The Supply Chain Cockpit

A High-level Performance Measurement System for a Semiconductor Supply Chain

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Preface

This study was conducted at, and sponsored by ST-Ericsson in Lund during five months in the winter and spring of 2010. This dissertation is the final examination of my master in Industrial Engineering and Management. My field of interest is in business development and strategy formation and when I got the opportunity to do my master thesis for ST-Ericsson, studying the implementation of a High-level performance measurement system for ST-Ericsson's supply chain, I jumped to the challenge. I have got a unique experience following ST-Ericsson's transformation to become a unified company and a global player in the semiconductor industry, from first row.

ST-Ericsson has openly welcomed me to the organization and given me all help needed for this study, which I am very thankful for. I would like to express a special thanks and deep appreciation to Jesper Löfberg for his guidance as my supervisor and mentor at ST-Ericsson. I also would like to thank Peter Unelind, Mikael Tordenmalm and Charlie Yeh for their valuable input on my work. You have all given me not only professional input to my thesis, but also supported me in my personal development through construct criticism and always challenging my stand point.

A special thanks also goes to Bertil I Nilsson, my tutor from the department of Industrial Management and Logistics, for his input and always positive feedback on my work. You have guided me through the academic part of my thesis and taken a lot time to reinsure I was on the right path.

Lund, June 2010

Carl-Johan Dhejne

Abstract

Organizations have over the latest decades seen a growing need for new multi-dimensional measures for evaluating their business performance, since traditional accounting models for long have proven not to be applicable to the modern business environment. Together with the need for timely information this has caused extensive requirements on the ERP-systems which often do not meet the needed requirements. This study investigates how a performance measurement *cockpit* can be developed for a supply chain to serve this purpose.

The wireless semiconductor company, ST-Ericsson, was formed in 2009 by bringing together Ericsson Mobile Platforms (EMP) and ST-NXP Wireless, into a joint venture between the parent companies Ericsson and STMicroelectronics. As a result of the merger ST-Ericsson became one of the market leaders in wireless technology and a supplier to four of the top five handset manufacturers in the world.

After the merger the division L3M was created, mainly from parts of the past EMP organization, and became operational in 2010. EMP was a design house for mobile platforms which relied on partners for supplying the hardware, only delivering the accompanying software themselves. ST-Ericsson was also made into a non-manufacturing company that outsourced its production, but still had full product ownership. For the former EMP employees and the L3M team this meant a whole new supply chain process, with real hardware ownership. L3M partly lacked capabilities and competences in the supply chain management field. Another problem was keeping track of the allocated cost in the supply chain, which resulted in a need for a performance measurement system.

With the use of the business intelligence tool QlikView a performance measurement system-prototype, named the *Supply Chain Cockpit* was developed, and studied in a clinical method, for L3M's supply chain. By mapping the supply chain process, the *cockpit* was developed to align the performance measurement system with the division's strategy and targets to enable competitive advantage through sustainable supply chain performance.

Together with deeper knowledge of the supply chain, the result was a prototype of a user-friendly, clear and visual performance measurement tool, with the ability to extract timely reports for upper management. The prototype compiles and stores data, with a powerful ability to drill down into the data for analysis of the material. Organizations can easily drown in their own data and the Supply Chain Cockpit displays how data can be compiled and performance visualized without lowering the data granularity.

Sammanfattning

Organisationer har under de senaste decennierna sett ett växande behov av nya flerdimensionella mätvärden för utvärdering av deras verksamhet eftersom de traditionella redovisningsmodellerna sedan länge har visat sig inte vara tillämpningsbara för den moderna affärsmiljön. Detta har tillsammans med behovet av att erhålla aktuell information orsakat omfattande krav på ERP-system vilka ofta inte uppfyller de nödvändiga kraven. Denna studie undersöker hur en prestationsbedömnings-cockpit kan utvecklas för företagets försörjningsskedja för att tjäna just detta syfte.

ST-Ericsson bildades 2009 genom att sammanföra Ericsson Mobile Platforms (EMP) och ST-NXP Wireless, i ett joint venture mellan moderbolagen Ericsson och STMicroelectronics. Som ett resultat av fusionen blev ST-Ericsson en av marknadsledarna inom trådlös teknik och leverantör till fyra av de fem största mobiltelefonstillverkarna i världen.

Efter sammanslagningen skapades divisionen L3M, främst från delar av den gamla EMP-organisationen, och blev operationell 2010. EMP var ett designhus för mobila plattformar som förlitade sig på partnerföretag för att leverera hårdvara, medan de själva enbart levererade den tillhörande mjukvaran. ST-Ericsson skapades även som ett icke-producerande företag med outsourcad produktion, men hade fullt produktägarskap. För de tidigare EMP-medarbetarna och det nya L3M-teamet innebar detta en helt ny process för försörjningskedjan, med ägarskap över hårdvaran. L3M saknade delvis kapabilitet och kompetens inom supply chain managementområdet. Ett annat problem var att hålla reda på de allokerade kostnaderna i försörjningskedjan, vilket sammanslaget resulterade i ett behov av ett prestationsbedömningssystem.

Med hjälp av Business Intelligence-verktyget QlikView utvecklades en prototyp av ett prestationsbedömningssystem, kallat *the Supply Chain Cockpit.* Prototypen har utvecklats och undersökts med en klinisk metod för L3M försörjningskedja. Genom processkartläggning av försörjningskedjan har cockpiten utvecklats för att anpassa prestationsbedömningssystemet till divisionens strategi och mål för att möjliggöra konkurrensfördelar genom en hållbar prestanda i försörjningskedjan.

Tillsammans med fördjupad kunskap om försörjningskedjan, var resultatet en prototyp av en användarvänlig, tydlig och ett visuellt prestationsbedömnings-verktyg, med möjlighet att ta fram aktuella rapporter för ledningen, med en kraftfull förmåga att dyka ner i data för vidare analys av materialet. Organisationer kan lätt drunkna i sin egen information och denna Supply Chain Cockpit visar hur data kan sammanställas och visualisera operationell prestation utan att offra upplösningen.

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Glossary and Abbreviations

3GP = 3G Platforms (Division)
ASIC = Application Specific Integrated Circuit
ASSP= Application Specific Standard Product
Back-end = Assembly, test and finish of dice
BSC = Balanced Scorecard
CD = Committed Delivery Date
CTO = Central Technology & Strategic Planning Organization
Die = Silicon Chip (dice in plural)
EMP = Ericsson mobile platforms
ERP = Enterprise Resource Planner
ETC = 2G, EDGE, TD-SCDMA & Connectivity Solutions (Division)
EWS = Electrical Wafer Sort
Fab = A production unit for semiconductor wafers
Front-end = Die production from silicon wafer
JIT = Just In Time
KPI = Key Performance Indicator
KRI = Key Result Indicator
L3M = LTE & 3G modem solutions (Division)
LTE = Long Term Evolution (4G access technology)
P&L = Profit and Loss
PI = Performance Indicator
PMS = Performance Measurement System
QlikView = Business Intelligence Software
QlikTech = Owner and developer of Qlikview
RD = Requested Delivery Date
SCOR = Supply Chain Operations Reference-model
SCM = Supply Chain Management
ST-NXP = ST-NXP Wireless
ST = STMicroelectronics
VMI = Vendor Managed Inventory
Wafer = Silicon disc in 12’’ or 8’’
WIP = Work In Progress

1 Introduction

This chapter will provide an introduction of the study, with the company background of ST-Ericsson, a problem description together with the purpose and the objectives of the study. The target group, delimitation of the study and an outline of this report ends this chapter.

1.1 Background

ST-Ericsson is a high tech company that develops and manufactures semiconductor platform technologies for wireless products such as mobile phones and USB-dongles. ST-Ericsson was formed in February 2009 as a joint venture with 50/50 ownership between LM Ericsson and STMicroelectronics (ST). The joint venture was formed by bringing together the divisions Ericsson Mobile platform (EMP) from Ericsson and ST-NXP Wireless (ST-NXP) from ST. As a result of the merger ST-Ericsson became one of the market leaders in wireless technology and a supplier to four of the top five handset manufactures in the world. The new company had one of the largest intellectual property portfolio rights in the industry and covered all the available technologies on the markets; from 2G technology for entry phones to the cutting edge technology at that time, LTE or 4G access technology. ST-Ericsson had approximately 8000 employees worldwide.

In late 2009 the brand new organization was set and most of the reconstructing and integration work was finished. Three divisions had been formed and were based mainly on the infrastructure technologies. The divisions were L3M, 3GP and ETC. L3M stands for LTE & 3G modem solutions, 3GP had mainly 3G technology and ETC had mainly 2G technology. Besides the main divisions there was also a number of supporting central functions like Sales, Finance and Operations.

The division L3M was to a great extent concentrated to the Lund site in Sweden and the Nuremberg site in Germany, which were dominated by former EMP employees. This put extra stress on the transformation to a ST-Ericsson division, since the employee perspective was almost entirely from the Ericsson side while most of the systems used came from the ST side.

One of the main differences between EMP and ST-NXP was that EMP did not have any own production or product ownership. EMP was a design house for mobile platforms which relied on partners for supplying the hardware, for example ST. EMP delivered the software which enabled the hardware to function as required for the specific application. ST-Ericsson was also made into a fabless company that outsourced its production to ST and external foundries, but still had full product ownership. For the former EMP employees and the L3M team this meant a whole new supply chain process, with real hardware ownership. Before the merger the

R&D Access unit L3M is based upon was more or less considered a cost center. During the reconstructing in the fall of 2009, it had been transformed to a profit and loss responsible division, resulting in new requirements for costs control.

Since the L3M team had little experience in supply chain management most of the production planning was outsourced to the sister division 3GP, with its planning organization situated at the Grenoble site, in France. In January 2010 the L3M division went live and hardware components were starting to be delivered to customers, which L3M had full responsibility for. L3M's sales were rapidly increasing and the need for a performance measurement system (PMS) for the supply chain was apparent. See *figure 1* for ST-Ericsson and L3M's time line.

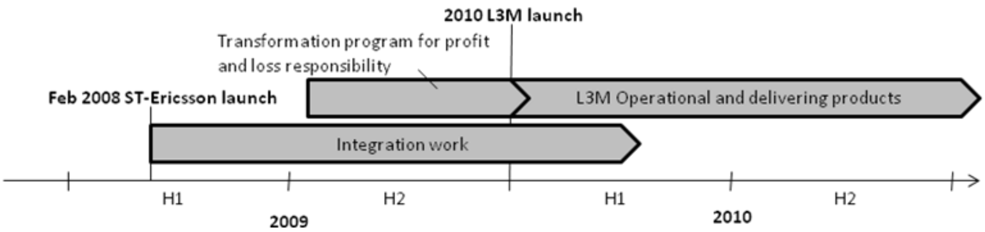

Figure 1. ST-Ericsson and L3M's Time Line

1.2 Problem Description

The semiconductor industry is considered to have one of the most complex supply chains of any industry, for many reasons, partly because of a very long lead-time and complicated production procedures. L3M partly lack capabilities and competences in this field, which need development. Another problem is keeping track of the allocated cost in the supply chain, due to production costs, capital build up and value added in the different production steps. In order for L3M to extend their competences in the supply chain process and keep track of the costs and the performance there within, a new performance measurement system would be a great tool for improvements. After the merger there was no uniform ERP-system used for the supply chain activities and none of them provided an easy to use interface with visual presentation of the different supply chain aspects.

The author was given a unique opportunity to take part in the process of bringing a new PMS and reporting package in place. The PMS was named the *Supply Chain Cockpit*, since the system should provide a picture of the status of the supply chain, much like a cockpit has gauges and meters to give a picture of the aircrafts flying performance. A great challenge in this project is extracting the right data from a vast ocean of information and corporate documents circulating within the company. And as a last challenge converging the information into a user-friendly, clear and visual performance measurement tool.

1.3 Purpose

The purpose of this study was to design and develop a prototype of a high-level performance measurement system that suits L3M's supply chain needs. The prototype was then tested and evaluated and will serve as a basis for deciding if it is a satisfactory PMS for L3M. The purpose of the PMS is to serve as an analysis tool of the supply chain performance, with the ability to extract reports for upper management. The system should also enable the company for continuous improvements that in the long run can give ST-Ericsson competitive advantages in their supply chain performance.

The secondary purpose of this study was to develop insight and knowledge about L3M's supply chain. This means, raising the competences in the new supply chain process for the employees at L3M, for which this report should serve as an internal document about L3M's supply chain.

1.4 Objectives

The objective was to construct a performance measurement system that can be implemented right away from the prototype. The prototype should also be in line with the company's and the division's strategies and targets.

A secondary objective, directed to the academic society, is for this study and this report to give insight and knowledge into implementing a performance measurement system for a supply chain in a company in a post merger state. Bringing two companies together is a long, wearing and tearing process that in many cases fails. Understanding the new conditions, in this case transforming into a hardware company, and start focusing on the business instead of the integration is crucial. This study investigates how going through a supply chain strategy review can help in the transformation process.

1.5 Target Group

The target group for this dissertation is mainly the staff at ST-Ericsson and primarily those within L3M Operations. This dissertation is not only an evaluation report of a performance measurement system; it should also serve as a handbook on L3M's supply chain.

A secondary target group is students and staffs at universities and higher educations, which are interested in the field of supply chain management, performance measurement systems, strategy formation and change management.

1.6 Delimitations

The research conducted at ST-Ericsson started out as an exploratory study, by defining and learning about the supply chain. Along the way, as new hurdles and missing links were discovered, certain aspects of the supply chain process was excluded in the Supply Chain Cockpit while others were added. These parts are all motivated and explained in chapter 5 and 6, the empirical framework and analysis. The study was limited to the division L3M's supply chain because of the sheer magnitude of the supply chain and the limiting timeframe during which the study was conducted. Another interesting aspect of L3M, from a research perspective, is that L3M is new to this process, which makes an interesting case in how a performance measurement system is developed for an existing and functioning supply chain.

1.7 Report Outline

To get the complete picture of this study and an understanding of how the theories and methodologies are used for the empirics and analysis chapter (the main part of the dissertation), the report can be read cover to cover. An alternative approach, for the more well-read in the subject, is to read the introduction, continuing at the empirics for the rest of the report and looking back to the theoretical framework and methodology where referenced. The logic of the chapter divisions is described below and represented in *figure 2*:

Introduction – Gives the reader the needed background of ST-Ericsson, which led to the initiating of the study. Followed by the background are a deeper problem description and the purpose and objectives of the study. The chapter ends with the target group, delimitations and this report outline.

Methodology – Presents the methodology which the study is conducted according to, starting with a general background on methodologies and ending with the chosen ones.

Theoretical Framework – Presents the relevant theories in supply chain management, process management, performance measurements and SCOR, which the empirics and the analysis later is based upon, together with the methodology chapter.

Introduction to ST-Ericsson's Supply Chain – Provides an introduction to the semiconductor production processes and supply chain business models, used by ST-Ericsson, since it is central for the empirics and the analysis.

Empirical Framework – Presents the relevant empirics gathered at ST-Ericsson during the time of the study.

Analysis – Presents the analysis of the relevant empirics in relation to the purpose and objectives of the study.

Discussion – Provides a discussion about whether if the purpose and objectives of the study was met and what the implications are in an academic perspective

Conclusion – Provides the results of the study and the conclusions and recommendation to ST-Ericsson together with suggested future studies.

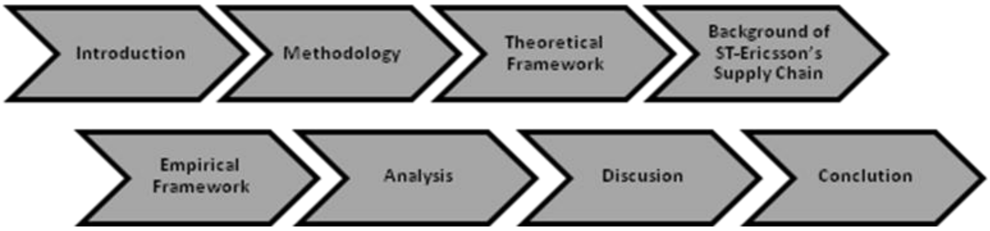

Figure 2. Report Outline

2 Methodology

This chapter provides a discussion of methodologies for the research conducted at ST-Ericsson, which serves as a background for the motivation of the chosen methodology.

2.1 Case Study

Case study methodologies are used when studying single cases in depth and are an empirical investigation of a contemporary phenomenon within its real life context. It is especially appropriate when the boundaries between phenomenon and context are not clearly evident (Yin, 1994). The objective of the case study is to obtain valuable and unique insights in the studied object or phenomenon, which is not obtainable by other methods (Denscombe, 2000).

A case study can be exploratory, descriptive and explanatory or a combination of the three (Yin, 1994). If the study is exploratory the aim is defining the questions and hypotheses of a subsequent study. A descriptive case study presents a complete description of a phenomenon within its context and an explanatory case study compiles data, explaining the full cause and effect relationships (Seuring, 2005). In order for a case study to serve as a critical example the studied object need to fulfill certain criteria's; for example, that it is a unique case, a typical and representative case or a case that can provide a longitudinal study in time (Seuring, 2005).

Over the years there has been considerable criticism of the case study method, claiming it is not rigor, since it can allow the investigator to present equivocal and biased findings and conclusions. These are properties that lay in the investigators ability to execute the study and are difficult to control. It can be argued that this also is evident in other more frequently used study methods, e.g. surveys, though more prominent in case studies. Another concern is that there is no ability to generalize from a single case. In contrast to surveys, case studies cannot be generalized to a population, but like experiments it still can be generalized to a theoretical proposition. (Yin, 1994)

Case studies are an appropriate study method for analysis of a supply chain and managerial issues with highly unstructured problems, which can be dealt with in an exploratory research design. For supply chain management studies, case studies allow for identification and description of critical variables. (Seuring, 2005)

2.2 Action Research

Action research is a study method with many similarities to case studies. The study method is used when the study object is to be improved or a problem there within needs to be solved, while it is being studied. The research begins with observing a situation or phenomenon to identify and clarify problems. This can be done by a case study approach. The next step is constructing suggestions for solutions of the problem. The last step is an evaluation of the solution, by observations and analysis of it in its context. (Höst, Ragnell & Runeson, 2009)

Action research is characterized by four different traits. First, action research is very practical oriented and deals with real problems and questions that arise, mainly in workplaces and in organizational contexts. Second, change is integrated with the research both as a way to deal with the problem and a way to gain greater knowledge about the phenomenon, meaning that an alteration of the studied object can result in wider knowledge about the object. Third, action research is a cyclic- or iterative process that is repeated until the solution is satisfactory. Fourth, the research process is participative, with the central people of the research. (Denscombe, 2000)

2.3 Clinical Research

Clinical research is a study method with a heritage from medicine studies, though the method is also applicable to organizational context and suitable for studies of transformation processes. Clinical research is often described as synonymous to action research, though they can be distinguished in relation to the initiator of the problem area. In clinical studies the case company makes the distinction of the problem, in action research it is the investigator who makes the distinctions. The methodology is founded on the notion that both the work and the views should actively be exchanged between the researcher and the client (or case company). (Sköld, 2007)

2.4 Scientific Approach

There is two main ways of conducting an academic study: inductive and deductive approach. The inductive approach starts with gathering empirics and from it draw generalized conclusions about the cases. With a deductive approach the study begins with a theoretical hypothesis, which serves as a base for drawing conclusions about the studied case. (Alvesson & Sköldberg, 2008)

An alternative approach is an abductive one, where empirics of a case are analyzed by a theory. Then new empirical studies are made to verify the theoretical conclusions. (Alvesson & Sköldberg, 2008)

2.5 Qualitative and Quantitative Methods

Qualitative research focuses on open, ambiguous empirics. A qualitative research has a starting point from the studied objects perspective, while quantitative research is based on the investigators perception of how the object should be characterized from a set of dimensions. There has been debate about qualitative versus quantitative methods. Though the argument now seems to have settled to a consensus that the choice of method has to be related to the research problem and the nature of the studied object. (Alvesson & Sköldberg, 2008)

2.6 Validity and Reliability

The quality of case study research is often established through test of validity and reliability. In social research these quality tests are commonly divided into construct validity, internal and external validity and finally reliability. (Yin, 1994)

Construct Validity

Construct validity is concerned to see whether the right operational measures are being used for the concepts being studied. This can be problematic in case study research, since there easily can be subjective judgments when collecting data. To avoid subjectivity the operational measures should be set in relations to the original objectives of the research. (Yin, 1994)

Internal Validity

Internal validity is concerned with the cause-and-effect relationships, and whether they are described fully, without leaving out any effecting aspects. The Internal validity test is only applicable to Explanatory cases. (Yin, 1994)

External Validity

External validity makes the case studies able to draw generalizations from findings. The difficulty of making general assumptions in a case study has been criticized and is the biggest concern about the case study method. (Yin, 1994)

Reliability

Reliability tests if another investigator that goes through all the same steps as described by the original investigator arrives at the same findings and conclusions. The goal of this test is to minimize errors and biases. (Yin, 1994)

2.7 Methodology of the Study

The chosen method for the study at ST-Ericsson was a combination of a case study and clinical research. For the understanding of all the cause-and-effect relationships in the supply chain and the organization at large, the case study approach was used. The situational context of ST-Ericsson was of high complexity and quite unique, making it suitable for a case study. The employees at the Lund site also needed better understanding and insight of the supply chain process, both within and outside the company, which reinforces the choice of a case study approach.

However, there was also an urgent need for a performance measurement system and a reporting system for the supply chain and the development of a prototype was placed upon the author of this dissertation. Since there was expectation on a functioning prototype the research needed corrective actions throughout the timeframe of the study, which led to the choice of a clinical research for this part. ST-Ericsson offered a unique opportunity to study how a high-level performance measurement system can be developed in a time of rapid change in a post merger state. In order to seize this opportunity the clinical method needed to be adapted, meaning that a risk of biases of the researcher and limiting reliability followed. The need for this PMS-system was expressed by ST-Ericsson, hence the choice of a clinical study and not an action research, otherwise the methodology followed the basics of action research. The work with the PMS was carried out in a project group, with employees at ST-Ericsson, which adds up to a research that is practical, participative and integrated with change.

The developed system was tested as far as possible, though time was a restrictive factor. The time constraint limited the development of the system to a first prototype, which if implemented needs to be continuous improved and tested for the validation of the PMS. The research was also agile and altered along the way to fulfill the requirements of both the company and the changing environment. It would be a stretch to say that this was an iterative process, but the study went fourth and back continuously between the objectives and the updated requirements, checking their compliance.

A qualitative method was used in the case study of the company in order to capture different aspects of the supply chain. Since one of the aims of the study was to gain a greater understanding of the supply chain, a quantitative approach with a preset comprehension would limit the analysis. A qualitative analysis allowed the analysis to go in parallel with the empiric findings and the development of the PMS-system.

Though this study was qualitative the aim was that it would results in a system, which is based on a quantitative approach for the analysis of the supply chain. The qualitative method was used to develop the parameters for the quantification of the studied object.

As the choice of a qualitative method indicates, the study was also an abductive approach. The study started with a theoretical review to identify similar cases and best practices. The theoretical review was followed by empirical gatherings, to be able to draw conclusions with the theoretical background. From the first analysis, the theory was revised and another round of empiric gathered, this time with the purpose to test the theoretical background and the conclusion from the first analysis. In this way the findings was validated in an abductive manner.

For the empirics both primary and secondary sources were gathered. The primary sources of information were mostly gathered through semi-structured interviews, workshops and observations at the Lund site of ST-Ericsson. The secondary sources were mostly company documents and reports made for various purposes in the organization. All the documents used was thoroughly investigated and checked by employees in the project group for validation of the content.

With this wide variety of both primary and secondary sources, gathered through different methods, the construct validity was ensured. In the continuous work there were control against the employees with the greatest knowledge in the organization, and the work progress was corrected and changed in accordance to their expertise to guarantee the internal validity.

The external validity was hard to obtain, but on the other hand this study was of the exploratory and descriptive kind, which do not have the same requirements on external validity as an explanatory study. Benchmarking was used to some extent to gain better external validity. There was benchmarks done against other divisions and functions within ST-Ericsson, and there was a review of benchmarks done from other sources, such as the Supply Chain Counsil (SCC). To some extent the benchmark within the organization was done by ST-Ericsson employees from the project group, which in a sense is a triangulation since the project group members benchmark their view, and in the end passes it on to the author. The author's research findings were validated through the project group members and other knowledgeable employees within the organization.

The reliability in the study was hard to ensure in a satisfactory manner. The confidentiality issues hinder the publishing of documentations, numerical data. Even without the confidentiality the settings of the study is impossible to duplicate. With a clinical method in this unique situation the aim was that the research resulted in new valuable research findings that would not be gained otherwise.

3 Theoretical Framework

This chapter provides a theoretical framework which is used during the empirical gathering but primarily for the analysis that leads to the conclusions of the study.

3.1 Supply Chain Management

The term *supply chain* is used in literature to describe the network of inter and outer company relations, used in order to bring a product or service to the market. Defining the supply chain depends on where the focal point of the chain is set and the link can be visualized as below, from standpoint of what is here referred to as the organization (ISO 16949, 2002):

Supplier ⟶ **Organization** ⟶ **Customer**

From the theory of supply chains the term *supply chain management* (SCM) was introduced in the 1980's, and gained a widespread use in the 1990's. The term comprised several management fields, for example purchasing and supply, logistics and transportation, operation management, marketing, organizational theory, management information system and strategic management (Chen & Paulraj, 2003). A common definition of SCM is that the supply chain encompasses all activities associated with the flow and transformation of goods from raw materials stage (extraction), through to the end user; and SCM is the integration of these activities through improved supply chain relationships (Seuring, 2005).

Even though the field of SCM is comprised of many fields, the term is closely related to logistics and maybe more so to logistics management. The terms are often being used synonymous. Mattsson (2007) states that logistics encompasses the problem areas of planning, developing, organizing, coordinating and controlling the material flow. The difference between the two terms is that SCM gives a comprehensive picture of the supply chain and all its links, not only from one company's perspective. Further, the benefits for all the members of the chain are considered and the flow of services and information are included (Mattsson, 2004).

An SCM perspective on business processes usally create performance improvements through reduction in total cost and inventories by forming strategic alliances and increasing information sharing with all the channel members (Gunasekaran, Patel, & McGaughey, 2004). The fact that SCM tries to construct a relationship between actors in the supply chain to provide mutual benefits, reflects a decentralized, horisontal and non-power based structural link among the supply chain members (Chen & Paulraj, 2003). This has made the field of SCM represents one of the modern business management by recognizing that individual business no longer compete as soley autonomous entities but rather as supply chains (Chen & Paulraj, 2003).

3.2 Process Management

Traditionally producing and distributing companies have been organized by function (Mattsson, 2004). In the modern and more dynamic environment, the functional organization has proven to have a number of flaws. In order to tackle these problems and get an organization in line with its business environment, companies have to a larger extent adapted a process view of their business.

The motive behind a functional oriented organization has been that efficiency rises through specialization. But combining a number of specialized functions does not ensure efficiency for the entire company. Another principle behind functional organizations has been to divide organizations by input and resources. For example, purchasing staff as a resource are grouped together to handle the inputs to the production process. This principal is not as intuitive as the former, since the company primarily gets its revenue from the output in form of products. From this point of view, it would mean that the company rather would be organized according to the output, which is the products and material flow in the organization. (Mattsson, 2004)

A process view of the organization aims to get alignement with the customers' needs and the product and information flow through the organization. The process approach emphasis a more comprehensive view of the company; from a need expressed by the customer, through all the activities to the satisfaction of the customer needs (Ljungberg & Larsson, 2001).

In order to describe an organization in terms of processes, a definition of a process is necessary. There are numerous ways to describe a process and many definitions have been presented. ISO 9000 (2000) defines the term process as:

> *"Set of interrelated or interacting activities which transforms input into output.*
>
> *Note 1: Inputs to a process are generally outputs of other processes.*
> *Note 2: Process in an organization are generally planned and carried out under controlled condition to add value."*

In order to add value processes uses information and resources to transform input into output (Ljungberg & Larsson, 2001) and as the definition indicates the purpose of a process is to add value. The purpose of a process approach is to eliminate non-value adding activities, so solely those activities that do add value are being used. This might seem obvious but there are many non-value adding activities in corporations (Mattsson, 2004) and through a process approach, organizaitons can significantly cut costs and increase performance and quality, by a more efficient use of resources (Hammer, 2007).

Teamwork is key in organizations with a process approach, since a process transcend functional barriers and even company borders. In this way a process view of the organization encompasses more activities and often of greater complexity (Ljungberg & Larsson, 2001). These aspects are especially true for the field of supply chain management. The problem of getting an integrated solution for customers and the delivering company, goes back to the functional organization, where separate companies in the supply chain can be seen as individual functions, trying to maximize their gain. With a process approach it is necessary for the organization to break through these problems to get the integrated colaboration over company lines that the supply chain concept aims to do (Mattsson, 2004).

In the process approach of an organization, the function has been transformed to competence and resource centers (Ljungberg & Larsson, 2001). Resource owners or line managers contributes with resources to the processes and a process owner has the responsiblity that the process is running smoothly (Ljungberg & Larsson, 2001). The processes should be managed as a system by creating and understanding the processes networks, their sequences and interactions (ISO 9004, 2009). The network can be described by a process map as a result of a process mapping.

3.2.1 Process Mapping

The first step towards a process approach of the organization is to map the processes within the company. Processes are specific to companies and vary depending on the type, size and the level of maturity of the organization in question. The second step is to determine all activities within each process, and adapt them to the size and the distinctive features of the organization (ISO 9004, 2009). Organizations often have been allowed to become more rampant and consequently harder to grasp. Often processes that have been developed logically have over the course of time been changed, often from an internal and functional limited perspective. With process mapping the link between the resources and the activities becomes more evident. (Ljungberg & Larsson, 2001)

Processes are normally divided into *main processes, supporting processes* and *managing processes*. The main processes are the most important processes for the organization, i.e. without any of the main processes the business stops working. The main process can also be defined as the processes that add value to the customer. The supporting processes purpose are to sustain the main processes and enable them to work properly; they do not add any value to the customer on their own, instead they are valued by their ability to support the main processes. The managing processes are managing and coordinating the main processes. Identifying the main processes is the first step to create a base for process oriented business development. (Ljungberg & Larsson, 2001)

From the three types of processes an abstraction of the organization can be acheived. The traditional organizational charts is still an artifact from the functional organization and does not give a true picture of the modern organization. The organizational chart shows more or less how the resources are divided and how the reporting path and power structure are built up. It does not show what really is performed and how collaboration works to serve the customers. The main processes show how the customers needs are fulfilled, and the companies employees roles becomes more clear and recognizable in regard to the customers' needs. (Ljungberg & Larsson, 2001)

Processes are often represented as an arrow, with input that comes in and output that comes out, as shown in *figure 3* below. The input and the output can be either physical producs, documents or actions from decisions taken by individuals. The activities in the process require resources and there is a continous exchange of information between the process and its environment. A process can be broken down either to activities or sub-processes, or to a part of a higher level process.

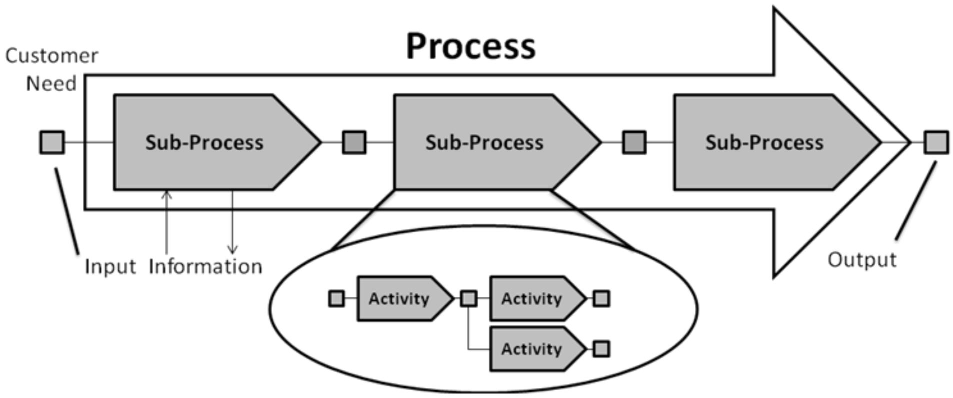

Figure 3. Process with sub-processes and activities (adaption from Ljungberg & Larsson, 2001, p 193)

There are different methodologies for conducting a process mapping.

Walk through is when the conductor of the process mapping physically follows the process flow and interviews the responsible person for each activity. (Ljungberg & Larsson, 2001)

A virtual walk through is done by gathering several representatives from the process and letting every representative explain their part of the process. (Ljungberg & Larsson, 2001)

Process design is used when there is no formal process to map, where individuals have had the ability to create his or her own path, which is often valid for smaller processes. The way to conduct this is to create a common picture of the process. (Ljungberg & Larsson, 2001)

A sub-process is often a part of a complex network of several processes. Mapping according to one of the mentioned methods can help make processes that have been kept invisible in the functional organization, visible. After the mapping the non-value adding activities can start being removed and the unnecessary snaky processes can be streamlined to meet the customers needs (Ljungberg & Larsson, 2001). In order to ensure that the processes and practices stay effective and efficient, the organization should have continuous practices that monitor, measure, analyze, review and report the performance of the processes for the sustainable effect of the process approach (ISO 9004, 2009).

3.3 Performance Measurement Systems

In the latest decades there has been a growing interest for *performance measurement systems* (PMS) and today it has been turned into a subset of the field of operational management. Companies have seen a growing demand for multi-dimensional measurements to evaluate their business. Traditional accounting has been criticized for encouraging short-term decision-making and its focus on external requirements makes it inapplicability to modern manufacturing techniques. (Bourn et al, 2003)

Measuring the organization does not only provide the ability to assess the performance of the organization. Deciding what to measure, how to measure and what the targets will be, are all acts which influence individuals and groups within the organization. Hence, performance measurement is an integrated part of the management planning and control systems. There is a wide range of performance measurement systems, based on multi-dimensional measures, developed and described in management literature, but the underlying basis for them can be very different. The differences lay in the procedure for how the measures are selected and also how the system is implemented. Below follows three types of procedures for a performance measurement system. (Bourn et al, 2003)

The need led procedure is a top-down approach where the customer, business and stakeholders needs are identified and used for the development of the performance measurments. The business progress is monitored against these sets of needs in the PMS. (Bourn et al, 2003)

The audit led procedure is more of a bottoms-up approach where existing performance measurements are auditied. The gathered information are used to challenge the status quo and used as a basis to improve the existing measures in a PMS. (Bourn et al, 2003)

The model led procedure uses a theoretical model of the organization for the design of the PMS. (Bourn et al, 2003)

3.3.1 Performance Measurement

Performance measurement can be defined as the process of quantifying the efficiency and effectiveness of actions taken in the organization. It is always necessary with a reference framework against which the efficiency and effectiveness can be judged and therefore a performance measurement is not relevant in isolation. In the past performance measurements have been criticized for judging performance against the wrong frame of reference. Today there is a widespread support for the belief that performance measurement and PMS should be developed from strategy. (Bourn et al, 2003)

The term *key performance indicator* is often used for the strategic performance measurement. The term has been widely adopted by practitioners. Parmenter (2007) states that there has been an growing missuse of the term and the meaning of it has been undermined. Permenter argues that performance measures need to be divided in three: *key result indicators* (KRI), *performance indicators* (PI) and *key performance indicators* (KPI).

Key Result Indicator - KRIs consists of generic measures that is aggregated from many actions. Typical KRIs are for example customer satisfaction or return on working capital. These types of measures tells the general direction of the company, but not what is needed to do to improve the results. KRIs are not involved in the day-to-day management, however it is appropriate to present for the board. (Parmenter, 2007)

Performance Indicator - Performance indicators are what build up the KRIs and consists of what is really being measured, but unlike the KPIs they are not key for the succes of the company. Among numerous of PIs, lays the KPIs. (Parmenter, 2007)

Key Performance Indicator - Parmenter (2007) define key performance indicators as representing **"**a set of measures focusing on those aspects of the organizational performance that are the most critical for the current and future success of the organization". Characteristics common in KPIs are that they often are non-financial measures which are measured continuously, daily or even with higher frequency. KPIs ties responsibility to induviduals or teams and should trigger corrective actions. Since the KPI's are defined as key for the organization, improvement would have a great positive impact. (Parmenter, 2007)

3.3.2 The Balanced Scorecard

Kaplan and Norton (1996) developed a management system called the Balanced Scorecard (BSC), which is a multi-dimensional, need led performance measurement system. The BSC is designed to align assets and capabilities to the corporate strategy. The framework builds on financial measures, but it extends the traditional accounting model to include other measures to capture other aspects of the organization's activities. Kaplan and Norton have a view on organizational performance from four perspectives: *financial, customer*, *internal business process* and *learning and growth perspective*, which make up the basis of the scorecard framework, see *figure 4*. The objectives and measures of the scorecard are derived from an organization's vision and strategy. With this setup the BSC clearly reveals the value drivers for long term financial and competitive advantage. (Kaplan & Norton, 1996)

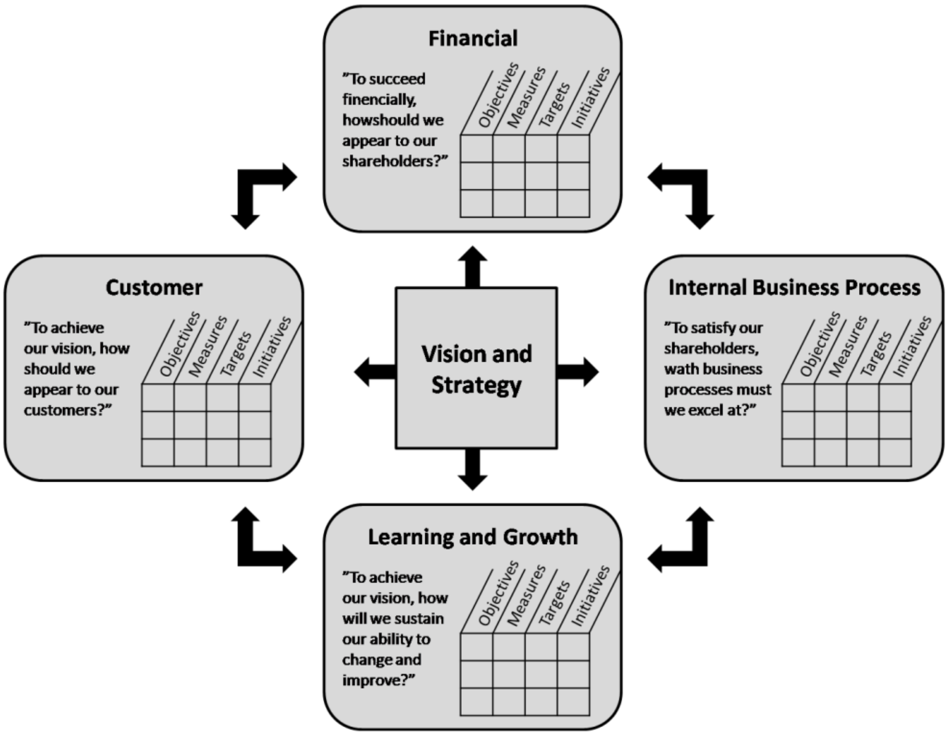

Figure 4. The Balanced Scorecard Framework (adaption from Kaplan & Norton, 1996, p 9)

Financial Perspective - The balanced scorecard starts off with the financial measures, which describes the tangible outcomes from the strategy. Traditional financial measures like return on investment and shareholder value are lag indicators that show whether the strategy is succeeding or failing. (Kaplan & Norton, 2004)

Customer Perspective - The customer perspective describes the value proposition (Kaplan & Norton, 2004), that managers identify through targeting the customers and market segments where the company will be able to compete (Kaplan & Norton, 1996). The customer perspective measurements are often generic measures such as customer satisfaction and customer retention (Kaplan & Norton, 1996). What customers' value is of great difference from industry to industry and always changing over time, so consistent alignment of actions and capabilities with the customer value proposition is the core of strategic execution (Kaplan & Norton, 2004).

Internal Business Process Perspective - The internal business process refers to the value chain of a company, which encompasses the innovation, the operations and the postsales service processes in a company. In order for the organization to create the value that the customers inquire, the few critical processes that have the greatest impact on strategy need to be identified (Kaplan & Norton, 2004). Traditional performance measurement systems have been focusing on improving existing departments and responsibility centers (Kaplan & Norton, 1996). With the BSC's top-down approach, entirely new business processes can be revealed (Kaplan & Norton, 1996).

Learning and Growth Perspective - The learning and growth perspective identifies the intangible assets most important to the strategy. In this perspective the human capital, the systems used or information capital and the corporate climate are all required to support the value-creating internal processes. These assets need to be compiled and aligned to the critical internal processes. (Kaplan & Norton, 1996)

The logic behind these perspectives can be drawn backwards from the financial measures. Financial targets can only be achieved through satisfied customers and the customer value proposition describes how the customers will be satisfied. The internal processes describe how the organization will create value to the customer. Intangible assets support the internal processes and provide the foundation for strategy alignment. In this way the BSC clearly can describe and visualize the cause and effect relationship of tangible and intangible resources and capabilities through to financial results. (Kaplan & Norton, 2004)

The BSC maps the strategy and forces the organization to clarify the logic of how it will create value and from whom. All processes in the organization should be managed well, but the few strategic processes must receive special attention and focus since these create the differentiation of the strategy. The art of strategy is to identify and excel at the critical few processes that are the most important to the customer value proposition. In this way the BSC framework is not only a performance measurement system, but also a strategic management tool. (Kaplan & Norton, 2004)

3.3.3 Supply Chain Performance Measurement

SCM practices have shown that efforts focused on carefully managing the supply chain can produce financial benefits for all participating firms in the supply chain. Improved performance does not come automatically, hence the importance to assess performance in SCM. (Gunasekaran, Patel & McGayghey, 2004)

Implementing a supply chain performance measurement system for the supply chain always starts off with mapping of main processes within the supply chain, to get higher granularity of the measures. The major processes can also be divided into levels, with corresponding metrics, to clarify appropriate levels of management authority and responsibility. One differentiation of levels is strategic, tactical and operational level. (Gunasekaran, Patel & McGayghey, 2004)

3.3.4 Factual Approach to Decision Making

One of the key benefits from implementing a PMS in an organization is the ability to make informed decisions, reinforced by data. Taking decisions based on analysis of data and information is called a *factual approach to decision making*. Applying this approach can increase ability to demonstrate the effectiveness of past decisions through reference to factual records and increase the ability to review, challenge and change opinions and decisions. Since it is hard to stay blind to raw data it will lead to correct taken decisions. (ISO 9004, 2009)

3.4 SCOR-Model

The Supply Chain Council is a consortium of close to 1000 members of companies that have developed a framework for supply chain systems, called the Supply Chain Operations Reference model (SCOR). SCOR is a process reference model for supply chain management, constructed with the basis of a need led procedure. The model spans from the supplier's supplier to the customer's customer as seen in *figure 5* below.

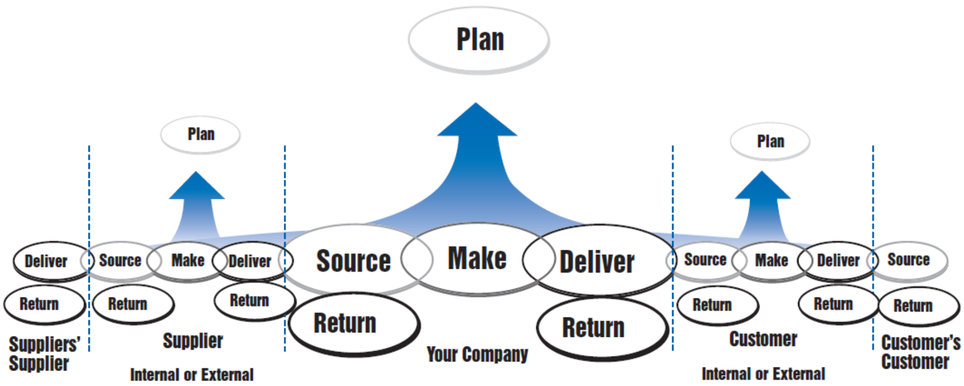

Figure 5. SCOR span. (Supply Chain Council, 2008)

SCOR aims to take on an SCM perspective by providing a standardized language, standardized metrics, and common business practices which can be benchmarked between companies in the SCOR network. (Supply Chain Council, 2010)

The SCOR-model divides supply chain processes into five subtypes of processes: plan, source, make, deliver and return. These five processes are called the *level 1* processes. Each level 1 process consist of a set of *level 2* processes, for example a sourcing process can be one of the three level 2 processes: source stocked product, source make-to-order product or source engineer-to-order product. The level 2 processes can further be broken down to a third level.

3.4.1 Implementing the SCOR Methodology (Harmon & Business Process Trends, 2003)

To set up a supply chain based on SCOR, the Supply Chain Council has established a SCOR Project Roadmap, which can be seen as a methodology. Paul Harmon & Business Process Trends (2003) have extended this methodology in order for using companies to define the existing supply chain in line with the SCOR methodology. Paul Harmon suggests six phases of implementing the SCOR methodology:

0. *Review Corporate Strategy*
I. *Define the Supply Chain Process*
II. *Determine the Performance of the Existing Supply Chain*
III. *Establish the Supply Chain Strategy, Goals and Priorities*
IV. *Redesign the Supply Chain as Needed*
V. *Enable Redesign and Implement.*

0. Review Corporate Strategy

This is not much of a phase as it is a commitment and a decision to undertake a supply chain strategy review to improve the existing supply chain performance. If the company is new to SCOR it is necessary to work through phase I and II.

I. Define the Supply Chain Process

The first phase is an analysis of the existing supply chain. SCOR provides a common vocabulary and a notion system for defining the major processes, starting with the level 1 processes. Once the level 1 processes are mapped, the analysis can dig deeper into the second level. When defining the supply chain process it is often sufficient to map down to the second level of processes, but if there still is further insecurities, mapping the third level for some processes can be necessary.

II. Determine the Performance of the Existing Supply Chain

Starting at phase II, when the processes are mapped, the existing supply chain can start getting measures to evaluate the existing performance.

SCOR has defined five generic performance attributes and three levels of measures that can be used. These attributes is divided into an internal and a customer faced perspective, see *Table 1*.

Using the SCOR generic measures enables the company to benchmark the supply chain performance to the relevant industry. Once some historical data is gathered the management needs to decide how the supply chain is to be changed.

Table 1. SCOR Performance attributes (Paul Harmon & Business Process Trends, 2003, p 8)

	Performance Attribute	Performance Attribute Definition	Level 1 Metric
Customer Facing	Reliability	The supply chains performance in delivering: the correct product, to the correct place, at the correct time, in the correct condition, in the correct quantity, with correct documentation, to the correct customer.	Delivery Performance
			Fill Rates
			Perfect Order Fulfillment
	Responsiveness	The velocity at which a supply chain provides products to its customers.	Order Fulfillment Lead Times
	Flexibility	The agility of a supply chain in responding to marketplace changes.	Supply Chain Response Time
			Production Flexibility
Internal Facing	Cost	The cost associated with operating the supply chain	Cost of Gods Sold
			Total SCM Costs
			Value-Added Productivity
	Assets	The effectiveness of an organization in managing assets to support demand satisfaction. This includes the management of all assets: fixed and working capital.	Cash-to-Cash Cycle Time
			Inventory Days of Supply
			Asset Turns

III. Establish the Supply Chain Strategy, Goals and Priorities

The SCOR attributes provide a good understanding of the strength and the weakness of the supply chain. From phase 0 an organizational plan and the corporate strategy are established, that now can be compared with the supply chain performance to set a supply chain strategy.

From the performance attributes SCOR suggest that the company decides where the supply chain should be superior, have advantage, parity or be below industry average. The company’s supply chain cannot be expected to be superior in every category, but it should be very good in at least one or two. The categories the company chooses to put their efforts in to becoming superior should reflect the supply chain strategy, which relates to the corporate strategy. With the competition model presented in *Table 2* the company can get a picture of the As-Is situation and what is necessary to reach the To-Be situation.

Table 2. Competition Model for the supply chain performance (Paul Harmon & Business Process Trends, 2003, p 10)

Competition Model		
Performance attributes	**Performance versus Competition**	
	As-Is	**To-Be**
Reliability		
Responsiveness		
Flexibility		
Costs		
Assets		

X Superior **O** Average **o** Parity

IV. Redesign the Supply Chain as Needed
SCOR provides a number of tools for redesigning the supply chain. By examining the sub-processes down to the third level, the company can benchmark the best practices within the processes on a detailed level.

V. Enable Redesign and Implement
The last phase is enabling and implementing the supply chain strategy, using software and human performance improving techniques. Then data must be gathered to determine if the supply chain is meeting the set targets.

3.5 Theoretical Summery
From the theory on supply chain management, process management and performance measurement, SCOR provides a framework on how to organize the supply chain according to a deliberate strategy which draws back from the customer. The balanced scorecard set the SCOR-model in an outside-in context of the whole organizations activities. The BSC explains how the separate parts of the organization comes together to provide a value proposition to the customer, expressed from the corporate vision and strategy. This is done by using a performance measurement system that measures the performance of the different perspectives. The internal perspective advocates measuring the value chain according to a process view and the supply chain is a subset of the value chain.

All theories stress the importance of measuring the performance to enable improvements and alignment with strategies. The SCOR methodology enables an implementation of a supply chain performance measurement-system.

4 Introduction to ST-Ericsson's Supply Chain

The supply chain in the semiconductor industry is known to be very complex. Therefore this chapter will provide a background to the production processes together with background on supply chain business models.

4.1 Production Process

The hardware of a mobile phone platform is composed of a set of integrated circuits, the core ones being part of the chipset. The chipset are composed of *applications specific integrated circuits* (ASIC) or *application specific standard products* (ASSP), typically split up into radio frequencer, baseband and power management devices/chips. All of these are silicon chips (or die), which are encapsulated with a protecting compound material. The production up until the silicon die is called Front-end production and encapsulating and testing the die is called Back-end production. The whole production process can be divided in four production steps, two in Front-end and two in Back-end: Diffusion, Electrical Wafer Sort (EWS), Assembly and Test & Finishing (see *figure 6*). All these processes can be done in different locations, and in ST-Ericsson's case are located worldwide. This allows for several Back-end production facilities that can serve different markets.

Wafer production (or Diffusion) is production of silicon wafers. Silicon cylinders are sliced into wafers, which is a silicon disc much like an LP-disc in size. 25 wafers is one lot in production and the smallest amount to start production. Through a series of production steps the circuits is created on the surface of the wafer. Depending on the product specifications and the production technology, each wafer consists of 1000-5000 dice and every die consist of up to 1 billion transistors. Hence, the lead-time for Diffusion is very long, everything from 8-20 weeks. In the Electrical wafer sort, chips on the wafer are tested and then sawed into dice. The lead-time for EWS is a few days up to one week with transfers. In the Assembly process the dice is encapsulated and in the Test & Finish process - tested again and prepared for transport and delivery with final marking. The whole Back-end process lead-time is about 10-14 days.

The total lead-time for the hardware production is very long, depending on the type of product, process technology and the manufacturing facilities the lead-time can be up to half a year, which of the greatest part of the time is spent in the Front-end production. Every step of the production has its own identity and for every possible production route in different plant creates unique products. This means that there is not a single code defining what is sold to the customer, there is possibly 20 codes defining products in every production step belonging to the same commercial product.

Since ST-Ericsson is fabless, it does not have its own production, which instead is handled by ST or external production foundries that ST or ST-Ericsson outsources to. ST-Ericsson naturally uses ST's supply chain infrastructure to a great extent to take advantage of scale benefits and competences in SCM.

4.2 Supply Chain Business Model

ST-Ericsson has several different supply chain business models towards its customers. Two of the most common, which are used by L3M, is presented in *figure 6*.

The first model is a traditional order system, where the customer places orders and ST-Ericsson delivers to the customer in accordance with a committed delivery date (CD). Order lead-time is 4 to 16 weeks. The order lead-time can be different from customer to customer, depending on the contract.

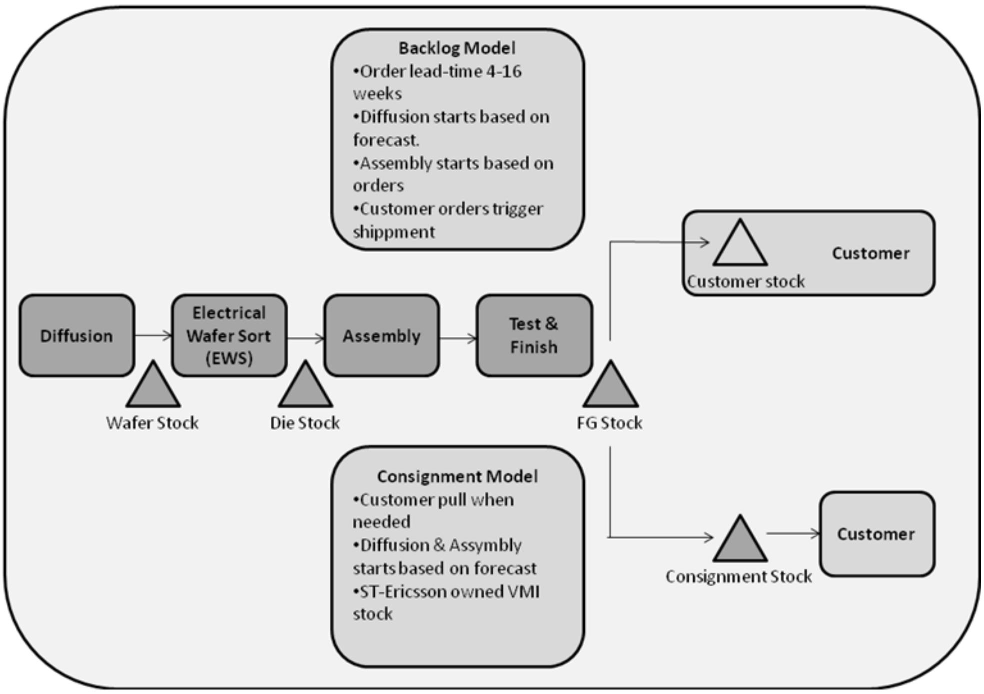

Figure 6. Production steps and delivery according to the two supply chain business models (adaption from internal document)

The second model is a consignment model, where ST-Ericsson has a *vendor managed inventory* (VMI) placed at the customer. The customer takes the products from the stock at any time, which is registered automatically by ST-

Ericsson and the customer is invoiced. ST-Ericsson is obligated to keep the stock between a minimum and maximum level.

Since the lead-time for production is so long ST-Ericsson has to start production based on forecasts. Generally Back-end production is started when a real order is placed. To trigger production ST-Ericsson uses internal orders, which are replaced by the real orders once they are placed.

5 Empirical Framework

This chapter presents the empirics gathered during the 5 months of the study at ST-Ericsson. The empirics consists of the information belonging to the supply chain processes and performance measurements within ST-Ericsson that led up to the development of the Supply Chain Cockpit, for which the empirics are presented last in the chapter.

According to an exploratory case study methodology and the theory presented in chapter 3, the supply chain was mapped. Once the supply chain was mapped and performance measurements were identified, the development of the prototype started.

This development work was done according to a clinical research method, but the work flow followed the methodology presented in the theoretical framework, that is based on SCOR. Therefore the empirics and the analysis follow the steps presented in *section 3.4.1 review of the corporate strategy* and *define the supply chain process* are presented in this chapter, while *determine the performance of the existing supply chain* and *establish the supply chain strategy, goals and priorities* are presented in the analysis. The last two steps of the SCOR methodology was out of this research's scope and is not presented here. If needed, the two last steps *redesign the supply chain* and *enable redesign and implement* changes was left for L3M to carry out themselves in the future.

Besides the two first steps of the SCOR methodology, the existing performance measurements found in ST-Ericsson and the empirics for the evaluation of the supply chain cockpit are presented separate last in this chapter.

5.1 Review of Corporate Strategy

The division L3M was created based on a lot of legacy from former EMP. EMP was a company delivering software, but after the merger of EMP and ST-NXP, L3M was created to be a hardware delivering division. Even though the division was set up in the supply chain of ST, the employees in L3M had little knowledge of the supply chain and a complete supply chain strategy review was needed to be done, based on the corporate strategy and targets.

ST-Ericsson's vision is to be the global leader within wireless technologies, which was the guideline for the corporate strategy. Target was placed on L3M which was broken down to L3M Operations level, but there was no clear supply chain strategy specific for L3M, at the time of the study.

5.2 Define the Supply Chain Process

ST-Ericsson has a process approach of the organization and is controlled on that basis. The supply chain process is one of the four main processes in ST-Ericsson, see *Figure 7*. ST-Ericsson is in a high volume business and delivers several billons of components every year; hence the significance of this process is extensive. After the integration of EMP and ST-NXP during the fall of 2009 and the spring of 2010, the supply chain management processes was mapped for the new company by the central function for supply chain management. Together with a project group, the author conducted a mapping of the supply chain parallel with the work done by the central SCM function. The mapping was done at the division with L3M in focal point and with a more high-level perspective that does not drill down to details. The mapping was done as a virtual walk through in a series of workshops with the project group and interviews with knowledgeable employees in the processes.

The purpose of this process mapping was mainly to understand what the L3M responsibilities comprise of, and what is being done by whom, to enable for developing a Supply Chain Cockpit. As described in the background, the supply chain process is new to L3M, and was needed to be better understood. Therefore a part of the purpose was to find and understand what is being measured today and what can be measured.

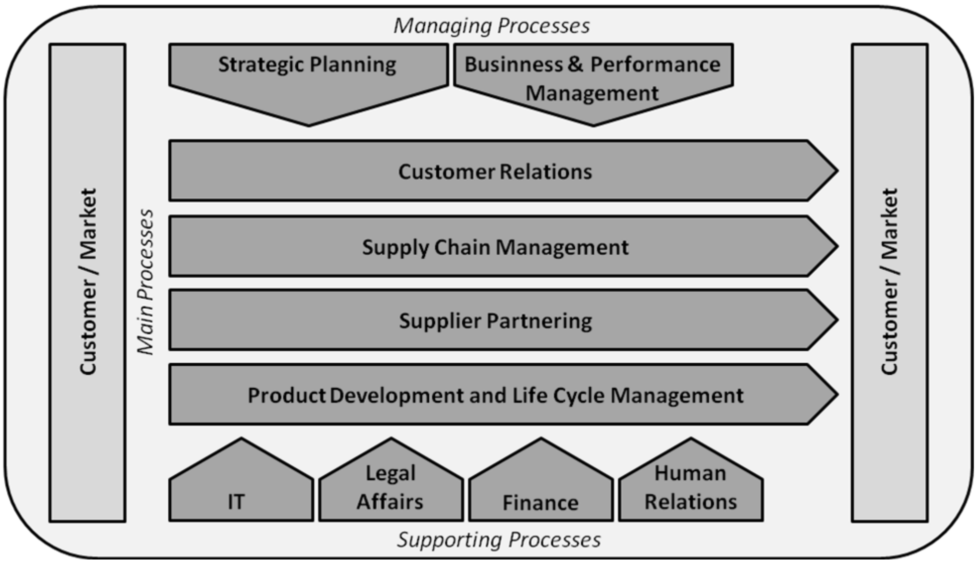

Figure 7. ST-Ericsson Process Map (Adaption of internal document, 2010)

5.2.1 Process Identification with SCOR

SCOR was used as a framework to identify the major sub-processes within the supply chain process, relevant for L3M. With the processes Plan, Source, Make, Deliver and Return in mind a subset of processes was identified in ST-Ericsson's supply chain. *Demand management, Capacity management* and *Manufacturing planning* were recognized as Plan processes. Most of the sourcing of activities are handled centrally by ST-Ericsson and was regarded as outside of L3M's scope of interest at the time of the research. Inventory management and Manufacturing was recognized as Make processes and one Delivery process was identified. Lastly, a Return or Quality conformance process was identified. *Figure 8* provides a schematic picture of the high-level process map of L3M's supply chain.

The sub-processes are described in detail below, though first a short presentation is needed. *Demand management* is the process that compiles the demand forecast and billing plan for L3M and is being done in collaboration between central sales and L3M. *Capacity management* is the process of allocating and planning capacity for production and is done by 3GP for L3M, and ST-Ericsson central. *Manufacturing planning* is a matching of demand and supply to trigger production, which is done by 3GP for L3M. The *manufacturing* of L3M's products is done by ST or external foundries. *Inventory management* is handled mainly by 3GP for L3M to secure that inventory levels are in line with customer requirements and company targets. *Delivery* is handled by the external foundries logistics functions. *Return* or quality problems are handled by a central quality function in ST-Ericsson.

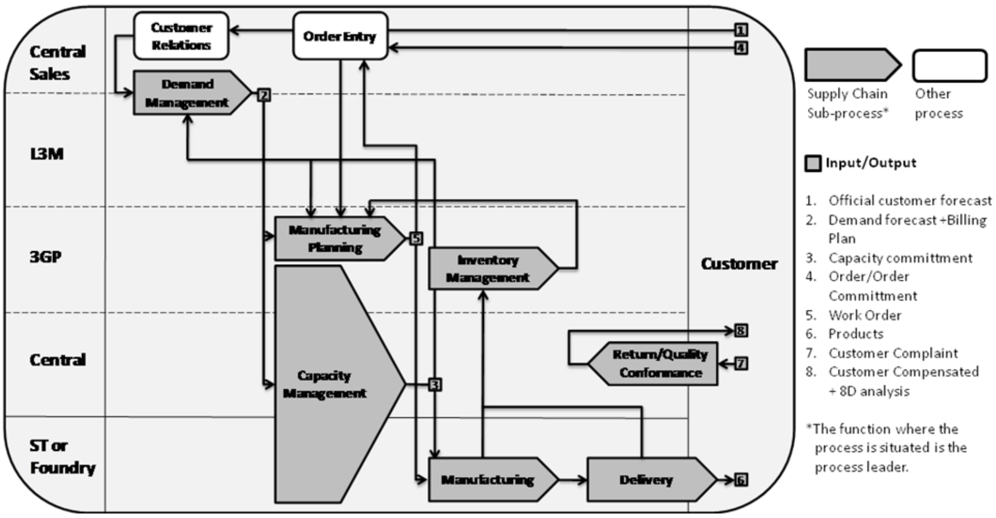

Figure 8. L3M's SCM process map

5.2.2 Demand Management

There are three sub-processes for the demand management. Every sub-process has a corresponding demand and billing plan associated with it, which is the output of the processes. There is a 5 year, a 2 year and an 1 year plan and the differences of the plans are their time frames and their frequency. The 5 year plan is made once a year and the 2 year plan are made three times per year and are used for securing capacity on the long and medium term. The 1 year plan, called the Sales and operation plan (S&OP), is used to allocate capacity on the short term and is done every month. The 5 year plan is out of this dissertation's scope and will not further be discussed.

Sales and Operation Plan

The S&OP is a demand forecast and a billing plan for 12 months ahead. The forecast is constructed by a bottoms-up approach, where the demand for each customer is forecasted based on platform volumes. The billing plan is then constructed by estimating the revenue associated with the forecasted demand. The demand forecast is classified in three risk classifications. These three scenarios are an estimate of the likelihood that the demand will be reached.

The demand data is based on the commercial product and once the demand is sent on to the planning and capacity processes the data is converted into data based on the different steps in production. There is no tracking of the demanded products in the rest of the supply chain, meaning that the products in the production process cannot be linked to specific demand data.

The demand forecast is compiled in collaboration with L3M and Central Sales. Within Central Sales there are customer units, with the sales personal facing the customers. The customer unit receives an official forecast of the customers demand, based upon platform volumes, and makes judgments on the information's reliability, corrects the demand accordingly and in some cases fabricates the demand when customer data is missing. The customer units have an one year focus on the demand.

The responsibility for the demand from L3M's part lays on Product Marketing and Operations. Product Marketing is responsible for marketing L3M products, which can be described as the back-office of central sales in the divisions. The customer units are responsible for selling the division's products, but product marketers are always involved as well to speak for the division, which means that the product marketers also have a strong customer interface and customer knowledge. The product marketers have a two year focus for the demand management process. Product marketers also have more knowledge on product introduction plans than the customer units.

Operations responsibility is to make supply chain related judgments on the demand forecast and handle the administrative part of putting all the information together to an S&OP document. Operations is also responsible for comparing the forecast with the actual historical data, to set the forecast in perspective to actual outcomes.

In monthly meetings L3M Operations and the division's product marketers discuss with the customer units the demand forecast. A consensus will try to be reached but in case of differences in opinion L3M often has the last say, since they own the plan.

2 Year Plan

The 2 year plan is to a large extent done in a similar way as the S&OP. The responsibility for this plan lies more on the product marketers since they have a longer time frame, than the customer units. The central function CTO is also involved in the 2 year plan and makes market analysis that is compared with the bottoms-up demand. This aspect makes the 2 year plan a combination of a bottoms-up and a top-down approach.

5.2.3 Capacity Management

The S&OP goes into the capacity allocating process. The capacity need is compiled and consolidated for all business units on a top-level in ST-Ericsson. 3GP compiles their capacity need together with L3Ms need. ST-Ericsson's capacity need is then allocated and distributed among the business units. The process has a long lead-time, before a response is returned to the demand management and manufacturing planning processes, with the committed capacity. The response is divided into one committed capacity plan for Front-end and one for Back-end.

5.2.4 Manufacturing Planning

3GP plan the production for L3M's products. The planners continuously match the actual demand with the supply. The demand comes either from real orders or automatic generated order from the VMI stocks. For real orders a commitment to the customer is sent to Central Sales. This is done automatically or manually by the planner, based on a classification set by the planner.

The demand update is matched against the stock levels, work in progress and goods in transit, which is the data the planner makes manufacturing orders based upon. Real orders that are confirmed to the customers typically result in the start of production in the Assembly. Diffusion for these products is started based on forecasts. For the VMI orders the goal is to have a fixed inventory level at a certain number days of sales at the VMI hub, which is balanced by starting production in Assembly and Diffusion.

The work orders generated from the planners is inserted to a master production schedule system (MPS) that plans the start of production lots in detail.

5.2.5 Manufacturing

The MPS system generates work orders to the manufacturing Front-end and Back-end facilities and production gets started according to the delivery plans, or when there are resource limitations information is fed back to the planners. In the manufacturing process the inventory data is continuous updated for handling in the inventory management process.

5.2.6 Inventory Management

The inventory management processes secure that the inventory policy is retained according to corporate goals and customer arrangements. Inventory data is reported from the manufacturer but the divisions are responsible and handle the management of the inventories; in L3M's case 3GP handles most of responsibilities. The processes also control the obsolescence status of stocked products and the sales function is notified to trigger a sales campaign, otherwise the products are written off and scrapped.

Inventory is handled in two ways in ST-Ericsson - a financial perspective and a planning perspective on inventory. In agreement with ST or external foundries, ST-Ericsson owns most of the inventory after the start of production but not all inventories. So in a financial perspective only the inventory owned by ST-Ericsson is interesting and is included in the profit and loss statement, but from a supply chain management and planning perspective everything has to be included. Reporting on inventory is done in both ways.

5.2.7 Delivery

The Delivery process is like the production of the products outsourced to the external foundries logistics functions and they perform all transportation either between production facilities, to VMI hubs or to the customers. ST-Ericsson is notified when a shipment is delivered.

5.2.8 Return/Quality Conformance

Central quality in ST-Ericsson handles the returns and quality complaints. This can be anything from technical problems with the hardware design or delivery problems, for example wrong quantity shipped. For every complaint a case is started to investigate and correct the issue. This is done with an 8D analysis. If needed representatives from responsible functions are involved in the quality case work. The customer is compensated and the 8D analysis is handed over to secure that the issue will not be repeated and is resolved in a satisfactory manner.

5.3 Performance Measurements

Various measurements or indicators were being used in ST-Ericsson at the time of the study. By searching ST-Ericsson's intranet for reports and documentation and by asking relevant personnel, the existing measurements in the organization was identified for the analysis according to an audit led procedure presented in the theoretical framework, *section 3.2.1*.

As described in *section 1.2* there was no uniform ERP-system implemented in ST-Ericsson. The company relied on a couple of different systems for different purposes and to a large extent documents, e.g. huge Excel-files, was used and e-mailed to concerned parts after completion. Below are the indicators found presented.

5.3.1 Yield

Yield is a performance indicator for the production efficiency and gives the percentage of usable components after each production step. For example, if the assembly yield is 97%, 97% of the ASICs are satisfactory produced - the rest have to be scrapped. Reasons for the yield-value can be anything from the production quality issues to the initial design of the chip. The yield for one production step is calculated by taking the average of the lot yields. The total yield for a product can be calculated as:

$$Yield_{Total} = Yield_{Diffusion} \times Yield_{EWS} \times Yield_{Assembly} \times Yield_{Test\ \&\ Finish}$$

5.3.2 Cycle Time

Cycle times (CT) are like the yield calculated for each production step and product. In the computation only manufacturing time is included, not transfer time and non-working days are excluded from the cycle time. The cycle time for one production step is calculated by taking the average of the lot cycle times plus the standard deviation. The total cycle time is calculated by adding the cycle time for each production step as:

$$CT_{Total} = CT_{Diffusion} + CT_{EWS} + CT_{Assembly} + CT_{Test\ \&\ Finish}$$

5.3.3 Cost of Goods Sold

The cost of goods sold (COGS) is the volume dependent costs associated with the products. This includes the manufacturing cost and all transfer related costs. From a financial perspective, tracking this month to month the inventory variations have to be added to the COGS, since the manufactured products does not relate to the sold products in the same month.

Determining the COGS turned out to be a hard task. More or less the information for the manufacturing costs is the total manufacturing cost turning up in the P&L plus the transfer costs, freight and duties in a separate post and one post for inventory variations. Drilling down further to a product view is possible but requires more of an investigation, which is not done by automation.

5.3.4 K-Factor

The K-Factor is not primarily an indicator, but a factor used for the financial calculation of the inventory value. The factor gives the ratio between the actual manufacturing costs and the targeted cost. The K-Factor is calculated for the Front-end process and the total manufacturing process. This means that it gives the value added after the Front-end manufacturing process and the value added up to the finished goods stock.

5.3.5 Inventory Value

The inventory values are measured in ST, foundries and ST-Ericsson for all stocks, work in progress and goods in transit. The inventory is valued according to the K-factor, based on where in the process flow the products are.

5.3.6 Inventory Turns

Inventory turns is calculated for each product and measures the frequency the inventory is replacing. Inventory turns is a measure of the return on the capital asset in inventories. The formula for Inventory turns is:

Turns = 13 weeks of billing/ average inventory

5.3.7 Committed Delivery Date and Requested Delivery Date (CD=RD)

In order to measure ST-Ericsson's ability to meet the customer's requests the percentage of orders where the committed delivery date is equal to the requested delivery date is measured and labeled as *CD=RD*. Orders placed within six months to 21 days before the delivery date are included in the calculation, with the exception for orders committed to the requested date, placed within the 21 days constraint. The indicator has no days of tolerance. The exclusion of late placements of orders are done according to what is considered a reasonable order lead-time for ST-Ericsson, without excluding orders where ST-Ericsson performed better than one would expect. Early orders are excluded because of the inability to plan to the day, with such extensive timeframe.

5.3.8 Delivery Delinquency

As an indicator of Delivery delinquency by ST-Ericsson, there are three measures for this. When orders are shipped late they are also invoiced late – in the same way, when orders are invoiced late they often are delivered late, which is what is measured. The three delinquency indicators that are measured are *CD Delinquency, RD Delinquency* and *Aged Delinquency*.

CD Delinquency: The value of the orders not invoiced with an expired commitment delivery date.

RD Delinquency: The value of the orders not invoiced with an expired requested delivery date.

Aged Delinquency: The value of the orders not invoiced with an expired commitment delivery date, weight with a time factor. Aged Delinquency = CD Delinquency (days from CD < 15) + 2 x CD Delinquency (15 < days from CD < 30) + 4 x CD Delinquency (days from CD > 30)

The delinquency values are also measured in *weeks of sales* (WOS), for the BUs and the divisions.

5.3.9 Global Late Delivery (GLD)

Global Late Delivery is an indicator for late deliveries and VMI level offences, calculated from three measures: *Late customer deliveries*, *late internal deliveries* and *VMI Below*. The measures are weight with quantity of shipped products total for each business unit.

Late customer deliveries: Percentage of shipped quantity delivered to customers late, with a JIT window tolerance of 4 days.

Late internal deliveries: Percentage of shipped quantity delivered to buffer stock late, with a JIT window tolerance of 4 days.

VMI Below: Percentage of days, inventory levels, in VMI's, is below weeks minimum inventory quantity target.

5.3.10 Quality Complaints

All quality complaints are handled as separate cases by the central quality function. As an indicator number of components effected by quality complaints per million of components shipped is measured. There is no differentiation of the type of quality complaints in this indicator.

5.4 The Development of the Supply Chain Cockpit

For the development of a Supply Chain Cockpit-prototype a benchmark was made to evaluate which system to use. Quite early on QlikView was decided to be used for developing a prototype of a PMS, because of its ability to get an easy to use system with visual representations of the indicators.

A prototype that serves L3M's needs and is aligned with the targets and strategies, required a manual development with the choice of QlikView. QlikTech, the manufacturer of QlikView, have standardized products, but none of them were suitable for this application, because of how the data is structured in ST-Ericsson. ST-Ericsson had no uniform ERP-system for handling data, but used several for different purposes. In addition the intranet was used for publishing reports and a lot of information was distributed in e-mails, often as Excel sheets. The available data needed to be distinguished after which the prototype could be designed to upload the data. The last step was building an easy to use interface for the viewer.

During four months the quantitative data was gathered at Operations in ST-Ericsson, concerning the sub-processes in L3M's supply chain. The data was used for developing and evaluating the Supply Chain Cockpit-prototype. The prototype was used and tested for the reporting at one quarterly closing period and the following two monthly closing periods. The system was corrected and changed between the reporting periods in line with the used clinical research method. Two S&OP decision meetings were also observed and studied on how the Supply Chain Cockpit could be used for factual decision making.

5.4.1 Quantitative Data

The quantitative data consisted of all the listed indicators and measures presented in *section 5.2*, in addition to several S&OPs and actual costs and sales from P&L statements.

Due to the sensitive nature of this data, it will not be presented in this dissertation on request from ST-Ericsson.

5.4.2 Reporting Periods & Decision Meetings

Since L3M had just started to function in early 2010, the first reporting for L3M Operations was done during the time of the study. During meetings and workshops the reporting procedure was observed in order to develop the prototype to simplify the work associate with putting together the reports and presentations. The prototype was used during the periods, for verification and testing.

Every month the 12 months demand forecast is committed to in a decision meeting. During the meeting, with all responsible managers present, the demand plan is reviewed and decided upon. Two of these decision meetings were observed in order to evaluate the prototype on its ability to serve as a basis for factual decision making.

6 Analysis

This chapter follows from the empirics and continues on the third and fourth step in the methodology presented in the theoretical framework: Determine the performance of the existing supply chain and establish the supply chain strategy, goals and priorities. Lastly, the developed supply chain cockpit-prototype is evaluated in this chapter.

6.1 Determine the Performance of the Existing Supply Chain

The quantitative data gathered during the study was not sufficient to determine the performance of the supply chain, because of the short time of data records. Instead the performance of the existing supply chain was qualitative determined by evaluating the sub-processes identified and the performance measurements that are designed to capture the performance of the processes. The evaluation was done for the existing performance measurements, where existed. Otherwise, if needed, new performance measurements were identified and will be presented in this chapter.

6.1.1 Demand Management

The demand management process was the only process that L3M was process leader of together with Central Sales, and therefore this process received the highest attention in the analysis.

The demand management could be seen as the start of the supply chain process, see *figure 8* in *section 5.2.1*. This process has implications on the following processes and could set a good foundation for the rest of the supply chain. Since the start of production is based on forecasts, the decisions taken in this process, result in large capital investments and a risk exposure. An overestimated forecast means a high-level of inventory that will linger until the demand have caught up, and in a worst-case scenario the products have to be scrapped. On the other hand, if the forecast is underestimated the supply chain will have trouble meeting the demand and potential sales are lost. Even if the demand is higher than the forecast and the orders are placed within the lead-time, L3M will struggle getting the needed capacity in manufacturing, since the demand forecast is the input to the capacity allocation process. During 2010 this was a major issue for ST-Ericsson, since there was a great capacity shortage in the industry, and a real problem for L3M. After the dramatic downturn in 2008 very little investments had been made in the foundries worldwide, this affected the whole industry when the economy was beginning to recover.

Clearly, accuracy in the forecast is important for the success of the supply chain and needs to be satisfactory measured and carried out in a sufficient way.

Forecast Accuracy

Forecast accuracy was not measured in a unified way in ST-Ericsson. Comparing the forecast against actual sales in volumes, might seem as an obvious way to measure, but with ST-Ericsson's demand management process it is a bit more complicated.

The forecast is done every month, twelve months ahead and the following two processes are updated accordingly, se *figure 8* in *section 5.1.2.* The question then is when to compare with the actual sales? Should the demand forecast accuracy be defined as when the first forecast is done, i.e. one year before the actual sales; or should it be defined as how accurate the forecast is one month before sales, already within the production lead-time, when the latest forecast is made? Or should the forecast accuracy be measured by comparing the forecast placed closest to the actual lead-time of the production (4-6 months), so that the production has not yet been issued? There is no correlation between the forecast and the internal order that starts the production, meaning that there is no tracking between products in the manufacturing process and what was forecasted. This makes it difficult to make any tracking like the one described. The demand management process is in many ways like a black box that numbers are put into, without any visibility until the products are delivered to the customer.

A second aspect of the demand forecast is that comparing total sales against the forecast as an indicator can be misleading since effects can be hidden or forecast misjudgments get smoothed out, that would only appear down on the product level. Anyhow, this indicator gives a ballpark of the accuracy in the forecast process, but this should be closely followed on customer level by Operations. The information needs to be fed back to the customer units and the product marketers.

Since the demand management process was very new to L3M, forecasting was not an easy task which was apparent in the division's first month of sales. If the forecast placed one month prior to the actual sales is not accurate, L3M will have a lot of problems when the volumes are rising. Measuring the accuracy one month prior was considered a good start for L3M, as one of the members of the project group noted:

> *"We have to learn to crawl before we can walk."*

The next step is deciding on an appropriate target for the forecast accuracy, and which action to take when the outcome violates the tolerance.

Risk Estimate
Since the forecasting process is so difficult and new to L3M the level of associated risk, with the forecast process, was also recognized to be an important measure. With the risk classification it is easy to measure the ratio between the classifications, month to month. The other divisions had a tough target of the risk estimate, though this was not considered appropriate for L3M. The other divisions are in a much more mature market, with steady trends on their sales. L3M had at the time only ramping products and high volatility of the sales and if L3M was to capture new business opportunities and win new customers they had to take higher risks. Still, monitoring L3M's risk estimate and deciding an appropriate target is considered very necessary.

Demand Management Work Flow
Since the demand management process was new to L3M there were a lot of teething problems associated with it. Operations and Product Marketing employees were new in their roles and the customer units were unaccustomed to sell L3M's products.

When the forecast is build up from a bottom-up approach customer by customer and platform by platform, there is a great risk for deviations, if there are systematic errors in the forecast process. The demand is done with several of corrections by individuals; which creates risks for systematic errors. For example, the customer units focus on serving their customers and are not too keen on lowering the customers demand and risking that they are not served sufficiently if the customers' official demand holds. There is an anti-pole in L3M with the product marketers and Operations to serve as a counterweight to the customer units. But this process was unfortunately not unified. There are a handful of product marketers all with their own information sources and channels to set the customers official demand in perspective. Operations have one person in charge for balancing the demand in relation to actual sales and other supply chain perspective. Perhaps Product Marketing also should have one person devoted to the demand process instead of several doing it on the side of their other activities. In this way the demand management process can get more unified and hopefully result in better forecasts.

6.1.2 Capacity Management
From the capacity management process it is really just one thing that is interesting for L3M - is the requested capacity granted? This is, as described in the empirics, a quite slow and long process. The response returns as committed capacity for every production step and the demand is based on the commercial products, there is a matching issue. The genealogy is described by unique codes but their inter mutual link is not visually apparent, i.e. the codes have to be known by heart or looked up. This can cause problem with defining what is committed or

not and could require some investigation. But since the committed capacity is so important, it will be investigated if there are limitations in the capacity.

What is important in this process is clear and was dealt with within L3M. The fact that the mapping of the requested and committed capacity was not simple no indicators were defined in the capacity management process. Consequently nothing was implemented in the Supply Chain Cockpit from this process.

6.1.3 Manufacturing Planning

The manufacturing planning process is handled by planners in 3GP who are fully devoted to this sub-process. The planners have a structured way of working with clear targets, therefore L3M’s role in this process is purely to stay informed and monitor their products. As described in the empirics the orders get confirmed in this process and the delivery date is set. From L3M’s perspective this is the most important aspect to monitor in this process.

L3M have to establish a relationship to the planning organization and notify when their products and customers get neglected, primarily in the conformation of orders. As described in the empirics, the order conformation is occasionally done manually by the planners, for key orders this must be monitored. Since L3M have a lot of new customers the relationship may depend on meeting these customers requests when they place their first orders.

Order Conformation (CD=RD)

The order conformation is an important aspect from the customer perspective of the supply chain. A supply chain that is not delivering according to the customers’ requests is soon going to lose business. Hence the importance of keeping track of the indicator CD=RD. Since the indicator only includes orders placed 21 days before the requested delivery date, ST-Ericsson have defined that orders placed later will not be considered reasonable to meet. But for orders placed earlier than 3 weeks before the delivery date, the aim must be to meet the orders requested delivery date. At least for mature products this should be the aim. Tolerable targets have to be set according to the supply chain strategy.

6.1.4 Manufacturing

The manufacturing process is the biggest and most important process in the supply chain concerning the costs, quality, lead-time and flexibility to meet up and down sides in demand. Because of its importance the central supply chain function closely follows the manufacturing performance in ST and foundries with several KPIs. On L3M’s part it is mostly about monitoring the performance of L3M’s products and the cost that L3M have to carry.

Yield and Cycle Time

Yield and cycle time are the performance indicators which are available down on product level for each step. A good yield lowers the cost because of a more optimal resource usage. A low cycle time raises the ability to meet the customer demand and indirectly raises the service. This makes yield and cycle time good indicators for the manufacturing performance on product level, and suitable to keep track of. Setting a reasonable target for these indicators is depending on what L3M's supply chain strategy is to be, which is discussed further in *section 6.2*.

Cost of Goods Sold

As described in the empirics, extracting manufacturing costs for the individual products is not easy in ST-Ericsson. Ideally one would like to monitor the cost for each product from all production steps to be able to do margin analyses. Of course, keeping track of the total manufacturing cost for L3M is important, but it limits the level of analysis considerable, and it is more of a financial task but handled by Operations in L3M.

Because of the trouble associated with the manufacturing cost only the total costs for each production step was implemented in the Supply Chain Cockpit. This also makes it hard to set a target on the COGS, but one target is forecasted COGS. The forecasted COGS is depended on the forecasted volume that has to be considered when this target is set.

K-Factor

Determining the manufacturing performance by the related costs is really just relevant when it is put in relationship to the produced volume. With the limiting factors of the COGS, some other aspect of the manufacturing costs has to be used. ST-Ericsson uses the K-Factor in order to value its inventory, but this is also a good indicator of the manufacturing performance in term of cost, since it is measured against a target cost. The K-factor is calculated on business level, for Front-end and the total production.

When the actual cost continuously is compared to the target cost, uncontrollable effects should be filtered away like material costs or salary levels for labor. When the targets are set these aspects are considered so that the manufacturing process is only measured on its ability to control the manufacture cost against a cost target they have control over.

6.1.5 Inventory Management

With the lengthy production process for the semiconductor industry there is a lot of capital invested in the supply chain. In order to get a good return from the working capital, it is important to manage the inventory levels well. There is always a balance act, finding the right inventory and service level. Just lowering the inventory levels always comes with the price of a worsening delivery service. But with good inventory management the levels of inventories can be reduced without compromising delivering performance.

Inventory Turn

Inventory turn is a good measure of the return on the working capital. ST-Ericsson has a target on an inventory turn that is in correlation with the production lead-time, which is a reasonable target. For L3M the turns were considerably lower than the company target from that perspective. Just as for the risk estimate in the demand management process, the company target is not applicable for L3M. At the time of the study L3M had no mature products, only ramping products, which effects the turns negatively. Exposing the supply chain to higher risks in the demand management process also affects the inventory levels, which in turn affect the inventory turns.

By monitoring the inventory turns for all products, for those with low turns, product termination can be considered. Products just spending time in stock may cost more than they bring in even if they do generate some sales. This gets truer with the maturity of products. In the early life cycle when the product is ramping the turns should not be considered too much. For mature products it is important to have a good turn and for products in the end of the life cycle this should be monitored closely. As described L3M had ramping products at the time of the study, but when the products reach maturity, the turns have to rise if the supply chain is to be successful.

Inventory Value

The turn is a good indicator to measure the return of products, but if there are a lot of different products the inventory value gives the magnitude of the impact. The inventory value can then serve as a ranking of the products, so by starting to examine the turns of the product with highest inventory value the improvements can start where they make the greatest difference.

For obsolescence products the inventories have to be written off and scrapped, which should be monitored by L3M. The inventory values are also an input for the demand management process. If sales have not matched what was demanded, there may be an excess inventory, since the demand is not as great as expected. There cannot be a specific target for the inventory value, which is indirectly set by the turns, but when the time comes for L3M perhaps it should be targets for ageing products to write off the inventories.

6.1.6 Delivering

In the semiconductor industry *just in time* deliveries (JIT) has become standard if not a VMI stock is used, either way it means that following up on the deliveries are essential when measuring supply chain performance. ST-Ericsson has used the measures aged delinquency and global late delivery (GLD) for this.

Aged Delinquency

The delinquency measure is a frequently measured indicator which gives the ability to act on present orders that are not yet delivered. The problem with the indicator is that it is based on what is invoiced, which means that software and services can become delinquent or even invoice problem result in a triggered indicator. Concerning delivery performance, only high volume hardware should be considered when this indicator is flagged.

Of course getting invoices paid is important but it should not be mixed with delivering performance. The target for this should be to always act on delinquent products and find the root cause of the problem.

Global Late Delivery

The global late delivery measures history of what was delivered late or if the levels in VMIs have been under minimum. This measure is a good indicator for visualizing trends of the delivery performance. But GLD measures a mix of indicators, just as the delinquency measure mixes delivery performance with software sales and services. GLD is a combination of three indicators and perhaps VMI below, late internal deliveries and late customer deliveries should be looked at separately, so the content of the indicators is clear and understandable. For example: Let's say that 5% of all deliveries are shipped late and the VMI-stock has been below the minimum level 2% of the time. Looking at these both two indicators are easy and understandable to grasp. A corresponding GLD of 7%, which is a combination of deliveries that are shipped late and the percentage of days the VMI-stocks have been below the minimum level, is not intuitive. The combined indicator does not really say anything.

6.1.7 Return and Quality Conformance

A part of a good relation to ones customers is to correct errors when they occur and in the supply chain process many things can go wrong, since this is when the actual delivery of the product occurs. In ST-Ericsson this process has been considered so essential that there is a central quality function for it. Central quality handles all complaints and leads this process. The work process is very structured and together with the corrective actions; the root cause of the problem is found and documented in an 8D analysis. The conclusion of this is that complaints are handled well, but from L3M's supply chain perspective there was not a lot of feedback from this process to Operations. Since the process of handling complaints gives a lot away from what the customers are not satisfied with, it is a pity if this information is not used by Operations in their continuous development of the supply chain. Because of the limiting information about this process, it was not implemented in the cockpit-prototype.

Quality Complaints

Since the indicator for quality complaints reflected all quality aspects, not only supply chain related, the indicator was not considered appropriate for the Supply Chain Cockpit and was excluded.

6.2 Establish the Supply Chain Strategy, Goals and Priorities

If the Supply Chain Cockpit is to fulfill its purpose, the metrics that are measured should relate to the corporate strategies, goals and priorities. When the study was conducted no clear supply chain strategy was present, hence this section serves as groundwork for establishing a strategy and priorities for L3M's supply chain.

The performance indicators found and suggested in *section 6.1*, are mapped to SCOR's performance attributes in *Table 3.* By determining a strategy from the performance attributes and priorities broken down from the corporate targets, a set of KPIs can be decided upon among the performance indicators.

6.2.1 Evaluation of Performance Attributes

With the performance indicators described in the empirics or defined in this chapter, SCOR's performance attributes can be evaluated, see *table 3*. In this way it can be determined if the Supply Chain Cockpit will cover the aspects: reliability, responsiveness, flexibility, cost and assets for the supply chain in the prototype. What is noticeable in *table 3* is coverage of all the aspects by at least one indicator, which is very positive since it is the performance of the attribute that is interesting not the indicator per say. Even though there is coverage, the question still stands if the indicators are accurate measures of the attributes.

In the customer perspective there are three good service indicators measuring the delivery. CD=RD, aged delinquency and late customer shipments are all measures that is very important to be seen as a reliable supplier and were considered to be KPIs. The combination of these three indicators complements each other well. RD=CD makes sure that the customers are served properly in the future, aged delinquency is a measure L3M can act on right away to find root causes and solve the problem of the late delivery and finally late customer deliveries can visualize delivery performance trends for use in analyses.

In the internal perspective there is also a good set of cost and asset related indicators. Inventory turns and inventory value are traditional ways of measuring and controlling working capital and recognized as KPIs. On the cost side there are some troubles but the K-factor gives a general idea of how the supply chain are performing in terms of cost, and will serve as a KPI.

When it comes to the responsiveness and flexibility of the supply chain, the measures are not as good. What is important for the customer when it comes to the responsiveness is order lead-time. The production cycle time is also important and affects the customer, but to really understand the customer perspective, the order lead-time is a better measure. Flexibility is primarily about the supply chain's ability to have flexibility in the production procedures and to be able to meet changing demands. These production related issues are handled centrally in

ST-Ericsson, but what L3M can do is providing accurate forecasts and to some extent meet up sides with inventories. With the classification of core, risk and opportunity ST-Ericsson has an estimate on the up and down side. With a higher risk estimate there is a higher ability to meet upsides.

Table 3. ST-Ericsson's Supply Chain Performance Indicators Mapped to SCOR's Performance Attributes

	Performance Attribute	Performance Attribute Definition	ST-Ericsson PIs
Customer Perspective	Reliability	The supply chains performance in delivering: the correct product, to the correct place, at the correct time, in the correct condition, in the correct quantity, with correct documentation, to the correct customer.	Aged Delinquency
			GLD
			CD=RD
			Forecast Accuracy
	Responsiveness	The velocity at which a supply chain provides products to its customers.	Cycle Time
			Forecast Accuracy
	Flexibility	The agility of a supply chain in responding to marketplace changes.	Risk Estimate
Internal Perspective	Cost	The cost associated with operating the supply chain.	COGS
			Yield
			K-Factor
			Forecast Accuracy
			Risk Estimate
	Assets	The effectiveness of an organization in managing assets to support demand satisfaction. This includes the management of all assets: fixed and working capital.	Turns
			Inventory Value

The forecast accuracy and risk estimate was recognized as the last KPIs. The forecast accuracy and the risk estimate are different compared to the other indicators in the sense that they indirectly affect several of the performance attributes both in the customer and internal perspective.

6.2.2 Supply Chain Strategy

As described in the empirics ST-Ericsson works with targets, based on the corporate vision and mission statements, which gets broken down from every hierarchical level in the company even down to individual level. From a top-down approach the strategy broken down to L3M Operation was translated to supply chain priorities. The following areas were formulated:

- Competitive Supply Chain Performance
- Cost Efficient Supply Chain
- Cost Control in the Supply Chain
- Accurate Forecasts

These four supply chain priorities serves as the basis for a supply chain strategy. A competitive supply chain performance is referring to the customer perspective of the supply chain and what is expected from ST-Ericsson according to the industry standard. A cost efficient supply chain refers to the internal perspective and how ST-Ericsson uses its resources to meet the customer requirements. Cost control of the supply chain is essential in order to handle the internal processes in the supply chain and follow up on L3M's profit and loss responsibilities. The Supply Chain Cockpit will in itself serve as a tool to keep cost control. Lastly, the forecast accuracy was considered so important that it will serve as a top priority. The forecasting process also affects every other aspect of the supply chain, but it is hard to distinguish what is a result of the forecasting process from other supply chain effects. This is also apparent in the performance attributes table (*table 3)*, where the demand forecast indicators appear in several boxes.

From the supply chain priorities and the SCOR performance attributes a scorecard was constructed to capture the supply chain priorities with KPIs, see *table 4*. The next step is to set targets for each of these KPIs. Setting targets on these should be consistent with the strategy. *Table 2* in the theoretical framework is a good model to consider when setting the targets based on a supply chain strategy. ST-Ericsson cannot excel in every performance attribute, therefore it must be realized that they should focus on those attributes that is consistent with the supply chain strategy. As Kaplan & Norton (see *section 3.3.2*) puts it:

> *"The art of strategy is to identify and excel at the critical few processes that are the most important to the customer value proposition"*

Table 4. The Supply Chain Scorecard

Supply Chain Scorecard			
Objective		**KPI**	**Target**
Cost Control in the Supply Chain	Accurate Forecasts	Forecast Accuracy	
		Risk Estimate	
	Cost Efficient Supply Chain	K-Factor FG	
		K-Factor Semi-FG	
		Inventory Turns	
		Inventory Value	
	Competitive Supply Chain Performance	CD=RD	
		Aged Delinquency	
		Late Customer Shipments	

6.3 Evaluation of the Supply Chain Cockpit

Based on the quantitative data gathered during the time of the study the Supply Chain Cockpit-prototype was developed and fitted to serve L3M Operations purposes in QlikView. Also the three reporting periods and the two decision meetings were used in this way. Presented here is the evaluation of the QlikView prototype.

A strength with QlikView is the ability to compile data from several different data sources right off different ERP-systems or Excel-files. This was of great benefit for L3M since they had several different ERP-systems and documents circulating within the company used as the primary source for the information.

QlikView gives the ability to present a large amount of data in a very esthetic way for the viewer. See *figure 9* in appendix I for the interface view of the Supply Chain Cockpit prototype, with the total numbers of the demand forecast presented. Perhaps the biggest strength of this software is the possibility to drill down on aggregated numbers to see the individual data points. This gives an enormous advantage to finding the cause of deviations in the data, which eases the analysis of the supply chain to a great extent.

The demand forecast was for example implemented in the prototype. The total trend of the demand is a very important aspect of the demand forecast, but understanding the demand trend customer by customer is also very important. Just by one click the demand for one customer can be presented. Another important aspect is to see the demand trend for each platform and just like choosing a customer for a closer look the same can be done for a platform. Further there is the possibility to present the demand trend by platform with the bars split by customer as shown in *figure 10* in appendix I. Likewise, there is the opportunity to present the demand trend by customer with the bars split by platform as shown in *figure 11* in appendix I. With QlikView there are many abilities to present linked data in any thinkable chart or table. This is just a few examples of what is possible to visualize.

For some more aspects on QlikView, look at QlikTech's presentation of the software in appendix II.

6.3.1 Reporting Tool

QlikView is a convenient tool for reporting and was tested in the three reporting periods. In QlikView there is the ability to directly convert graphs or tables into pictures that can be used for presentations. There is also the ability to make the choices for the properties that are needed for reporting and then export the aggregated data to Excel, just by one click as well.

In the first reporting period QlikView served as an analytic tool, but all the charts and tables were created manually or by Excel. By observing problems popping up and what was considered as important in the heat of the moment, putting together a report for top management, new developments of the prototype was identified. The Supply Chain Cockpit-prototype was then altered in line with the clinical method used to serve as a better tool by the next reporting period.

By the second reporting period, the prototype was also used for extracting charts to the report. In this reporting round the compilations of the report was considerable faster than during the first run. What was done in days the first reporting period was transformed into a couple of hours work the second time around. Still, some manual work was made and the cockpit prototype was again altered and some details tweaked.

By the third reporting period the prototype was polished even more to serve its purposes as a reporting tool. Most of what was used for the reports was implemented in the Supply Chain Cockpit by this time around.

6.3.2 Basis for Factual Decision Making

The decision meeting for the S&OP was an example of when a Supply Chain Cockpit could serve as a basis for factual decision making. During the first meeting Excel was used, which did not make it easy for the viewer to take on the information. Presenting with Excel is full of distractions, but there is the ability to make changes on what to present. In the second meeting PowerPoint was used with graphs from Excel, which made it much more presentable for the viewer. The drawback was that there was no ability to investigate the data in detail if questions were raised.

6.3.3 Drawbacks

The drawback of the prototype is mostly linked to the scale of which the prototype was developed for. QlikView is excellent at handling large amounts of data, which is uploaded right of the ERP-systems, e.g. SAP. This requires an extensive groundwork of programming for the uploading of data and publishing the information in QlikView. Due to the time constraint and the scale of this project, only the data related to L3M was used and without either IT or ERP experts the prototype was not developed for automatic handling of this information. The result was that the employees at L3M Operations have to extract data from the ERP-system manually, to a varying degree, and upload it to QlikView by an intermediate step in Excel. This is extra work for the employees and a new way of handling the data. The underlying basis of QlikView is a database concept which requires knowledge in programming for execution of concepts in the prototype. Excel, in contrast, is based on a more visual programming, where the linkage can be visually tracked. Employees used to Excel can have trouble adapting to the database concepts way of thinking.

7 Discussion

This chapter discusses if the study answers what it set out to give answers to, by investigating if the purpose and objectives were met looking from the academic perspective.

From an academic perspective this study started out with the basis that a performance measurement system could be applied in ST-Ericsson, adapted from available theories on PMS. The development phase of this would then be studied and evaluated as a case experiment. The experience and the reality at ST-Ericsson was something different. In the organization there are lots of day-to-day problems and politics to handle, making an implementation of a PMS not as straight forward as the literature presents it. A performance measurement system prototype was nevertheless developed, which gives a high-level picture of the supply chain as it set out to do, but the link to the theory is perhaps not to the extent as one would hope. The prototype also meets the objectives, since it is implementable right away and is developed according to L3M's strategies and targets. ST-Ericsson and L3M definitely got a helpful tool though the addition to the field of PMS can be questioned.

The first concern from the academic perspective is the validity and reliability of the study. The problem areas concerning these tests are foremost the external validity and the reliability (presented in *section 2.6*), which are the ones giving the study the academic assurance. The reliability will never be met in the conditions the research was made. ST-Ericsson is in a rapidly changing environment and five months, which was the time frame of this study, would completely change the foundation of this kind of study in the company. Hence, this study would not reach the same conclusions if it was conducted again, which makes the reliability of the study unobtainable.

General conclusions of this study, which also can be argued, could not be drawn since the problems with external validity within case studies. Any conclusions about performance measurement systems in general are hard to draw from the study, but the case definitely serves as an interesting example of implementing a PMS as a transition program in a post merger company. The construct and internal validity is considered rather high, from the way the research was conducted, which will serve the basis from the conclusions drawn from this case.

Theories like the balanced scorecard (Kaplan & Norton, 1996) stress the importance of involving the employees and management in the implementation of a PMS since it can align the staff with the vision and the strategies of the company. The study proved for this case that implementing a PMS raised the knowledge about the supply chain within the organization. By conducting the development in a project group, involving managers and users and reporting with the PMS, the Supply Chain Cockpit can help facilitating a transition for L3M from being a software delivering company to becoming a hardware delivering division.

8 Conclusions

This chapter provides the final conclusions and lessons learned from the study with the focus on the implications for L3M and ST-Ericsson.

During the time of the study a great deal of knowledge was gained of L3M's supply chain and some general conclusions and areas for improvements were found, which are presented in this chapter. Foremost the result was a performance measurement tool that was developed and handed over to the employees at L3M Operations for continuous use. The results from the evaluation of the prototype are presented below.

8.1 Result

From the Supply Chain Cockpit-prototype a couple of distinctive advantages were distinguished:

- The process strategy work resulted in a supply chain scorecard with KPIs in line with the L3Ms strategy and targets, which was implemented in the Supply Chain Cockpit. This ensures that L3M Operations is measuring the correct indicators to meet the targets placed upon them.
- The prototype compiles data and stores it in one single report file. Data scattered in several different ERP-systems, various intranet reports and e-mailed information is gathered in one place. QlikView also enables storage of an extensive set of data, without lowering the usability in slow processes.
- The prototype allows for very esthetic and visual presentations of data that is very easy to use in QlikView. Therefore it can be used to extract charts and tables for reports or even be used as a presenting tool in itself.
- The prototype enables the user to drill down on data to find subsets of data, even down to the individual data points. QlikView also enables the linkage between data, so the user can access subsets of data from different aspects in the prototype, for example to look at forecasted volumes based on platforms or customers. These aspects of the prototype are very powerful for use in analysis of the material.

QlikView offers many possibilities to present and handle the data, which is not presented in this report or implemented in the Supply Chain Cockpit-prototype, but in case of a continuous use of the prototype new aspects can easily be implemented, changing the initial content.

Some disadvantages in the prototype were also distinguished:

- As the prototype was constructed, due to the timeframe of the study, it resulted in manual work by the employees gathering data from reports and ERP-systems to extract it to Excel before uploading in the QlikView prototype can be done.
- The underlying basis of QlikView is a database concept which requires knowledge in programming for execution of concepts in the prototype. Excel, in contrast, is based on more visual programming, where the linkage can be visually tracked. Employees used to Excel can have trouble adapting to the database concept way of thinking.

8.2 Conclusions and Recommendations

The work associated with the development of a Supply Chain Cockpit-prototype also resulted in some conclusions and lessons learned about the supply chain processes and the existing performance indicators.

- The demand management process was not running smoothly and a review of the process is needed to set the work procedures that enable a successful demand process. The roles of the participating stakeholders must be very clear and defined along with a uniform way of working. A forecasting role with responsibility over all customers should be considered, to get a focus in the forecasting process.
- The demand management process should be measured on the accuracy and risk estimate by L3M Operations. This information should be fed back to customer units and product marketers on a monthly basis to establish a cause and effect relationship of the demand management process.
- Continuous work to establish a supply chain strategy for L3M, with priorities and targets is needed. Targets for all KPIs should be set (see Table 4, section 6.2.2). The targets should be defined according to which attributes to excel at and which are of lower priority (see table 3, section 6.2.1).
- There is a tracking issue of the products in the supply chain. The demand is basically put into a black box from which numbers come out several months later when the products are delivered. Implementing a solution for the data tracking is a huge reconstruction that requires extensive work, but would ease the analysis considerable in the supply chain.

8.3 Future Studies

Since L3M was a brand new division at the time of the study, there was definitely room for many future improvements. Throughout the time of the study there was a few limiting factors, out of the scope of the study, which could be studied further and deeper.

For example, implementing a solution for the data tracking recommended in the previous section is a huge challenge and requires wide-spread and devoted work. How this could be implemented is a hard task to solve that would require further studies. Along with this a new ERP-system covering all the aspects of the supply chain would be of great help, but is also a huge commitment and very time-consuming work. QlikView is definitely a suitable system for a larger implementation and the prototype could be used as a starting point, but is today far away from a complete ERP-system.

In addition, a smaller study that would be a good extension of this study is to follow up on the actual data gathered through the prototype and an evaluation of the supply chain strategy. Working through the last two steps in the SCOR methodology presented in *section 3.4.2* would be the last piece of the puzzle for L3M's reaching a sustainable competitive advantage in their supply chain performance.

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Appendix I: The Supply Chain Cockpit in QlikView

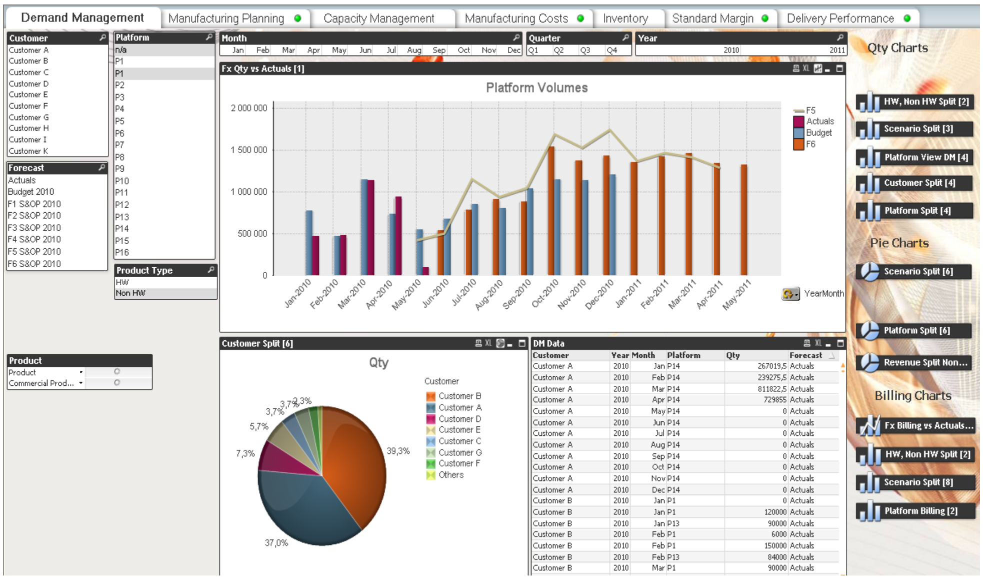

Figure 9. The supply chain cockpit interface in QlikView[*]

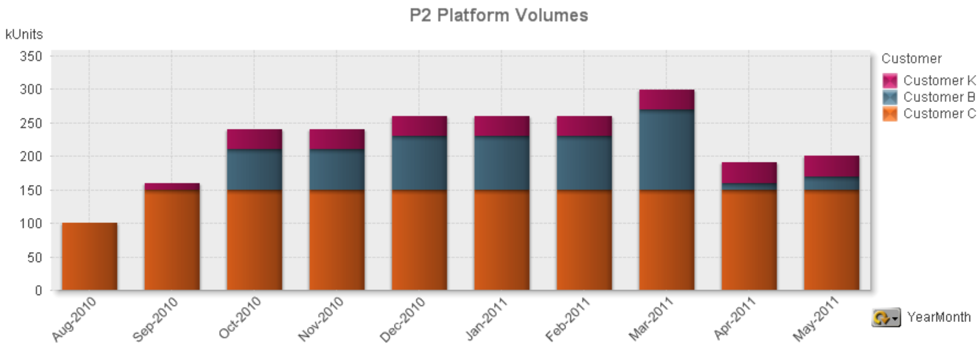

Figure 10. Platform view of demand trend split by customer[*]

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[*] The data from the Supply Chain Cockpit is fabricated on ST-Ericsson's requests.

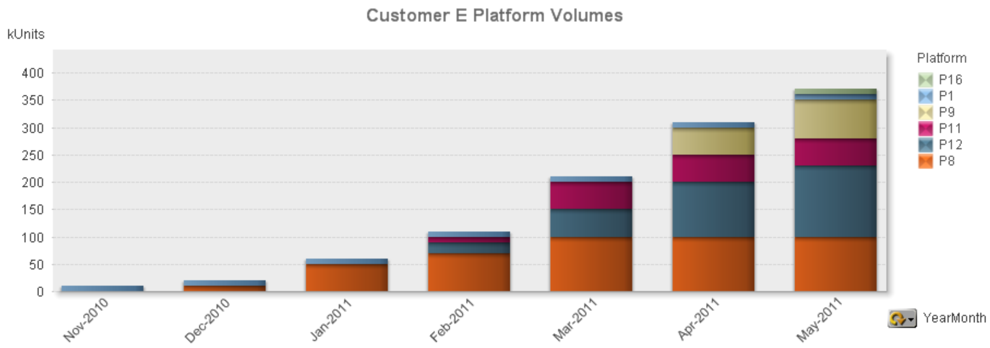

Figure 11. Customer view of demand trend split by platform *

* The data from the Supply Chain Cockpit is fabricated on ST-Ericsson's requests.

Appendix II: QlikView Description

QlikTech's own description of QlikView[i]:

Simple for everyone

QlikView is simple to use and easy to learn. It's designed for anyone and every part of your business. There are no complex interfaces, confusing screens or arcane commands and queries. Just point and click for all your business answers. QlikView's unique, award-winning associative technology works the way your mind does. It provides one-click access to visually rich, interactive dashboards anyone can build quickly and modify easily. It's a new rules approach that benefits business and power users alike.

Any-size deployments

Whether your company is a multinational enterprise, a single workgroup or a one-person shop, QlikView delivers the answers you need. Large companies with billions of records rely on QlikView to provide data and analysis across multiple departments. Workgroups use it for comprehensive insight into their unit-specific needs. And single users can leverage it in a compact deployment for all their data.

Rapid time to value

QlikView has enabled its customers to benefit from rapid time to value, measured in days, weeks or months. QlikView is a single product deployable with minimal effort from internal resources, or through our global network of 800-plus partners. Once QlikView is live, any user can easily create QlikViews that let them make better business decisions.

Enterprise proven, IT friendly

Many large institutions rely on QlikView's game-changing simplicity and rapid time to value. It can unify multiple data sources and easily integrates with your existing systems – including traditional BI software such as Cognos, Hyperion and Business Objects. More and more enterprises using legacy BI tools have turned to QlikView to meet specific departmental and business user requirements. Other enterprises are now adopting QlikView as their BI platform of choice as they continue experiencing unprecedented success with its enterprise scalability, manageability and support for key architectural and data security standards.
IT is often burdened with providing BI access to ever-increasing numbers of users who want to make better business decisions. The complexity of traditional BI puts IT in reactive mode to deal with slow-running queries and erratic response times that vex users. In contrast, QlikView empowers users to create and drive their own applications with minimal IT involvement. And its unique architecture automatically optimizes performance to ensure a consistent, highly-responsive user experience – freeing IT to focus on other activities.

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[i] (QlikTech Internationl AB. (2010). *QlikView 9 for Business Answars.* Retrieved May 26, 2010, from In-memory Business Inteligence - In-Memory Dashboard Reporting Analysis\ QlikView: http://www.qlikview.com/us/explore/products/in-memory-advantage):