature states: a preferred customer (Hüttinger, 2010; Schiele et al., 2010; Schiele et al., 2011a; Schiele et al., 2011b). The attractiveness of a buyer in order to gain such a status, depends on several factors.

First, perceived expected value: *"…the perceived trade-off or ratio between multiple benefits and sacrifices that is gained through a relationship."* (Hald et al., 2009). Expected value of a buyer consists of four elements namely; expected increase in yearly transactions (Walter et al., 2001), increase in growth (Noorderhaven et al., 1998), the suppliers' expectation of access to new buyers (Walter et al., 2003), and the expected competency development (Hald et al., 2009).

Second is perceived trust: *"...a trustworthy buyer or supplier is one who: does not act in a purely self-serving manner, accurately discloses relevant information when requested, does not change supply specifications, and generally acts in an ethical manner."* (Smeltzer, 2006, p. 40). The model of Mayer et al. (1995) proposes three factors which influence perceived trust: Ability, integrity and benevolence.

The third factor said to influence the attractiveness of a buyer, is perceived dependence: "*…the degree to which a buyer or a supplier needs to maintain the relationship with a supplier or a buyer in order to achieve desired goals."* (Hald et al., 2009, p. 965). If perceived dependence is high, this will decrease the buyer's attractiveness. If an organization considers above discussed points, they can become attractive for suppliers, and therefore have an increased change to become a preferred customer with preferential resource allocation.

Finally, a more practical improvement to increase significance towards suppliers is the pooling of demand which increases purchasing power at a specific supplier and therefore increase buyer significance. The purchasing department (together with R&D) reduces the number of suppliers by combining demands for standard parts in order to increase purchasing power at the remaining supply base (Stadtler, 2005; Monczka et al., 2010). Latter could be difficult for small organizations with little yearly purchasing turnover (Quayle, 2003; González-Benito et al., 2003). Therefore, another method, often used in food distribution, is to consolidate consignments of other actors in the region (Fleischmann, 2000) to increase the joint purchasing power at one specific supplier.

5.4.1. Implications and Recommendations concerning the low Significance for Strategic Suppliers

In order to gain preferential resource allocation, and suppliers actually willing to collaborate with CO, they have to become an attractive buyer, or even a preferred customer. It is important that CO is one of the first, or the best, organizations that very consciously aim for becoming a preferred customer within their supply chain because "*A latecomer to the partner scene may find that all potential partners with the necessary complementary strategic resources have already entered into alliances with other firms*." (Dyer & Singh, 1998, p. 672). This is a possibility because this way of thinking is relatively new. As stated in the previous chapter, for an organization to become attractive, three factors should be taken into account: perceived expected value, perceived trust, and perceived dependence. To make the buyer perceive these factors as attractive, communication is very important.

To increase the by the supplier perceived expected value of the relationship several strategies can be executed. An expected increase in yearly transactions or growth for example, can be achieved by the pooling of demand, towards that specific supplier (bundling purchasing of several small suppliers towards one single supplier). Increasing the supplier's expectation of competency development could be achieved by the sharing of information or forecasts so that both parties can learn from each other. Another technique is supplier development, in which a buyer helps developing a supplier in areas in which they experience a lack of performance (Monczka et al., 2010).

Being a trustworthy buyer consists for example of paying on time, and dealing with confidential material and information in an honest way. Trustworthiness and integrity are also perceived by third-party sources in the supply chain. Increasing trust is also reached by fairly dividing benefits within the relation, and flawless execution of processes (Morgan & Hunt, 1994; Wong, 2000).

In order to decrease the perceived dependence of CO, the supplier should not perceive that they are needed in a very high degree in order to achieve the goals of CO. This also has to do with the dividing of benefits as discussed above. Of course, a buyer cannot fully control how it is perceived by a supplier and the other way around. Third-party information and (historical) negative experiences also play a crucial role in this situation. Therefore, the two most important points for CO are the increase in perceived expected value and trustworthiness.

	Task	Responsibility
Increase perceived expected value	Pooling of demand	Purchasing
	Increase the learning capabilities of the relationships by information sharing (forecast and demand) and cooperation (training etc.).	Purchasing, Planning
Increase trustworthiness	Paying on time	Purchasing
	Limit rescheduling (frozen period in forecast)	Planning
	Fairly dividing costs and benefits in a relationship	Purchasing

Table 5-6: Implications with regard to the increasing of attractiveness towards strategic suppliers

5.5. Implementation overview

To summarize foregoing chapter, an overview is made of all the discussed improvements. Table 5-7 indicates the improvements, their effect on the causes and effects derived from the analysis, and in which part of the set of requirements they belong. CO's management also indicated their estimated chance of succeeded implementation of the improvements. This is based on their knowledge, but also experience with regard to CO's abilities, culture and strategies. Furthermore the order of implementation is given. The classification of parts, even as demand-driven purchasing with the use of the MRP-system is practically feasible within the current situation. Expectations are that this will greatly improve the processing of purchase orders within CO on a relatively short term. Second, or simultaneously, more strategic improvements can be implemented; supply chain monitoring, performance measurement and new supplier selection criteria can be introduced. Third, the planning department can share demand- or forecast information with important suppliers of critical items in order to assure on-time availability. Attempts to become a preferred customer will not be made on the short term. The main reasons for this are the market in which CO operates, and the relations with the current supply base. The next chapter will conclude this research.

Order of implementation	Improvement	Estim. chance of succeeded impl. (%)	Causes/Effects: Long waiting times	Service Defects	Unnecessary inventories	Low supplier dedication/significance	High Demand amplification	Rescheduling	Late moment of ordering	Imprecise forecasting	Lack of order release mechanisms	No monitoring techniques	Set of Requirements: Decrease Supplier delivery time	Decrease Variance in delivery times	Decrease Service defects	In-house stock max +10%	Module-based production	Decrease Forecasting scope	Link and share Planning	Information sharing
1	Inventory classification based on the supply lead-time using ROP, MRP and forecasting	85			x	x			x	x	x	x				x		x		
1	Demand-driven purchasing, MRP-driven ordering and VMI	75			x		x	x		x			x	x	x	x		x		x
3	Demand information sharing with (major) suppliers (CPFR)	70	x	x		x	x		x	x			x	x	x				x	x
3	A frozen period in shared forecasts	55	x			x		x			x							x	x	x
2	Supply chain monitoring and performance measurement	65	x	x		x						x	x	x	x					x
2	Adjusting supplier selection criteria	65	x	x								x	x	x	x					
	Increase attractiveness to become a preferred customer	30				x							x	x	x					

Table 5-7: The proposed improvements with their relation towards the causes/effects of long lead-times and the set of requirements

6. Discussion and Conclusion

Becoming the first in line when something important is being distributed is difficult, in particular when you are not the biggest or most important in that line. CO experiences that is difficult to gain reliable, fast deliveries of scarce and critical items. In the case of CO, this research discussed several methods which indicated a set of possible causes as reason that CO experiences long and unreliable delivery times of some suppliers, which indirectly lengthens their lead-time. The central research question for this study was: *"How can the lead-time of CO be decreased, by influencing the lead-time and variance suppliers' delivery times and the processing of purchase orders within the organization?"*

After introducing the concept and definitions of lead-time and the factors that it consists of, the first research question was meant to describe the current situation within CO in order to gain information about possible causes for long lead-time and high variability: "*How can the current situation within CO and at their suppliers be analyzed, and what are the causes of high lead-times and their variability in this situation?"* With the use of the VALSAT-Method (Value Stream Analysis Tool), four tools were chosen in order to analyze the current situation: (1) Process Activity Mapping; (2) Supply Chain Response Matrix; (3) Demand Amplification Mapping, and; (4) Quality Filter Mapping. This resulted in five possible causes with regard to long lead-times and high variability, of which four are discussed in this research: (1) a lack of order release mechanisms; (2) imprecise forecasting; (3) absence of supplier monitoring techniques, and; (4) low significance for strategic suppliers.

With the topics for improvements known, a set of requirements for solutions is generated on the hand of the second research question: "*What are the requirements for a future solution for reducing the lead-time and its variance, with regard to the analyzed causes and effects, according to the purchasing department and the management of CO?"* This resulted in the description of an optimal situation with regard to delivery times and variability. Furthermore are the limitations and constraints listed to take into account when designing the solutions.

The third research question focused on the solutions; a combination of the analysis and the set of requirements: "*What solutions can be derived based on the analysis, the researchers' knowledge and creativity, the set of requirements and theory, in order to decrease supplier lead-time and its variability with regard to purchased parts?"*. For each of the causes derived from the first research question, improvements are designed, namely: (1) inventory classification resulting in specific order release mechanisms per group including ROP, VMI and Forecast; (2) The sharing of demand- and forecast information with main suppliers, including a frozen period in the forecast; (3) supply chain monitoring and -measurement, even as additional criteria for new supplier selection, and; (4) increasing the attractiveness of CO as a buyer, in order to become a preferred customer.

Limitations in this research can be found both in data collection as in the execution of the analysis with the corresponding framework. Data collection is only done within CO (focus groups) because of the specificity of the situation. Interviewing employees and managers within CO was needed in order to gain information about the situation, procedures and the set of requirements. Information from outside the organization with regard to procedures, working methods and constraints of suppliers would on the one hand be helpful with regard to gaining insights in the mindset of suppliers. On the other hand, these mindsets and constraints vary by supplier, and this study proposes overall strategies with regard to the approach of suppliers in general. Furthermore, the framework used in order to choose suitable value stream mapping tools (VALSAT) is based on implementation of the *lean* principle. That was not the aim of this study, but on the other hand were these tools used to identify time wastes in the supply chain.

Strong points of this study are threefold; first, it proposes tools from literature in order to reduce lead-time within an organization. Most literature is internally focused in order to introduce for example lean-management. This research shows and indicates that literature, mainly discussing internal application of lean, JIT, and other, time-based strategies in a mass-production environment also successfully can be applied to identify flaws in a make-to-order environment, even in a whole supply chain. The second point is that it necessitates the organization to rethink their purchasing strategy (whether or not formally established), and indicate priorities with regard to purchasing practices. Third; this study shows both short- and long-term methods, based on existing literature, discussed on scientific, strategic, and operational level.

Further research could discuss the preferred customer status in order to gain preferential resources with regard to timely deliveries and product availability, while this topic is relatively new and mostly focuses on innovation. Furthermore, the role of forecasting uncertain demand (with for example the use of a rolling forecast) mostly remains on a highly scientific and mathematical level in the current literature.

Concluding, the improvements proposed sometimes can seem obvious. But the necessity for any kind of improvements on the fields discussed became clear. Also is shown that the tools for internal lead-time reduction can be discussed with regard to a well cooperating supply chain. This topic is applicable in both mass-production and in a make-to-order environment, as mentioned before. These two points create added value for the existing scientific literature with regard to this field. Of course, within a make-to-order environment, demand fluctuation will be more unstable and operation hours will fluctuate more than within a mass-production environment. Complete inventory-reduction is therefore nearly impossible, in particular in combination with complete reliable and fast deliveries. But internal, as well as external lead-time reduction in a make-to-order environment is certainly feasible. The initial situation, as well as the progress can be measured and monitored with the suggested tools, in order to easily indicate emerging problems and improvements.

Many organizations are in the same situation as CO; a (or no) sourcing strategy has been introduced when the organization was small. The growing of the company, together with changing markets caused this strategy to be incomplete or even outdated. Furthermore they find themselves in a position in which the organization purchases by bargaining and pressurizing, while increasingly more the importance of collaboration and information sharing is acknowledged. This study contributes to the recognizing of such a position, and the change towards a new, collaborative strategy.

7. Bibliography

Aken, V. J., Berends, H., & Bij, V. d. (2007). *Problem Solving in Organizations.* Cambridge: Cambridge University Press.

Alaca, H., & Ceylan, C. (2011). Value Chain Analysis using Value Stream Mapping: White Good Industry Application. *Proceedings of the 2011 International Conference on Industrial Engineering and Operations Management*, (pp. 933-938). Kuala Lumpur, Malaysia.

Angulo, A., Nachtmann, H., & Waller, M. (2004). Supply chain information sharing in a vendor managed inventory partnership. *Journal of Business Logistics* , 101-120.

Barrat, M., & Oliveira, A. (2001). Exploring the experiences of collaborative planning initiatives. *International Journal of Physical Distribution & Logistics* , 266-289.

Bartezzaghi, E., & Verganti, R. (1995). Managing demand uncertainty through order overplanning. *International Journal Production Economics* , 107-120.

Bartezzaghi, E., Verganti, R., & Zotteri, G. (1999). A simulation framework for forecasting uncertain lumpy demand. *International Journal of Production Economics* , 499-510.

Basit, T. (2003). Manual or electronic? The role of coding in qualitative data analysis. *Educational Research* , 143-154.

Beesley, A. (1994). A need for time-based process mapping and its application in procurement. *Proceedings of the 3rd Annual IPSERA Conference* (pp. 41-56). University of Glamorgan.

Benedetto, C. d., Calantone, R., van Allen, E., & Montoya-Weiss, M. (2003). Purchasing Joints the NPD Team. *Research-Technology Management* , 54-51.

Bilczo, T., Bugbee, L., Fitzhugh, J., Gilbert, D., Halladin, S., & Rubert, J. (2003). Aerospace Supply Chain Dynamics. In T. Harrison, H. Lee, & J. Neale, *The practice of supply chain management: where theory and application converge* (pp. 294-314). New York: Springer Science&Business Media, Inc.

Bloor, M., Frankland, J., Thomas, M., & Robson, K. (2001). *Focus groups in social research.* Thousand Oaks CA: Sage Publications.

Boone, T., & Ganeshan, R. (2007). The frontiers of eBusiness technology and supply chains. *Journal of Operations Management* , 1195-1198.

Brewer, P., & Speh, T. (2000). Using the balanced scorecard to measure supply chain performance. *Journal of Business Logistics* , 75-93.

Burbidge, J. (1984). Automated production control with a simulation capability. *Proceedings IFIP Conference Working Group 5-7.* Copenhagen.

Cachon, G., & Fisher, M. (2000). Supply chain Inventory Management and the Value of Shared Information. *Management Science* , 1032-1048.

Caniëls, M., & Gelderman, C. (2005). Purchasing strategies in the Kraljic matrix - A power and dependence perspective. *Journal of Purchasing & Supply Management* , 141-155.

Carey, M. (1995). Issues and applications of focus groups: Introduction. *Journal of Qualitative Health Research* .

Chen, F., Drezner, Z., Ryan, J., & Simchi-Levi, D. (2000). Quantifiying the Bullwhip Effect in a Simple Supply Chain: The Impact of Forecasting, Lead Times and Information. *Management Science* , 436-443.

Christopher, M. (1992). *Logistics and Supply Chain Management.* London: Pitman Publishing.

Cohen, M., & Ernst, R. (1988). Multi-item classification and generic inventory stock control policies. *Production and Inventory Management* , 6-8.

Culley, S. (1999). Suppliers in New Product Development: Their Information and Integration. *Journal of Engineering Deisgn* , 59-75.

Devers, K. (1999). How will we know "good" qualitative research when we see it? Beginning the dialogue in health services research. *Health Services Research* , 1153-1188.

Dong, Y., & Xu, K. (2002). A supply chain model of vendor managed inventory. *Transportation Research* , 75-95.

Dyer, J., & Singh, H. (1998). The Relational View: Cooperative Strategy and Sources of Interorganizational Competitive Advantage. *The Acedemy of Management Review* , 660-679.

Ellegaard, C., Johansen, J., & Drejer, A. (2003). Managing industrial buyer-supplier relations. *Integrated Manufacturing Systems* , 346-356.

Fawcett, S., & Fawcett, S. (1995). The Firm as a Value-Added System: Integrating Logistics, Operations and Purchasing. *International Journal of Physical Distribution & Logistics Management* , 24-42.

Fawcett, S., & Magnan, G. (2002). The rhetoric and reality of supply chain integration. *International Journal of Physical Distribution & Logistics Management* , 339-361.

Fern, E. (1982). The Use of Focus Groups for Idea Generation - The Effects of Gropu Size, Acquaintanceship, and Moderator on Response Quantity and Quality. *Journal of Marketing Research* , 1-13.

Fleischmann, B. (2000). Kooperation von Herstellern in der Konsumgüterdistribution [Cooperation of manufacturers in the consumer goods distribution]. In E. e. Sinz, *Kooperation im Wettbewerb [Cooperation in competition]* (pp. 167-186). Weisbaden.

Flick, U., Kardorff, E. v., & Steinke, I. (2004). *A companion to qualitative research.* London, UK: SAGE Publications Ltd.

Flores, B., & Whybark, D. (1987). Implementing Multiple Criteria ABC Analysis. *Journal of Operations Management* , 79-85.

Flores, B., Olson, D., & Dorai, V. (1992). Management of Multicriteria Inventory Classification. *Mathematical Computer Modelling* , 71-82.

Fontanini, P., & Picchi, F. (2004). Value stream macro mapping- A case Study of aluminium Windows for construction supply chain. *Proceedings of the 12th Annual Conference of the International Group for Lean Construction (IGLC-12).* Elsinore, Denmark.

Forrester, J. (1958). Industrial dynamics: a major breaktrhough for decision makers. *Hardvard Business Review* , 37-66.

Forza, C., Vinelli, A., & Filippini, R. (1993). Telecommunication services for quick response in the textile-apparel industry. *Proceedings of the 1st International Symposium on Logistics* (pp. 119-126). The University of Nottingham.

Fry, M., Kapuscinski, R., & Olsen, T. (2001). Coordinating Production and Devivery Under a (z,Z)-Type Vendor-Managed Inventory Contract. *Manufacturing & Service Operations Management* , 151-173.

Ganeshan, R. (1999). Managing supply chain inventories: A multiple retailer, one warehouse, multiple supplier model. *International Journal of Production Economics* , 341-354.

Gelderman, C., & Van Weele, A. (2002). Strategic Direction through Purchasing Portfolio Management: A Case Study. *International Journal of Supply Chain Management* , 30-38.

George, M. (2003). *Lean Six Sigma for Service.* New York: McGraw-Hill.

González-Benito, J., Martínez-Lorente, A., & Dale, B. (2003). A study of the purchasing management system with respect to total quality management. *Industrial Marketing Management* , 443-454.

Gosling, J., Purvis, L., & Naim, M. (2010). Supply chain flexibility as a determinant of supplier selection. *International Journal of Production Economics* , 11-21.

Gunasekaran, A., Patel, C., & McGaughey, E. (2004). A framework for supply chain performance measurement. *Int. J. Production Economics* , 333-347.

Gutierrez, R., Solis, A., & Mukhopadhyay, S. (2008). Lumpy demand forecasting using neural networks. *International Journal of Production Economics* , 409-420.

Guvenir, H., & Erel, E. (1998). Multicriteria inventory classification using a genetic algorithm. *European Journal of Operational Research* , 29-37.

Haartveit, E., Kozak, R., & Maness, T. (2004). Supply Chain Management Mapping for the Forest Products Industry: Three Case from Western Canada. *Journal of Forest Products Business Research* , 1-30.

Hadi-Vencheh, A. (2010). An improvement to multiple criteria ABC inventory classification. *European Journal of Operational Research* , 962-965.

Hald, K., Cordón, C., & Vollmann, T. (2009). Towards an understanding of attraction in buyer-supplier relationships. *Industrial Marketnig Management* , 960-970.

Handfield, R. (1993). The Role of Materials Management in Developing Time-Based Competition. *International Journal of Purchasing and Materials Management* , 2-10.

Handfield, R., & Nichols, E. (1999). *Introduction to supply chain management.* Upper Saddle River, N.J.: Prentice Hall.

Handfield, R., Ragatz, G., Petersen, K., & Monczka, R. (1999). Involving Suppliers in New Product Development. *California Management Review* , 59-82.

Hariga, M. (2000). Setup cost reduction in (Q, r) policy with lot size, setup time and lead-time interactions. *The Journal of the Operational Research Society* , 1530-1345.

Hautaniemi, P., & Pirttilä, T. (1999). The choice of replenishment policies in an MRP environment. *International Journal of Production Economics* , 85-92.

Hendrick, T., Carter, C., & Siferd, S. (1996). Purchasing's Involvement in Time-Based Strategies. *International Journal of Purchasing and Materials Management* , 2-10.

Hines, P., & Rich, N. (1997). The seven value stream mapping tools. *International Journal of Operations & Production Management* , 46-64.

Hines, P., & Taylor, D. (2000). *Going Lean.* Cardiff, UK: Lean Enterprise Research Center.

Hines, P., Rich, N., & Esain, A. (1998a). Creating a lean supplier network: a distribution industry case. *Eruopean Journal of Purchasing & Supply Management* , 235-246.

Hines, P., Rich, N., & Hittmeyer, M. (1998b). Competing against ignorance: advantage through knowledge. *International Journal of Physical Distribution & Logistics Management* , 18-43.

Hollander, J. (2004). The social contexts of focus groups. *Journal of Contemporary Ethnography* , 602-637.

Holweg, M., & Bicheno, J. (2002). Supply chain simulatoin - a tool for education, enhancement and endeavour. *International Journal of Production Economics* , 163-175.

Hopp, W., & Spearman, M. (1993). Setting Safety leadtimes for purchased components in assembly systems. *IIE Transactions* , 2-11.

Hopp, W., Spearman, M., & Woodruff, D. (1990). Practical Strategies for Lead Time Reduction. *Manufacturing Review* , 78-84.

Hüttinger, L. (2010). How to become a preferred customer of strategic suppliers? A large-firm perspective. *International IPSERA workshop on customer attractiveness, supplier satisfaction and customer value* (pp. 1-21). University of Twente.

Hyden, L., & Bulow, P. (2003). Who's talking: Drawing conclusions from focus groups- some methodological considerations. *International Journal of Social Research Methodology* , 305-321.

Inman, A. (1992). Time-Based Competition: Challenges for Industrial Purchasing. *Industrial Management* , 31-32.

Jacobs, F., & Whybark, D. (1992). A comparison of reorder point and material requirements planning inventory control logic. *Decision Sciences* , 332-342.

Jahnukainen, J., & Lahti, M. (1999). Efficient purchasing in make-to-order supply chains. *Int. J. Production Economics* , 103-111.

Jain, A., & Moinzadeh, K. (2005). A Supply Chain Model with Reverse Information Exchange. *Manufacturing & Service Operations Management* , 360-378.

Jessop, D., & Jones, O. (1995). Value stram porcess modelling: a methodology for creating competitive advantage. *Proceedings of the 4th Annual IPSERA Conference.* University of Birmingham.

Johnson, M. (1999). Collaboration Data Modelin: CPFR Implementation Guidelines. *Annual Conference Proceedings of the Council of Logistiscs Management*, (pp. 1-11). Cambridge.

Johnston, F., & Boylan, J. (1996). Forecasting for Items with Intermittend Demand. *Tje Journal of the Operational Research Society* , 113-121.

Jones, D. (1995). Applying Toyota principles to distribution. *Supply Chain Development Programme I, Workshop #8 Workbook.* Lutterworth: Britvic Soft Drinks Ltd.

Judson, K., Schoenbachler, D., Gordon, G., Ridnour, R., & Weilbaker, D. (2006). The new product development process: let the voice of the salesperson be heard. *Journal of Product & Brand Management* , 194-202.

Kempeners, M., & Van Weele, A. (1997). Inkoopportfolio: Basis voor inkoop- en marketingstrategie [Purchasing portfolio: The basis for for purchasing- and marketingstrategy]. In H. Van der Hart, & A. van Weele, *Dynamiek in Commerciële Relaties [Dynamics on commercial relationships].* Bunnik: F&G Publishing.

Kraljic, P. (1983). Purchasing Must Become Supply Management. *Harvard Business Review* , 109-117.

Kress, V., & Shoffner, M. (2007). Focus Groups: A Practical and Applied Research Approach for Counselors. *Journal of Counseling & Development* , 189-195.

Krishnamurthy, R., & Yauch, C. (2007). Leagile manufacturing: a proposed corporate infrastructure . *International Journal of Operations & Production Management* , 588-604.

Krueger, R. (1994). *Focus groups: A practical guide for applied research.* Thousand Oaks, CA: Sage Publications.

Lee, B. (2001). Value Stream Mapping. Wichita State University.

Lee, C., Ho, W., Ho, G., & Lau, H. (2011). Design and development of logistics workflow systems for demand management with RFID. *Expert Systems with Applications* , 5428-5437.

Lee, H., & Whang, S. (1998). *Information Sharing in a Supply chain. Research paper.* Stanford: Graduate School of Business, Stanford University.

Lee, H., Padmanabhan, V., & Whang, S. (1997). The Bullwhip Effect in Supply Chains. *Sloan Management Review* , 93-102.

Lee, H., So, K., & Tang, C. (2000). The Value of Information Sharing in a Two-Level Supply Chain. *Management Science* , 626-643.

Lee, S.-H., Diekmann, J., Songer, A., & Brown, H. (1999). Identifying Waste: Applications of Construction Process Analysis. *Proceedings of the Seventh Annual Conference of the International Group for Lean Construction* (pp. 63-72). Berkeley, CA, USA: University of California.

Leeuw, de, A. (2003). *Bedrijfskundige Methodologie.* Assen: Koninklijke van Gorcum.

Lehtinen, U., & Torkko, M. (2005). The Lean Concept in the Food Industry: A Case Study of Contract a Manufacturer. *Journal of Food Distribution Research* , 57-67.

Lian, Z., Deshmukh, A., & Wang, J. (2006). The optimal frozen period in a dynamic production model. *International Journal of Production Economics* , 648-655.

Liao, C.-J., & Shyu, C.-H. (1991). An Analytical Determination of Lead Time with Normal Demand. *International Journal of Operations & Production Management* , 72-78.

Massey, O. (2011). A proposed model for the analysis and interpretation of focus groups in evaluation research. *Evaluation and Progam Planning* , 21-28.

Mayer, R., Davis, J., & Schoorman, F. (1995). An Integrative Model of Organizational Trust. *The Academy of Management Review* , 709-734.

McGinnis, M., & Vallopra, R. (1999). Purchase and Supplier Involvement: Issues and Insights Regarding New Product Success. *Journal of Supply Chain Management* , 4-15.

McLafferty, I. (2004). Focus group interviews as a data collecting strategy. *Journal of Advanced Nursing* , 187-194.

McLaren, T., Head, M., & Yuan, Y. (2002). Supply chain collaboration alternatives: understanding the expected costs and benefits. *Internet Research: Electronic Networking Applications and Policy* , 348-364.

Metters, R. (1996). Quantifying the Bullwhip Effect in Supply Chains. *Proceedings of the 1996 MSOM Conference*, (pp. 264-269).

Miltenburg, J. (2001). Computational complexity of algorithms for MRP and JIT production planning problems in enterprise resource planning systems. *Production Planning and Control* , 198-209.

Min, H., & Yu, W. (2004). Collaborative Planning Forecasting and Replenishment: Demand Planning in Supply Chain Management. *The Fourth International Conference on Electronic Business* , (pp. 58-62). Beijing.

Monczka, R., Handfield, R., Giunipero, L., Patterson, J., & Waters, D. (2010). *Purchasing & Supply chain Management (European Edition).* London: South Western.

Monden, Y. (1993). *Toyoto Production System: An Integrated Approach to Just-in-Time* (2nd ed.). Norcross, GA: Industrial Engineering and Management Press.

Morgan, D. (1997). Focus Groups as Qualitative Research. *Qualitative Reseach Methods* , 6-17.

Morgan, R., & Hunt, S. (1994). The Commitment-Trust Theory of Relationship Marketing. *Journal of Marketing* , 20-38.

Nellore, R., & Soderquist, K. (2000). Portfolio approaches to procurement:analysing the missing the link to specifications. *Long Range planning* , 245-267.

New, C. (1993). The use of throughput efficiency as a key performance measure for the new manufacruring era. *The International Journal of Logistics Management* , 95-104.

Ng, W. (2007). A simple clasifier for multiple criteria ABC analysis. *European Journal of Operational Research* , 344-353.

Nicol, D. (1989). An innovative two-bin application for floor stock. *Production & Inventory Management* , 27-29.

Nijssen, E., Biemans, W., & de Kort, J. (2002). Involving purchasing in new product development. *R&D Management* , 281-289.

Noorderhaven, N., Nooteboom, B., & Berger, H. (1998). Determinants of perceived interfirm dependence in industrial supplier relations. *Journal of Management and Governance* , 213-232.

Novich, N. (1990). Distribution strategy: Are you thinking small enough? *Sloan Management Review* , 71-77.

Ohno, T. (1988). *Toyota production system: beyond large-scale production.* Toyclo: Diamond, Inc.

Olsen, R., & Ellram, L. (1997). A portfolio approach to supplier relationships. *Industrial Marketing Management* , 101-113.

Partovi, F., & Anandarajan, M. (2002). Classifying inventory using an artificial neural network approach. *Computers & Industrial Engineering* , 389-404.

Practical Management Research Group. (1993). *Seven Tools for Industrial Engineering.* Tokyo: PHP Institute.

Primo, M., & Amundson, S. (2002). An exploratory study of the effects of supplier relationships on new product development outcomes. *Journal of Operations Management* , 33-52.

Quayle, M. (2003). A study of supply chain management practice in UK industrial SMEs. *Supply Chain Management: An International Journal* , 79-86.

Ragatz, G., Handfield, R., & Scannell, T. (1997). Succes Factors for Integrating Suppliers into New Product Development. *Journal of Production and Innovation Management* , 190-202.

Ramanathan, R. (2006). ABC inventory classification with multiple-criteria using weighted linear optimization. *Computers & Operations Research* , 695-700.

Roberts, J. (2003). The Buzz About Supply Chain. *Inside Supply Management* , 24-31.

Romero, D., & Chávez, Z. (2011). Use of Value Mapping Tools for Manufacturing Systems Redesign. *Proceedings of the World Congress on Engineering.* London, U.K.

Rother, M., & Shook, J. (1998). *Learning to see: Value stream mapping to add value and eliminate muda.* Cambridge, MA USA: The Lean Enterprise Institute.

Saaty, T. (2005). *Analytic Hierarchy Process. Encyclopedia of Biostatistics. .* Pittsburgh, PA, USA: John Wiley & Sons, Ltd.

Saaty, T. (1990). How to make a decision: The Analytic Hierarchy Process. *European Journal of Operational Research* , 9-26.

Sahin, F., & Robinson Jr., E. (2005). Information sharing and coordination in make-to-order supply chains. *Journal of Operations Management* , 579-598.

Schiele, H. (2010). Early supplier integration: the dual role of purchasing in new product development. *R&D Management* , 138-153.

Schiele, H. (2006). How to distinguish innovative suppliers? Identifying innovative suppliers as new task for purchasing. *Industrial Marketing Management* , 925-935.

Schiele, H., Veldman, J., & Hüttinger, L. (2010). Customer attractiveness, supplier satisfaction and preferred customer status: review, concept and research agenda. *International ISPERA workshop on Customer attractiveness, supplier satisfaction and customer value* (pp. 1-19). Enschede: University of Twente.

Schiele, H., Veldman, J., & Hüttinger, L. (2011a). Customer attractiveness, supplier satisfaction and preferred customer status: review, concept and research agenda. *International ISPERA workshop on customer attractiveness, supplier satisfaction and customer value*, (pp. 1-50). Glasgow.

Schiele, H., Veldman, J., & Hüttinger, L. (2011b). Supplier Innovativeness and Supplier Pricing: The Role of Preferred Customer Status. *International Journal of Innovation Management* , 1-27.

Schmitz, J., & Platts, K. (2004). Supplier logistics performance measurement: indications fom a study in the automotive industry. *International Journal of Production Economics* , 234-243.

Shadish, W., Cook, T., & Campbell, D. (2002). *Experimental and Quasi-Experimental Designs for generalized Causal Inference.* Wadsworth: Cengage Learning.

Simatupang, T., & Sridharan, R. (2005). The collaboration index: a measure for supply chain collaboration. *International Journal of Physical Distribution & Logistics management* , 44-62.

Simatupang, T., & Sridharan, R. (2002). The Collaborative Supply Chain. *The International Journal of Logistics Management* , 15-30.

Simchi-Levi, D., Kaminsky, P., & Simchi-Levi, E. (2002). *Designing and Managing the Supply Chain.* New York, NY: McGraw-Hill.

Skjoett-Larsen, T., Thernøe, C., & Andresen, C. (2003). Supply chain collaboration: Theoretical perspectives and empirical evidence. *International Journal of Physical Distribution & Logistics Management* , 531-549.

Smeltzer, L. (2006). The Meaning and Origin of Trust in Buyer-Supplier Relations. *Journal of Supply Chain Management* , 40-48.

Spencer, M. (1995). Production planning in a MRP/JIT repetitive manufacturnig environment. *Production Planning and Control* , 176-184.

Sridharan, V., & Berry, W. (1990). Freezing the Master Production Schedule under Demand Uncertainty. *Decision Science* , 97-120.

Sridharan, V., & Laforge, R. (1994). A Model to Estimate Service Levels when a Portion of the Master Production Schedule is Frozen. *Computers & Operations Research* , 477-486.

Stadtler, H. (2005). Supply Chain Management – An Overview. In H. Stadtler, & C. Kilger, *Supply Chain Management and Advanced Planning: Concepts, Models, Software and Case Studies* (pp. 9-35). Berlin: Springer.

Stank, T., Daugherty, P., & Autry, C. (1999). Collaborative planning: supportnig automatic replenisment programs. *Supply Chain Management* , 75-85.

Steinle, C., & Schiele, H. (2008). Limits to global sourcing? Strategic consequences of dependecy on international suppliers: Cluster theory, resource-based view and case studies. *Journal of Purchasnig & Supply Management* , 3-14.

Stewart, B. (1995). Supply chain performance benchmarking study reveals keys to supply chain excellence. *Logistics Information Management* , 38-44.

Talluri, S., & Sarkis, J. (2002). A model for performance monitoring of suppliers. *International Journal of Production Research* , 4257-4269.

Taylor, D. (2000). Demand amplification: has it got us beat? *International Journal of Physical distribution & Logistics Management* , 513-533.

Tersine, R. (1994). *Principles of Inventory and Materials Management* (4 ed.). Prentice Hall.

Thayer, C., & Fine, A. (2001). Evaluation and outcome measurement in the non-profit sector: Stakeholder participation. *Evaluation and Program Planning* , 103-108.

Tommelein, I. (1998). Pull-driven scheduling for pipe-spool installation: simulation of a lean construction technique. *Journal of Construction Engineering and Management* , 279-288.

Tracey, M. (2004). A Holistic Approach to New Product Development: New Insights. *Journal of Supply Chain Management* , 37-55.

Verganti, R. (1997). Order overplanning with uncertain lumpy demand: a simplified theory. *International Journal of Production Research* , 3229-3248.

Vonderembse, M., & Tracey, M. (1999). The Impact of Supplier Selection Criteria and Supplier Involvement on Manufacturing Performance. *Journal of Supply Chain Management* , 33-39.

Wagner, M. (2005). Demand Planning. In H. Stadtler, & C. Kilger, *Supply Chain Management and Advanced Planning: Concepts, Models, Software and Case Studies* (pp. 139-157). Berlin: Springer.

Wagner, S., & Johnson, J. (2004). Configuring and managing strategic supplier portfolios. *Industrial Marketing Management* , 717-730.

Waller, M., Johnson, M., & Davis, T. (1999). Vendor-Managed Inventory in the Retail Supply Chain. *Journal of Business Logistics* , p.u.

Walter, A., Müller, T., Helfert, G., & Ritter, T. (2003). Functions of industrial supplier relationships and their impact on relationship quality. *Industrial Marketing Management* , 159-169.

Walter, A., Ritter, T., & Gemünden, H. (2001). Value creation in buyer-seller relationthips-Theoretical considerations and emperical results from a supplier's perspective. *Industrial Marketing Management* , 365-377.

Watson, N., & Robertson, A. (1996). A qualitative evaluatin of HIV and AIDS education to senior school children in Lothian Region, Scotland. *Health Promotion International* , 291-298.

Webb, C., & Kevern, J. (2001). Focus groups as research method: A critique. *Journal of Advanced Nursing* , 798-805.

Wibeck, V., Dahlgren, M., & Oberg, G. (2007). Learning in focus groups: An analytical dimension for enhancing focus group research. *Qualitative Research* , 249-267.

Willemain, T., Smart, C., & Schwarz, H. (2004). A new approach to forecasting intermittend demand for service parts inventories. *International Journal of Forecasting* , 375-387.

Williamson, P. (1991). Supplier strategy and customer responsiveness: Managing the links. *Business Strategy Review* , 75-90.

Willis, T., & Shields, J. (1990). Modifying the ABC inventory system for a focused factory. *Industrial Engineering* , 38-39.

Womack, J., & Jones, D. (1996). *Lean Thinking - Banish Waste and Create Wealth in your Corporation.* New York: Simon & Schuster.

Womack, J., & Jones, D. (2002). *Seeing the Whole: Mapping the Extended Value Stream.* Brookline, MA, USA: Lean Enterprise Institute.

Wong, A. (2000). Integrating supplier satisfaction with customer satisfaction. *Total Quality Management* , 427-432.

Xie, J., Lee, T., & Zhao, X. (2004). Impact of forecasting error on the performance of capacitated multi-item production systems. *Computers & Industrial Engineering* , 205-219.

Yao, Y., Evers, P., & Dresner, M. (2007). Supply chain integration in vendor-managed inventory. *Decision Support Systems* , 663-674.

Yücesan, E., & Groote, X. d. (2000). Lead times, order relase mechanisms, and customer service. *European Journal of Operational Research* , 118-130.

Zhou, P., & Fan, L. (2007). A note on multi-criteria ABC inventory classification using weighted linear optimization. *European Journal of Operational Research* , 1488-1491.

I. Value Stream (Macro) Mapping and Process Mapping

A review for value chain mapping tools is offered by Hines and Rich (1997). These authors discuss 7 different value stream and process mapping tools, using the 7 wastes of the Toyota production system (TPS) as a basis. Jones (1995) rewords these wastes to be more applicable in a specific case and Hines and Rich (1997) uses these in combination with a simplified value stream analysis tool (VALSAT) to choose a useful mapping tool. The fact that these authors use a case example which is about supplier lead-time reduction makes this paper highly applicable, even as the fact that Hines et al. (1998a) put this strategy into practice for creating a lean supplier network. Lee (2001, p. 2) concludes that VALSAT is *"a dynamic analysis, prioritisation and focusing tool, which if possible should be capable of using both tacit and subjective information as well as explicit or quantifiable information…"*.

In order to use this simplified VALSAT-method of Hines and Rich (1997), several steps have to be taken namely:

- Operationalize the seven (TPS) wastes to make them applicable to the specific case;
- Assign importance weights to the specific wastes; and after that
- Score the different mapping tools in combination with the wastes for usefulness and correlation (pp. 59-61).

Table I-1 gives an overview of the seven TPS wastes, and their operationalization that will be used within this study. The bases for these reworded wastes are the causes of lead-time and –variability increase of Table 1-1 in this research.

TPS-waste	Operationalization	
Overproduction	Stocks of (semi-) finished products	Stocks within CO of (semi-)finished machines, acting as a buffer.
Waiting	Supplier delivery time/ supplier order cycle time	The time needed for a supplier to process an order from when the order is received to delivery at CO.
Transport	Conveyance	The transport of orders or goods, both from suppliers to CO as internally.
Inappropriate Processing	Inappropriate processing	Machines or procedures that are too complex for the goal they serve.
Unnecessary Inventory	Excess Stock	Unnecessary stock or buffers of purchased parts, within CO's warehouse.
Unnecessary Motion	Unnecessary information movement	The unnecessary or inefficient movement of information within a value stream or a company.
(Service) Defects	Service defects	Delivery defects between customers and suppliers: Too late or too early deliveries, wrong quantities, or incomplete paperwork.

Table I-1: Reworded wastes

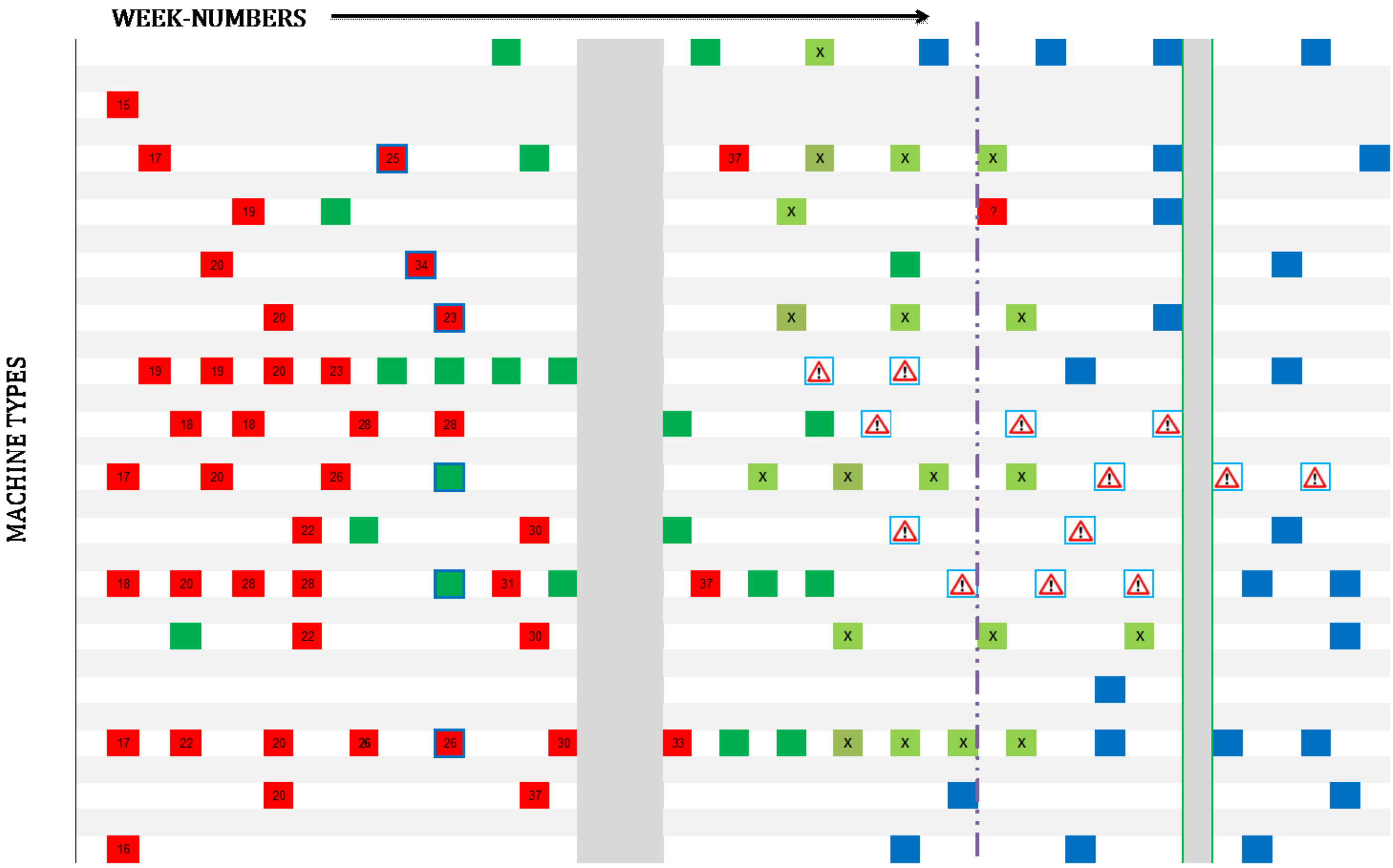
II. The Seven Value Stream Mapping tools by Hines and Rich (1997)

	Mapping Tool						
Wastes/structure	Process activity mapping	Supply chain response matrix	Production variety funnel	Quality filter mapping	Demand amplification mapping	Decision point analysis	Physical structure (a) volume (b) value
Overproduction	L	M		L	M	M	
Waiting	H	H	L		M	M	L
Transport	H			L			
Inappropriate processing	H		M			L	
Unnecessary Inventory	M	H	M		H	M	L
Unnecessary motion	H	L					
Defects	L			H			
Overall structure	L	L	M	L	H	M	H

Notes: H =High correlation and usefulness (9)
M =Medium correlation and usefulness (3)
L =Low correlation and usefulness (1)

Source: (Hines & Rich, The seven value stream mapping tools, 1997)

III. Rolling Forecast



Anticipated demand

Critical parts ordered in advance

X Released for production (not started up)

Started up (parts ordered)

Weeknr Sold and in production

25 week-line (release or cancel order here)

IV. Multi-criteria inventory classification: A detailed example

*"Consider an inventory with **I** items and these items are to be classified based on **J** criteria. The measurement of the **i**th item under the **j**th criteria is denoted as* y_{ij}*."* (Ng, p. 345). Next two pre-processing steps are, first; define the criteria positively related to the item score (or otherwise transformation is needed) and second; ranking the criteria on importance. Formula 1 and constraints 2-4 conclude in a weighted linear optimization with w_{ij} being *"... the weight of contribution of performance of the **i**th item under the **j**th criteria to the score of the item."* (p. 346), and S_i being the score of the ***i***th item.

(P1) (1)

s.t. (2)

(3)

(4)

This model transforms all original scores of an item for a certain criteria in a score on a scale of 0-1, basically in the same proportion. An example is shown in Table IV-1, based on case example of Ng (2007, p. 350). Annual Dollar Usage was used as the most important criterion in this case, and Lead Time as being least important as they are ranked on importance.

Item no.	Annual dollar usage	Average unit cost	Lead time	Annual dollar usage (transformed)	Average unit cost (transformed)	Lead time (transformed)
1	5840.64	49.92	2	1.00	0.22	0.17
2	5670	210	5	0.97	1.00	0.67
3	1075.2	5.12	2	0.18	0.00	0.17
4	467.6	58.45	4	0.08	0.26	0.50
5	336.12	84.03	1	0.05	0.39	0.00
6	190.89	7.07	7	0.03	0.01	1.00
7	25.38	8.46	5	0.00	0.02	0.67
Min	*25.38*	*5.12*	*1*			
Max	*5840.64*	*210*	*7*			

Table IV-1: Measures of inventory items and transformed measures. Based on: Ng (2007, p. 350)

After transformation of the item scores, Ng (2007) proposes the following steps (p. 348):

Step 1.Calculate all partial averages, –

*Step2. Compare and locate the maximum among these partial averages. The corresponding value is the score S_i of the **i**th item.*

Step 3. Sort the scores S_i's in the descending order.

Step4. Group the inventory items by principle of ABC analysis.

Steps 1 and 2 are executed in the table below. The partial averages (step 1) are calculated by taking the scores for a single ***i***th item into account, for all higher ranked ***j***th criteria. Average 1 only takes the Annual dollar usage into account, while average 3 is the average score of the ***i***th item on all three criteria. The maximum averages (step 2) of each ***i***th item are bold. These are sorted in descending order (step 3), in Table IV-3.

Item no.	**Annual dollar usage (transformed)**	**Average unit cost (transformed)**	**Lead time (transformed)**	**Partial average**		
				1	2	3
1	1.00	0.22	0.17	**1.00**	0.61	0.46
2	0.97	1.00	0.67	0.97	**0.99**	0.88
3	0.18	0.00	0.17	**0.18**	0.09	0.12
4	0.08	0.26	0.50	0.08	0.17	**0.28**
5	0.05	0.39	0.00	0.05	**0.22**	0.15
6	0.03	0.01	1.00	0.03	0.02	**0.35**
7	0.00	0.02	0.67	0.00	0.01	**0.23**

Table IV-2: Partial averages and scores of inventory items. Based on: Ng (2007, p. 351)

Item no.	**Annual dollar usage (transformed)**	**Average unit cost (transformed)**	**Lead time (transformed)**	**Score proposed by model**
1	1.00	0.22	0.17	1.00
2	0.97	1.00	0.67	0.99
6	0.03	0.01	1.00	0.35
4	0.08	0.26	0.50	0.28
7	0.00	0.02	0.67	0.23
5	0.05	0.39	0.00	0.22
3	0.18	0.00	0.17	0.18

Table IV-3: Measures of items under criteria and the proposed score by the model. Based on: (2007, p. 352)

After completing these steps, the ABC analysis can be executed to categorize the items on the proposed score by the model.