Mälardalen University Press Licentiate Theses
No. 70

A FRAMEWORK SUPPORTING THE COLLABORATION BETWEEN THE LOGISTICS- AND THE PRODUCT DEVELOPMENT PROCESS

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2007

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ISSN 1651-9256
ISBN 978-91-85485-38-3
Printed by Arkitektkopia, Västerås, Sweden

Abstract

IN THE COMPETITIVE environment of today's global markets, the demands of customers are increasing. They expect to get the best product at the lowest price with immediate availability. Logistics, including transportation, inventory maintenance, order processing, purchasing, warehousing, materials handling, packaging, customer service standards, and product scheduling must continuously be developed to meet the challenges of the market. The globalization, with longer distances to customers and suppliers, and the progressing trend of outsourcing are examples of why the importance of logistics has increased over the last few years.

A considerable part of the final product cost is frozen during the early product development phases. In the early phases of the product development process, the cost of making design changes is low compared to making changes later in the product development process. The product development decisions made in the early phases of the product development process have considerable impact on future manufacturing and logistics activities as well.

The objective of this research project is to develop a framework supporting the collaboration between the logistics- and the product development process. To do this, it has been essential to analyze which parameters influence the efficiency of the logistics process and the interface between the logistics- and the product development process. Also, to investigate how the logistics department can be integrated earlier in the product development process has been of interest. This has been done through both a theoretical review and also through a number of case studies.

The result and conclusion of this project is a framework that gives support for what to focus on, how to collaborate, in which phases collaboration is meaningful, and which persons need to be involved in the different product development phases. Working as the framework suggests will, hopefully, give closer collaboration between the logistics- and the product development process than without this supportive framework. The expectation of the collaboration is an earlier integration of the logistics department in the product development process and through this influence and increase the efficiency of the logistics process.

Acknowledgement

FIRST OF ALL I want to say my greatest thanks to my supervisor, professor Mats Jackson. He has always had time for discussions when needed and guided the research at all times. He has been an inspiring source with his positive attitude. I also want to send my deepest thanks to my co-supervisor Mats Deleryd who has taken time to read and discuss the research project.

I also want to say thank you to all my colleagues at the Department of Innovation, Design, and Product Development. I want to thank you for all the fruitful discussions during these years and for always being helpful, no matter what the problem was.

I want to thank Volvo Construction Equipment Component Division for has made this research project possible. In particular I want to say thanks to my supervisor and closest neighbor at Volvo, Karl-Ivar Käck, who has encouraged me in this work and conveyed his competence. My other colleagues at Volvo, who have answered questions and supported me in this work, should also get my greatest thanks. Especially the persons who have participated in the different case studies should have big thanks. I also want to send my thanks to Roger Ehn, who used to work at Volvo, and encouraged me to start this research work. An important person at Volvo has been Anette Brannemo for all inspiring discussions and who has brought a lot of joy into this research, thank you!

My appreciation also goes to all the other people at the other case study companies and the network/arena who have participated in the case studies.

Furthermore, I want to send my thanks to PilotVerkstaden who has financed a large part of this project.

Finally, I would like to send my deepest appreciation to my family for always being there and supporting me. I want to give a special thanks to my Thomas, who has always encouraged me to go on and always been there for me. Lastly, I want to say thank you to my two biggest causes of rejoicing in life, Julia and Viktor. You have definitely made me forget about work and shown me what is important in life!

Eskilstuna, January 2007

Anna Andersson

Publications

THIS RESARCH PROJECT is based on the following papers and technical report.

Paper A

Andersson, A. & Jackson, M., (2004), Efficient logistics development through regional collaboration, Proceedings of the 6th Research- and Application Conference of PLAN. 19th-20th August: Lund, Sweden.

Paper B

Hägg, A. & Andersson A., (2004), The impact of outsourcing on logistics, 4th International Seminar and Workshop EDIProD2004. 7th-9th October: Zielona Góra, Poland.

Paper C

Andersson, A., (2005), The interface between the logistics and the product development process, 14th International Conference on Management of Technology. 22nd-26th May: Vienna, Austria.

Technical Report

Anna, A. (2002). *Logistikutformning på företag i Mälardalen.* Technical report. IDPMTR:02:04. Department of Innovation, Design and Product Development. Mälardalen University: Sweden.

Typographic conventions

THE FOLLOWING TYPOGRAPHIC conventions are used throughout this licentiate thesis, except in the reference chapter, with the meaning as described below.

"Double quotations"	Double quotation marks are used to identify material quoted verbatim from other references.
Bold	The bold font is used for emphasis or to mark specific words that are essential to this research project.
Italic	The italics font is used to elucidate some words in the text to make it easier for the reader.
	The rectangle is used to mark the specific phrases or sentences that are essential in this licentiate thesis.

Definitions

THIS CHAPTER refers to the terms that are defined in this licentiate thesis.

Logistics (Logistics Process)

Logistics is the process of planning, implementing, and controlling the efficient, cost-effective flow, and storage of raw materials, in-process inventory, finished goods, and related information from point of origin to point of consumption for the purpose of conforming to customer requirements (Ballou, 1992).

Product development process

The product development process refers to the entire product life cycle time. It covers the process from the idea for a product and its production through to its market entry and disposal. The process is a defined order of specific tasks which is required to generate the necessary information for every stage of the process. (Bullinger and Warschat, 1995)

Concurrent Engineering

Concurrent engineering is a systematic approach to the integrated, concurrent design of products and their related processes, including manufacture and support. This approach is intended to cause the developers, from the outset to consider all elements of the product life cycle from conception through disposal, including quality, cost, schedule, and user requirements (Carlson-Skalak, 2002).

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"It is the one that gets lost who will find new ways to go"

- Nils Kjær

1 Introduction

This introduction includes a description of the background of the research project and the problem statement. Also, the objective, the research questions, and the delimitations of the research are described. The chapter ends with an outline of this licentiate thesis.

IN THE COMPETITIVE environment of today's global markets, the demands of customers are increasing. They expect to get the best product at the lowest price with immediate availability. Logistics, including transportation, inventory maintenance, order processing, purchasing, warehousing, materials handling, packaging[1], customer service standards, and product scheduling must continuously be developed to meet the challenges in the market (Ballou, 1992). During the 1980's and 1990's the focus on costs increased and companies focused on their core competencies. This led to that activities that could be performed more cost efficiently by other companies were outsourced. As an example external transportation and stock-keeping, so called third-part logistics, were often outsourced (Jonsson and Mattsson, 2005). A considerably progressing trend towards outsourcing of production and production-related activities has also led to an increased need for transportation, planning, and steering of logistics activities (Metall, 2002). These are some explanations to the increased influence of the logistics. Today, customers' requirements are not only focused on the physical product; they also include high service in terms of, for example, availability and flexibility.

Many firms have adopted a more strategic approach towards supply management and logistics (Storhagen, 2003). The efficiency of the logistics process within the production process is getting more and more significant as an enabler for flexibility and integration (Storhagen, 2003). This implies that there is a need for more knowledge about the logistics field ant its integration in the product development process.

Studies have shown that some 70-80% of the final product cost is indirectly frozen during the early design phases (Vallhagen, 1996). As a consequence, a large part of the productivity of a production process is dependent on product design. In summary, future success in industries requires concurrent engineering and co-operation between product and process development internally, within the company, and externally, towards suppliers and partners (Nilsson and Jackson, 2004). The cost of making changes in the early design cycle is merely a pencil eraser or a minor change on a CAD screen and, therefore, it is meaningful to involve

[1] Packaging in this licentiate thesis includes the entire package solution for a product during its life cycle (Klevås, 2005).

the logistics department[2] at an early stage to be able to influence and make changes in the product design which will affect the logistics process (Huthwaite, 1988).

According to Dowlatshahi (1999), the design decisions made in the early phases of product design and development will have significant impact upon future manufacturing and logistics activities. Mather (1992) states that the concepts design for manufacture and design for assembly, which focus on reducing costs by making products easier to produce, are becoming well-known. But these concepts are not sufficient. Products must also be designed so that the customer can be delighted by availability, responsiveness, and flexibility. A product that is not delivered when the customer needs it is not of much use, no matter how easy it is to produce. The design for logistics is one aspect of the product that is seldom considered in the product development process, but it is one of the most essential factors for a successful product (Mather, 1992). Examples from the case studies in this research project show that this is still the case in the manufacturing industry today. One example is a metal sheet which was designed to be too big to be able to be transported and needed to be redesigned into smaller details. Another example is the redesign of an item to become slightly thicker, which led to that instead of three items fitting on one pallet, only one item could fit.

The interface between the logistics- and the product development process is an intriguing area to focus on since the collaboration between product design and the logistics process has been highly disregarded and little work is being done on the interface of product design and the logistics process (Dowlatshahi, 1999). Little attention is paid to how to integrate suppliers in the product development process (Browning, 1997). However, the advantages of integrating the sub-suppliers at an early stage in the product development process are discussed by for example Peter (1996). Johansson (2006) points out that, despite the importance of integrating the logistics department in product development projects, there is little research made on how to manage it presented in literature.

1.1 Problem statement

Decisions made early in the design process within, for example, product development projects imply favorable possibilities to have an impact on lower total costs. Logistics decisions with structural influence have different prices depending on when they are made. The focus of the logistics process early in the design process within, for example, product development projects has often been neglected, maybe because of inadequate knowledge about the consequences of different logistics decisions (Storhagen, 2003). The aspect of the often too late consideration of logistics in the product development process is also discussed by for example Mather (1992) and Gupta and Dutta (1994). While product design accounts for only 5% of a product's cost, it can determine 75% or more of all manufacturing costs. Companies spend countless man-hours and dollars monitoring manufacturing processes that could have been simplified – or even eliminated – at the design stage (Huthwaite, 1988).

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[2] In this licentiate thesis the logistics department refers to the persons with logistics competence and that are working with logistics within the company.

In conclusion, it is meaningful to focus on the logistics process early in the product development process and thus improve the logistics process within production. Many of the decisions made early in the product development process will influence and set the framework for the logistics process in the order to delivery process. If the logistics activities and involvement are considered earlier in the product development process, the total cost will decrease. Figure 1 illustrates that decisions made early in the product development process give a higher possibility for having impact at a proportionately low cost. Later in the product development process the possibility to have impact is limited and is associated with a higher cost.

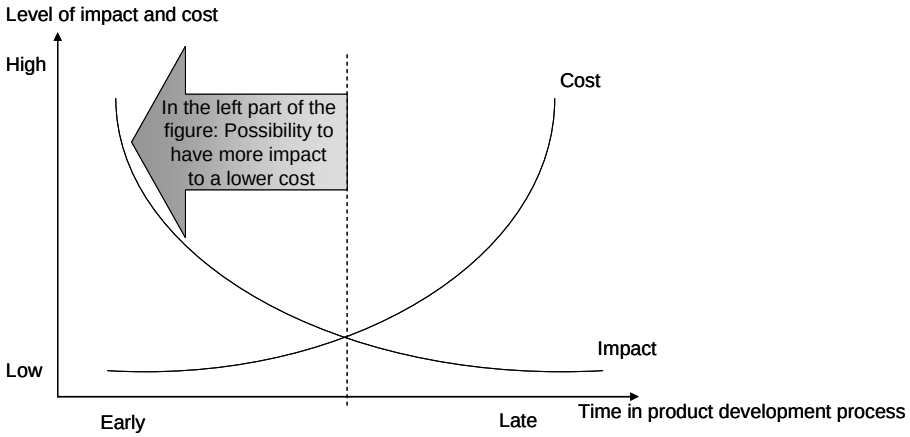

Figure 1 – A symbolic figure of how decisions made early in the product development process give a possibility for impact on a lower cost. The figure is an adoption and modification from Storhagen (2003).

Thomke and Fujimoto (2000) have performed a study which found a change in the maintenance phase to be roughly 100 times more costly than in the specification phase, not counting any indirect operational problems in the area. Late engineering changes, as a response to identified design problems, can still be very costly and time consuming. A product development change might influence the logistics process and if the logistics department is involved in the later phases and a change is made late it will, consequently, cost a lot more than if the logistics department had been involved earlier. Maybe the change could have been made in the early product development phases instead, to a lower cost.

1.2 Objective

It has been mentioned above that there is a need for the logistics department to be involved earlier in the product development process. As already mentioned in the problem statement the logistics department is often involved too late in the product development process, when a lot of the preconditions for product development already are set and there are small possibilities to make an influence. This results in higher costs.

An essential research topic is to look deeper into the interface between the logistics- and the product development process. It is an essential input to find which parameters, i.e.

distinguishing characteristics that influence the efficiency of the logistics process. There is a need for a framework to support the collaboration[3] between the logistics- and the product development process, to get the logistics department involved earlier in the product development process. The objective of this research project is, therefore, to:

> Develop a framework supporting the collaboration between the logistics- and the product development process.

A framework is defined as a set of principles or ideas used as a basis for one's judgment, decisions, etc. (Oxford Advanced Learner´s Dictionary of Current English, 1989). According to The Free Dictionary (2006), a framework is a simplified description of a complex entity of a process and a set of assumptions, concepts, values, and practices that constitute a way of viewing reality. Out of this, the objective of this thesis is a framework consisting of a figure of the product development process with the interface to the logistics process and a proposal of a way of working in the different product development phases to get the logistics department involved earlier in the product development process. The framework in this thesis is a first step towards a more complete methodology to support the design of the logistics process earlier in the product development process.

1.3 Research questions

To answer the objective of this research project, namely how to develop a framework supporting the collaboration between the logistics- and the product development process, it is necessary to analyze the interface between the logistics- and the product development process, which parameters that affect the efficiency of the logistics process, and how the logistics department can be integrated earlier in the product development process. Three underlying research questions have, therefore, been formulated.

To identify what an efficient[4] logistics process is, it is meaningful to look into which parameters affect the efficiency of the logistics process. With these parameters known, it is possible to see if the product development process has an influence on these parameters and, consequently, has an influence on the logistics process. Therefore, research question 1 was formulated as follows:

> RQ1. Which parameters influence the efficiency of the logistics process?

The logistics field is very wide and, therefore, this research has been limited to focus on one smaller part of logistics, namely the interface between the logistics- and the product development process. Interfaces can be seen in many contexts, such as product, process, or

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[3] Collaboration between the logistics- and the product development process means e.g. integration, co-ordination, teamwork, sharing of resources between the processes. This is further discussed in chapter 3.3

[4] Efficient means acting with a minimum of waste, expense, or unnecessary effort (The Free Dictionary, 2006).

organization. The value of a complex system is derived from the relationships between its parts. The interaction between different parts makes a system much greater than the sum of its parts and therefore it can be stated that the greatest leverage in system architecture is at the interfaces (Browning, 1997). This makes it of essential input to analyze the interface between the logistics- and the product development process and what it looks like and a second research question was formulated:

RQ2.	What is the interface between the logistics- and the product development process?

It has been shown that it is meaningful that the logistics department is involved early in the product development process. This is also confirmed by theory, for example according to Storhagen (2003), who says that decisions made early in the design process give a possibility to influence the product or service to be delivered at a lower final cost. Peter (1996) discusses the advantages of early supplier involvement and that involving sub-suppliers at an early stage can have advantages such as shorter lead times, lower costs, higher quality, shared costs and earlier availability of prototypes. If the logistics department is to be able to have an influence on product design decisions made early in the product development process, the logistics department needs to be present in the early phases of the product development process. It is a significant question if and how the logistics department is integrated in the product development process and this is the third research question:

RQ3.	How may the logistics department be integrated earlier in the product development process?

1.4 Delimitations

This project focuses on the logistics related to an industrial production system with manufacturing and/or assembly of physical products.

In this thesis, the production system is defined as the process of creating products from supplier to customer. Production as a whole must be seen as an integrated process that converts materials into goods. Physical distribution is a part of the production process and should be integrated, coordinated, and managed together with it (Drucker, 1990). Consequently, the production system includes the whole supply chain and, furthermore, the logistics process is an essential part of the production system. The logistics field is wide but, in this thesis proposal, logistics is seen as a competitive device; more efficient logistics creates more customer value and a more efficient production system, connected to the competitive priorities which originate from Skinner (1969).

In this licentiate thesis the focus has been the logistics process, which is seen as a part of the production process. The focus has been to integrate and support the collaboration between the logistics process and the product development process.

In this research, the focus has been to investigate the interface between the logistics- and the product development process but this does not mean that other fields within the logistics

field are less significant. The focus of this project is not how to produce a product with a lower product cost or a technically better product. Instead, the focus of this project is that an earlier involvement of the logistics department gives opportunities to influence the product development solutions and decisions made in the product development process, which may lead to a more efficient and cost efficient logistics process when the product eventually is manufactured.

The companies, the network, and the arena which have been studied in this research project are active in the region of Mälardalen in Sweden. About 30% of Sweden's population live in Mälardalen and the purchasing power is strong; about 35% of the total GNP (Gross National Product) is created here. Half of the revenue from taxation comes from the Mälardalen region. The region has a future-focused industrial tradition which has been the engine for growth in Sweden for many years. Important global companies are situated in the region, for example ABB, Ericsson, Bofors, and Volvo CE (Sköldestig et al, 2005). This makes Mälardalen a major region also when it comes to the logistics field. Another reason why the region Mälardalen was chosen is the closeness to Mälardalen University, where this project has been performed.

The main field for this licentiate thesis is the logistics field and for this reason the chosen literature about collaboration and interfaces is mainly from the logistics research (e.g. Wynstra et al (2001), Gupta and Dutta (1994). The concept concurrent engineering is the only discussed concept within the theory about the product development process since this is well established and is the most frequently referred concept by logistics researchers (Klevås, 2005).

1.5 Outline of the thesis

The first chapter, Introduction, describes the problem and the background of the research project. The objective of the research and the research questions are presented here. Also, the delimitations for the research are described in this chapter. In the methodology chapter, chapter 2, there is an introduction to methodology, methods in general, and then the chosen research methodology is presented and motivated. A discussion about validity and reliability is found in this chapter. The third chapter presents the theoretical framework. The purpose of the chapter is to acquaint the reader with the research field and some relevant fields and notions are discussed here. Different definitions of the relevant fields are discussed and also what the notions mean in this work. The discussed fields are: logistics, product development, collaboration, and the interface between the logistics- and the product development process. A summary of the appended papers is presented in chapter 4 and also a short summary of the results from the three appended papers is included. The proposed framework is presented in chapter 5 and the discussions and conclusions from this research and the results of the three research questions are found in chapter 6. Future research is also discussed in chapter 6. At the end of this thesis, the references used are listed and, also, the published papers are appended. Four appendices are found in this thesis and they describe, in more detail, the four case studies and the interviews the case studies are based on.

2 Research methodology

This chapter describes research methodology in general and the methodology that has been used in this research project. The case studies are summarized and there is also a discussion about why the methodology used was chosen.

RESEARCH METHODOLOGY intends to state the scientific application the author has used on formulated problems (Ejvegård, 1996). Åsberg (2001) defines research methodology as different procedures of data collection. It is essential to choose appropriate methodologies and data collection procedures when doing research to work out the answers to the formulated research questions.

This licentiate thesis belongs to the research area applied science within technological research. Therefore the objective of this research is the development of useful technologies that can be applied within engineering. The difference between technological research and natural sciences is that natural sciences seek to explain how nature works whereas technological research focuses on development of functional and useful technologies (Nordin, 1988).

Methodological approaches are different ways of making presumptions of reality. According to Arbnor and Bjerke (1994) there are three different methodological approaches: the analytic approach, the system approach and the actor's approach. The *analytic approach* implies that the totality is the sum of the parts. This means that the best individual parts will together constitute the best totality. In contrast to the analytic approach, *the system approach* says that the total differs from the sum of the parts, which implies that the relations between the parts are significant. The relations give plus or minus effects, so called synergies. Consequently, the system approach comprehends the parts from the characteristics of the totality. Within engineering design research and inter-organizational research the system approach is rather common, due to the art of the science and its systems of components and relations between them (Elfving, 2004). The third methodological approach is according to Arbnor and Bjerke (1994) the *actor's approach* which means that the entirety is understood from the characteristics of the parts. The actor's approach is not interested in explaining; instead the aim is to understand the social totality from the individual actors. The focus of the actor's approach is to map the meaning different actors put in their actions and their surroundings.

In industrial engineering companies it is important to avoid sub-optimizing, which is a risk if all parts of a company are doing the best from their perspective. It is essential for a company that all parts act together to meet the company's common goal. Logistics and, in this research project, the interface to the product development process, need to deal with inter-organizational issues. The relations between organizations and humans are essential to this

research. To reach efficiency in a company, it is important not to sub-optimize but to pay attention to how the different parts within a company act together and not as separate parts. This means that the separate parts are significant, but also the relations between the parts are significant and, based on this reasoning, the system approach has been applied in this project. This is also in accordance with Lambert et al (1998) who say that the system approach is a critical concept in logistics, since the logistics is a system in itself. It is a network of related activities with the purpose of managing the orderly flow of material and personnel within the logistics channel.

2.1 Research methodology in general

There are different ways of doing scientific research and Yin (1994) mentions five different research strategies: experiments, surveys, archival analysis, history, and case studies. Which strategy that should be chosen depends on the research goal and three conditions: type of research question, if the investigator has control over behavioral events, and the degree of focus on contemporary as opposed to historical events, see Table 1.

Table 1 - When to use which research strategy. The table is an adoption and modification from Yin (1994).

Research Strategy	Research Goal	Type of research question	Requires control over behavioral events?	Focuses on contemporary events?
Experiment	When research questions deal with operational links that need to be traced over time, rather than mere frequencies or incidence	How and why	Yes	Yes
Survey	Describe the incidence or prevalence of a phenomenon or when it is to be predictive about certain outcomes	Who, what, where, how many, how much	No	Yes
Archival Analysis	Describe the incidence or prevalence of a phenomenon or when it is to be predictive about certain outcomes	Who, what, where, how many, how much	No	Yes/No
History	When research questions deal with operational links that need to be traced over time, rather than mere frequencies or incidence	How and why	No	No
Case Study	When research questions deal with operational links that need to be traced over time, rather than mere frequencies or incidence	How and why	No	Yes

In general, case studies are the preferred strategy when 'how' or 'why' questions are being posed, when the investigator has little control over events, or when the focus is on a contemporary phenomenon within some real-life context (Yin, 1994). The objective of a case study is to take in a small part of a bigger context and through the case describe reality and

say that the case may represent reality (Ejvegård, 1996). Case studies are often criticized for lack of statistical reliability and validity. Also, it is argued that the risk when using only a few case studies is the loss of external validity. Still, the insight and relatively deep understanding facilitate analytical generalization so that findings can be generalized to theory (Yin, 1994). To overcome this dilemma, it is increasingly essential to select a representative case and validate the result continuously and not simply at the end of the study. Also, it is essential to describe the actual case carefully and to observe that conclusions drawn may be valid only for similar systems.

When collecting the data during the research there are different techniques for collecting data. Ejvegård (1996) describes a technique as the way the data is collected to be able to describe, compare, set up a hypothesis, or forecast something. The data collection may be done through, for example, searching literature, questionnaires, interviews, criticism of sources, statistical material, and direct observations. Interviews are one of the most menaingful sources of case study information. The strengths of interviews are a strong focus directly on the case study topic, insightfulness, and they provide perceived causal inferences. Weaknesses with interviews to be mentioned are preconceived responses and that the interviewee says what interviewer wants to hear (Yin, 1994). The consciousness of this has made the author attentive to possibly preconceived responses. Leading questions is something else that raises attention when using interviews as sources of evidence. The criticism is that the answers are said to depend on how the question is asked, so called leading questions. It is a well-documented fact that answers depend on the formulation of the question. But, according to Kvale (1997), this may depend on naive empiricism. According to him, the interview is a conversation where the data comes up in a human relation between the interviewer and the respondent. Instead, Kvale (1997) thinks the qualitative research interview is suitable for asking leading questions to test the reliability of the respondents' answers. Interviews are a common way of collecting data and, according to Arbnor and Bjerke (1994), interviews are used to a large extent within the system approach.

2.2 Research methods applied

When it comes to the logistics process and the interface to the product development process, it is essential to look into processes in industry and here, quantitative data are hard to come by. Instead, practical insight about the possibilities and problems in this area are needed in qualitative terms. The research questions in this project are of understanding character and of the type 'how' or 'why' and it is not possible to have control over behavioural events and, according to Table 1, two different research strategies are suitable: history and case studies. Historical methodology deals with the "dead" past, no relevant persons are alive to report on matters and an investigator must rely on primary documents, secondary documents, and cultural and physical artefacts as the main sources of evidence. Case studies are preferred when examining contemporary events, but when the relevant behaviour cannot be manipulated (Yin, 1994). This project does not deal with the "dead" past; instead concurrent events are meaningful to study in this project. The description of case studies above and the situation in this research project qualifies the case study to be a suitable research strategy. Lack of statistical reliability and validity is, as mentioned earlier, an often given criticism for case studies. Also, it is argued that the risk when using only a few case studies is the loss of external validity. Still, the insight and relatively deep understanding facilitate analytical

generalization so that findings can be generalized to theory (Yin, 1994). To overcome this dilemma it is essential to select a representative case and validate the result continuously and not simply at the end of the study. Also, it is meaningful to describe the actual case carefully and only draw conclusions that are valid only for similar systems.

According to Gummesson (2000), informal interviews and observations provide the best opportunity for the studying of processes. In this project, it has been meaningful to study different processes in industrial companies. Therefore, interviews and observations, mostly direct observations, have been techniques for collecting the data during the case studies. The collection of data has also been complemented by using literature reviews. Criticism of sources has been made continuously during the collection of the data. See Table 2 for which techniques for collecting data have been used for each case study in this research.

Four case studies have been performed within this research project. The objective of the case studies has been to answer the three research questions within this project. The empirical data in the case studies have mainly been collected by semi-structured interviews. Analysis has been performed after each case study, but also continuously during the case studies. The base for the case studies has been literature studies, which have been made continuously during the whole research project. The empirical data and results are presented in the appended papers, see paper A-C.

A qualitative research interview is often of a semi-structured nature and by this it means that it is not an open conversation and not a strict questionnaire. Instead, the interview is performed according to an interview guide with proposals of questions and different themes to talk about (Kvale, 1997). According to Yin (1994), there can be exploratory case studies, descriptive case studies, or explanatory case studies. Table 2 lists the case studies in this project and which type of case study they were. A large X means that it is the dominating type of case study and a small x means that this type of case study is less dominating.

Table 2 - The table shows the techniques used for data collection in the different case studies and which type of study the different case studies are.

	Technique for data collection			Type of case study		
	Search of literature	Interviews	Direct observations	Exploratory	Descriptive	Explanatory
Case Study 1	X	X	x		X	
Case Study 2	X	X			X	
Case Study 3	X	X	X	x	X	
Case Study 4	X	X	X	x	X	

The purpose of the case studies has been that they should answer the three formulated research questions, which together shall try to answer the overall objective of this project. Which research question that has been in focus in which case study can be seen in Table 3. A literature study has been performed throughout the research project and has had more or less input for all three research questions.

Table 3 - The table shows the focused research question/questions in the different case studies. A big X in the figure means that it is the main question answered in the case study. A small x symbolizes that the case study also has given an insight to the problem described in the research questions.

	Case study 1	Case study 2	Case study 3	Case study 4
RQ 1: Which parameters influence the efficiency of the logistics process?	X		X	
RQ 2. What is the interface between the logistics- and the product development process?			x	X
RQ 3. How may the logistics department be integrated earlier in the product development process?	x	X		

Summary of the case studies

The studied companies, the network, and the arena in this research are active in the region of Mälardalen in Sweden. Mälardalen is a region of interest with for example a large population, strong purchasing power, and a big part of the total created GNP (Gross National Product) in Sweden is created in this region. Several important global companies are also situated in this region, for example ABB, Ericsson, Bofors, and Volvo CE.

The interviews in the case studies 1, 3, and 4 were carried out in the same way and were semi-structured. Suitable persons were selected with regard to management level, experience, avoidance of sub-optimization, and positions in the company. The interviews were carried out face to face. All persons interviewed received the interview notes and accepted the rendered answers or the answers were discussed and rewritten until the interviewee satisfied. In case study 2 the interview questions were sent in advance electronically to the respondents. The respondents answered electronically and the answers were followed up by an interview by telephone or by a physical meeting. Some more details about the interview studies as choice of companies, how the interviews were carried out, choice of respondents, analysis of the answers and the questions in the different interviews can be seen in appendix 1-4 (appendix 1 for case study 1 and so on). All persons who were asked to be interviewed accepted in all case studies, that is to say that the percentage of answers were 100%. The case studies have also included other sources of evidence in form of direct observations, different documents from the companies, and the study of organizations. The literature study has also provided input to the answers for all the research questions.

Four case studies have been performed during this project. The results from three of the case studies have been presented and published in three different papers. Table 4 shows which case study result/results have been presented in which paper. The result from case study 1 was presented in a technical report, IDPMTR:02:04 (*Logistikutformning på företag i Mälardalen*) and the most essential observations from this case study are summarized in chapter 4.4.

Table 4 - Which paper the results from the different case studies have been presented in.

	Paper A	Paper B	Paper C	Technical Report
Case study 1				X
Case study 2	X			
Case study 3		X		
Case study 4			X	

2.3 Validity and reliability

Validity and reliability are two concepts which are often used to discuss the truth value in research results and to describe how well the data collection has worked out. Validity means to what extension a given methodology actually examines what it is intended to examine and reliability assigns to the consistency of the results (Kvale, 1997). Good validity and reliability are prerequisites to be able to generalize your results.

In a study with a qualitative attempt there is continuous work with validity and reliability. In a quantitative study it is most common that you, before the data collection starts, have chosen a data collection technique with known and acceptable validity and reliability for the desired purpose. In a quantitative study, the concepts validity and reliability are mostly connected to the data collection; that the right data is collected in a reliable way. In a qualitative study validity and reliability are about the data collection, but also about the following analysis of the collected data.

Reliability is about repeatability, which means that the procedures can be repeated, giving the same result. Reliability is dependent on how the measurements are performed and how the information is processed. You have high reliability if different and independent measurements of the same phenomenon give the same result. (Holme and Solvang, 1997). Through describing the procedure of the research in this chapter, chapter 2: Research Methodology, the author has tried to make the research reliable. Since background and experience are different between individuals, the proposed framework in this thesis probably had not looked exactly the same if another individual had built it. Still, the main contents and parts would probably look similar to this proposed framework.

Validity is to what extent researchers have studied what they had sought to study rather than studying something else (Gummesson, 2000). The validity is dependent on what we measure and if this is clear in the research questions formulated (Holme and Solvang, 1997).

The validity is of importance if another researcher repeats the presented research in this licentiate thesis. This is problematic in case studies as every case is dependent on a number of persons interviewed and a number of companies, which are changed and developed over time. The current environment affecting the companies is also changed. To prevent this problem the empirical results are used for getting practical insight in parallel with the literature studies and the theoretical reasoning is the basis for the conclusions in this licentiate thesis. A lot of the empirical results in this research project are from one company within the Volvo group. This is due to the access the researcher has to the company as an industrial Ph. D. student.

There are different tests of validity which are: construct validity, internal validity, and external validity (Yin, 1994). These tests are used within empirical research and consequently they are relevant for case study research. Construct validity is about establishing correct operational measures for the concepts being studied and avoid for example using subjective judgments to collect the data. This has been secured through multiple sources of evidence in the case studies in this research project. Table 2 shows the different techniques used for data collection in the different case studies. Internal validity is to establish a causal relationship and certain conditions are shown to lead to other conditions. Internal validity is only for explanatory case studies and not for descriptive or exploratory studies. In this research, no explanatory case study has been performed, see Table 2, and therefore internal validity is not

of immediate interest in this research project. External validity deals with the problem of knowing whether the findings in a case study can be generalized beyond the immediate case study, which means that the external validity says if the results are valid outside the specific case study. Critics typically state that single cases offer a poor basis for generalizing. Therefore, it is of importance to keep in mind that survey research relies on statistical generalization and case studies rely on analytical generalization. In analytic generalization the investigator is striving to generalize a particular set of results to some broader theory. In this research, external validity has sought to be secured through the research questions being answered by more than one single case study, see Table 3, and the literature study complementing in answering these questions.

3 *Theoretical framework*

This chapter describes some theory within fields essential to the research project. These are logistics, product development, collaboration, and the interface between the logistics- and the product development process.

THIS CHAPTER states some relevant theory for this research project. As described in the introduction chapter 1.1, logistics is the main field for this project in this licentiate thesis. Thus, the first field to be discussed in this theory chapter is logistics. Logistics is a wide field and the delimitation in this project is the interface between the logistics- and the product development process. Theory about the product development process is, therefore, essential input for this research and is the second field in this chapter. Since this research looks into how to collaborate and analyses the interface between the logistics- and the product development process, it is also of interest to introduce the reader to some theory about collaboration and the interface between the logistics- and the product development process. This is done after the field logistics and the product development process have been presented. The theoretical chapter ends with a summary of the literature that has been presented in this theoretical framework chapter.

3.1 Logistics

It has, in principle, always been the case that the things which people demand are not produced where people want to consume them, or are not accessible at the time the customers desire to consume them. In earlier times, no well-developed transportation and storage system existed and the movement of goods was limited to what an individual could personally move and storage of perishable commodities was possible only for a short time. This forced people to live close to the sources of production. This is still the case in some parts of the world. As the logistics systems improved, consumption and production began to separate geographically in most places in the world (Ballou, 1992). The need for transportation of goods, people, and information has arisen and with this also the need for making the logistics efficient.

In military logistics has principally been focusing on an efficient moving and steering of forces. The Gulf War in the Persian Gulf 1991 is called the logistics war. The difference between this war and other wars was that the logistics activities as transportation of all men to the area, moving and controlling during the acts of war, and also the sending home of forces and material were performed by one and the same person. All decisions and movements were performed in considerably less time than in earlier wars. The more modern

understanding of logistics developed during the Second World War. By that time, the development and usage of different mathematical models for optimizing businesses' transportation and steering problems started to be used. After the war, this was transferred to solve transportation and storage problems. After a while the term logistics was introduced.

During the end of 1940s logistics was introduced among researchers and the US industry with a focus on separate activities and mathematical optimization for transportation solutions. During the 1960s the view on logistics was widened to a more total view. In the 1960s and the 1970s there was a new view regarding logistics efficiency. Earlier, logistics had only been seen as a cost driver, but now it was more obvious that logistics could have an influence on the receipts, through, for example, increased customer service. During the 1980s influences from the Japanese car industry had a profound impact on logistics implying a change from producing large series towards to producing on customer orders. During the 1990s until today there has been an increasing importance of involving other actors than one's own company. The importance of information flow, short lead times, and flexible processes has grown. Customer specific orders have expanded which puts larger demands on logistics and there is a higher focus on cost which, for example, has led to outsourcing to other countries within Europe and Asia (Jonsson, 2004).

The increased global competition in today's markets has led to a trend within the industry which is that the physical product becomes less important; the physical parameter, such as functionality, performance, and technical quality are taken for granted. It has become more meaningful to supply a total solution together with the physical product. The service the company offers the customers before, during, and after the supply of the physical product becomes more and more meaningful, which has increased the importance of the logistics performance (Mattsson, 2002a).

The logistics process is an essential part of the production system in a company. The production system is, in this research, the process of creating products from supplier to customer. Production is seen as an integrated process that converts materials into goods. Physical distribution is a part of the production process (Drucker, 1990). Consequently, the production system includes the logistics process.

3.1.1 Definition and scope of logistics

In any organization, the primary goal of logistics is to support the organization's customer service goals in an effective and efficient manner (Lambert et al, 1998). Logistics is a broad field with many different definitions and according to Ballou (1992) *"the overall mission of logistics is to get the right goods or services to the right place, at the right time, and in the desired condition, while making the greatest contribution to the company"*.

In this research, the chosen definition of logistics originates from the Council of Logistics Management (CLM), a professional organisation of logistics managers, educators, and practitioners formed in 1962 (Ballou, 1992):

> *"Logistics is the process of planning, implementing, and controlling the efficient, cost-effective flow, and storage of raw materials, in-process inventory, finished goods, and related information from point of origin to point of consumption for the purpose of conforming to customer requirements."*

This definition is chosen since it includes the whole flow of goods from raw materials to the end user and it is more of a process than a profession that is described.

Except logistics, another commonly used term, which has grown significantly in use and popularity since the late 1980s, is supply chain management. The term supply chain management is often used as a substitute or synonym for logistics. Lambert et al (1998) state that "*supply chain management is the integration of business processes from end user through original suppliers that provides products, services, and information that adds value for customers*", which is a much broader term than the term logistics. One difference between the terms logistics and supply chain management, as defined above, is that supply chain management is the management of all key business processes across members of the supply chain. Examples of the key businesses are customer relationship management and customer service management. This research project deals with what is included in the term logistics.

There are many activities which are associated with logistics and it is hard to put up a complete list. Bjørnland et al (2003) have made a list with some examples of different activities and decisions, which are usually associated to the subject field logistics, and they are:

- Transportation: For example the planning, realization, and following up of transportation.
- Warehousing and inventory management: For example inventory control and the structure of the inventory (as models for order quantities and safety stock).
- Material handling and packing: For example internal transportation and the design of packaging.
- Order processing and customer service activities: For example order transaction, order receiving, delivery, delivery times to the customers, and accessibility of products.
- Forecasting: Forecasting on item level from the sales forecasts.
- Production Planning: The aim of production planning is to see to that capacity is used rationally.
- Purchasing and supply: For example choosing suppliers, strategies for supply of materials, deliveries at the correct time, quality, and price.

As the list of activities above shows, logistics is a wide field and its activities will affect a number of the functional fields in a company. Other fields will in turn affect the logistics considerations (Dowlatshahi, 1996). Figure 2 illustrates how the design for logistics cuts across several functional fields according to Dowlatshahi (1996).

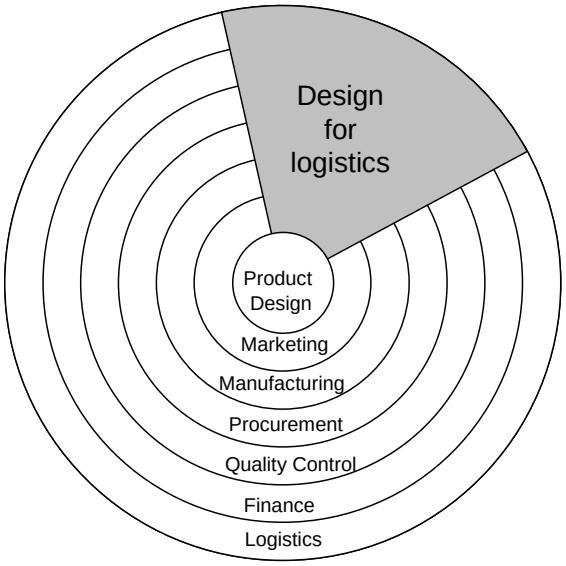

Figure 2 – Design for logistics cuts across several functional fields. The figure is an adoption and modification from Dowlatshahi (1996).

The scope of logistics can also be described from a process view. A process is an arranged sequence of activities which has the aim to transform some kind of input to output. The input might be information or material and so might the output. According to Jonsson and Mattsson (2005) five of the core processes within a manufacturing company are the most central for the logistics process. There are several logistics activities within these five core processes and this is presented in Figure 3 below.

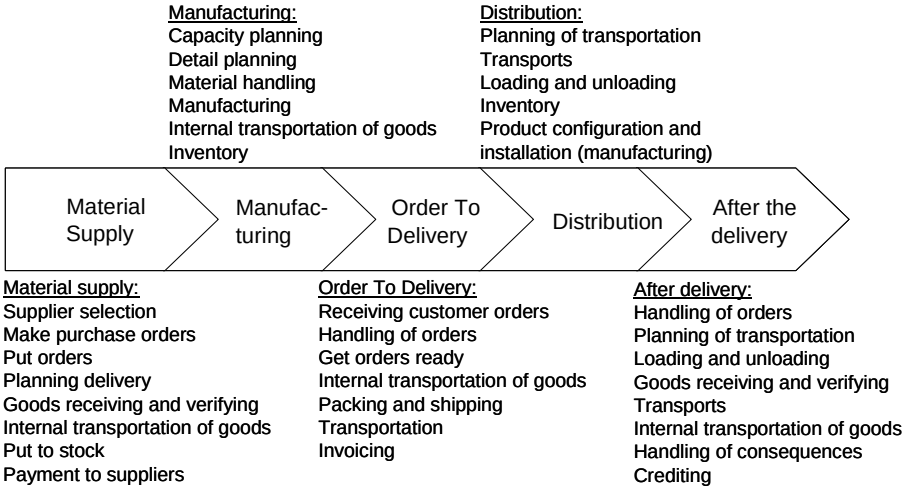

Figure 3 – Logistics activities for the five core processes. The figure is an adoption and modification from Jonsson and Mattsson (2005).

The overall goal for all commercial businesses is to make a profit (Mattsson, 2002a). Therefore, it is of significance to define efficiency parameters that affect the profitability of a company. According to The Free Dictionary (2006) the term efficient means acting with a minimum of waste, expense or unnecessary effort. In this research project, it is essential to look into what an efficient logistics process is and how the logistics process influence the efficiency of a company.

3.1.2 Efficient logistics

The purpose of the logistics process is to improve efficiency in companies. One way of describing efficiency is to use different efficiency parameters, which each represent efficiency in a certain manner. The way the logistics process influences efficiency in companies can be described with the help of parameters which affect the company's receipts, costs, assets, and environment. There are also parameters which indirectly measure the logistics process' ability to achieve the goals of efficiency for a company, for example time and flexibility (Jonsson and Mattsson, 2005).

If the logistics process is going to make a contribution to the company's overall profitability, there are two aspects through which it may do so. The first aspect is to decrease the company's costs and the other is to increase the company's receipts through high customer service. This means that it is as significant to work with customer service as it is to work with logistic costs (Aronsson, et al 2004). Customer service and costs are, consequently, essential values to measure to see if the logistics process fulfils the overall goal for the logistics, to create good customer service to a low cost (Aronsson, et al, 2004). According to Aronsson et al (2004), there are three groups of measurable values: tied up capital, time, and customer service. The tied up capital is, for example, the average value in stock, work in progress, and the product value (tied up capital for the product in terms of the purchasing cost and work laid down). Examples of measurable values in the group of time are: lead-time, throughput time, and inventory turnover. In the group customer service examples of measurable values are: lead-time, information, flexibility, customer adaptations, percentage of fill from stock, delivery capacity, and delivery dependability.

The efficiency parameters that define a company's material flow efficiency and affect the business profitability can be expressed in terms of customer service and costs (Mattsson, 2002a). According to Mattsson (2002a), material administrative customer service is defined as "*all the activities which create surplus value for the customer and which deal with carrying through the customer order process, supply of material flow information, and performance of material administrative services*". Customer service is divided into three parts: delivery, information, and logistics service. The logistics service is to supply services as a complement to the physical product as, for example, bar-codes on products for faster and more secure identification of supplied products or to take the responsibility for controlling the customer's inventory. Delivery service includes different efficiency parameters and they are percent of fill from stock, inventory service level, delivery capacity, delivery dependability, delivery time, and delivery flexibility. Efficiency parameters within the term cost include four different parameters and they are: tied up capital, capacity utilization, volume[5]-, and product

[5] Volume flexibility is sometimes also named capacity flexibility.

mix flexibility, and logistics costs (related to the material flows or production/working up value, for example transportation and inventory costs); (Mattsson, 2002a). Table 5 shows the different efficiency parameters according to Aronsson et al (2004) and Mattsson (2002a) and it also has a short description of the parameters.

The problem with increasing the efficiency of the logistics process is that some activities with the aim to improve some parts of the business might have negative effects on other parts of the business (Lumsden, 1998). One action which has the intention to decrease costs can, at the same time, make the degree of service lower, and by that lower the receipts in the long term. One example of this is the transportation cost. A lower transportation cost might give a higher cost for inventory and the tied up capital would be affected. This means that it is essential to look at the whole logistics field, which consists of three components, according to Lumsden (1998): customer service, tied up capital, and logistics costs. Mattsson (2002a) also writes about the dilemma that some of the efficiency parameters go against each other. To solve this dilemma you might need to give priority to the actions which, at the largest extension, support the company's competitiveness.

Table 5 - Efficiency parameters for the logistics process according to Aronsson et al (2004) and Mattsson (2002a) with a short description of the parameters.

Aronsson et al (2004):		
Group:	Efficiency parameters:	Short description:
Tied up capital	Average value in stock,	How much material there is in stock, in average.
	Work in progress	The tied up capital in form of material in products started in the product flow.
	Product value	How much tied up capital in the product in the part of the flow where the product is right now (the tied up capital is the price for purchasing the tied up material and the laid down work).
Time	Lead time	The time from order is laid until delivery is received.
	Throughput time	The time it takes for a product to pass a certain part of the flow.
	Inventory turnover	How often you change your inventory, based on the average item (based on the average inventory).
Customer service	Lead time	The time from order is laid until delivery is received.
	Information	Exchange of information between suppliers and customers. Important information for the supplier might be the demand from the customer and important information for the customer might be which customer service the supplier is able to offer.
	Flexibility	The ability to create prerequisites to handle unplanned circumstances irrespective of if it is the customers or the markets that is changed. This paramater flexibility includes both delivery, volume and product mix flexibility.
	Customer adoptions	Needs from customer to get the products delivered in a way which differs from the company's normal way to deliver, for example faster transportation or other packages.
	Percent of fill from stock	How big part of the order is available from stock when the customer put the order (only for items in stock).
	Delivery capacity	If the delivery is made in the right time.
	Delivery dependability	Ability to deliver correct products in correct quantity and to correct quality.

Table 5 (Continuation): Efficiency parameters for the logistics process according to Aronsson et al (2004) and Mattsson (2002a) with a short description of the parameters.

Mattsson (2002a):		
Group:	Efficiency parameters:	Short description:
Customer service (Delivery service)	Percent of fill from stock	The probability that an item kept in stock is avaliable from stock, mostly used for dimension inventory size.
(Delivery service)	Inventory service level	The probability that an item kept in stock can be delivered directly at a customer order.
(Delivery service)	Delivery capacity	Ability to deliver according to time agreeed with the customer (companys with customer order driven production instead of item in stock as row above).
(Delivery service)	Delivery dependability	If correct products are delivered in correct quantities.
(Delivery service)	Delivery time	The time from customer order to delivery.
(Delivery service)	Delivery flexibiliy	The ability to change according to the customers wishes in a delivery situation regarding for example delivery time and delivery quantity.
(Information service)	Information	Exchange of information between suppliers and customers. Important information for the supplier might be the demand from the customer and important information for the customer might be which customer service the supplier is able to offer.
(Logistics service)	Logistics service	Supply services as complement to the physical product as for example bar-code on products for faster and more secure identifying of supplied products or to take the responsible for controlling the customer's inventory.
Cost (Resource consumption)	Tied up capital	Capital which is tied up and can not be used in a better way. The parameters average value in stock, product value and work in progress (parameters according to Aronsson et al (2004)) are examples of tied up capital.
	Capacity utilization	Capacity is here an expression for production- and material flows resources from a volume perspective. This means that it is a performance measure for the resoruces that exist within a company.
	Capacity- (volume-) and product mix flexibility	Product mix flexibility: The ability to quickly and cost efficiently adapt the production and material supply to fluctuating demand between existing products. Volume flexibility: The ability to quickly and cost efficiently increase or decrease the produced volumes in the company, irrespective of if there at the same time are changes in the mix between products.
	Logistics costs	May be splitted in costs related directly to the material flows and costs related to production/working up value. For example transportation and inventory cost.

To make the business processes more efficient and, consequently, also the logistics process, there are several different ways that can be used, according to Mattsson (2002a). These strategies for making processes more efficient can be classified in the following categories:

- Simplification and rationalization: Render more efficient through reducing the complexity in the flows and processes and eliminating unnecessary activities.
- Exchange of information: Make the process more efficient through faster communication and information more adapted to its purpose.
- Automation: Make the process more efficient through transfer identification activities, information activities, and decision activities to computerized systems.
- Reconfiguration: Make the process more efficient through redistribution and putting together performance and responsibility for activities and sub-processes between departments and companies.

– Collaboration: Make the process more efficient through collaboration and synchronization of material flows, payment flows, and information flows.

According to Mattsson (2002a), these strategies are preferably performed in a certain order, which is to start with simplification and rationalization. After this it is suitable to improve the exchange of information and thereafter to automate. Closer collaboration and synchronization of the different flows are preferably done last.

3.1.3 Summary of the logistics theory

The history of logistics has been mentioned in this chapter; the development from being a military concept transferred to companies. The chosen definition of logistics in this research project, according to the Council of Logistics Management (CLM), a professional organisation of logistics managers, educators, and practitioners formed in 1962 (Ballou, 1992), was presented. In the subchapter about efficient logistics, it is mentioned that customer service and costs are essential values to measure to see if the logistics process fulfils the overall goal for logistics: to create good customer service to a low cost and contribute to the company's overall profitability (Mattsson, 2002a, Aronsson et al 2004). Efficient logistics means to perform the logistics activities in such a way that the logistics process contributes as much as possible to the company's overall profitability and then, according to the theory, the terms customer service and cost are essential. Within these two terms a number of examples of parameters which will affect the efficiency of the logistics process are mentioned.

A produced product will, later in the process, be stored, handled, and transported. If it is considered as early as in the design phase of the product how it will be produced, assembled, and handled in the production and logistics process, this will gain the system later on in the process. This is a part of *concurrent engineering* (Storhagen, 2003) and it is pointed out that there should be collaboration between the logistics- and the product development process. This makes it essential to look into literature about the product development process.

3.2 Product development process

There are several worldwide tendencies in the economy that have affected product development. Bullinger and Warschat (1995) mention three main tendencies that the competitive situation can be characterized by today. Firstly, there is a shift from a seller's to a buyer's market and this means that the supply of products is higher than the demand. Secondly, the increasing globalization has led to a global spread of markets and lines of business. This is leading to a larger number of powerful competitors in regional markets. The last characteristics are the change that has occurred with respect to the significance of technology. Nowadays, the control of technology is a basic requirement for participating in innovative markets, but it is not sufficient for the success of a new product. Companies in innovative markets which are not able to react in an appropriate and efficient way to the three tendencies above will lose competitiveness. A variety of products in the market and short reaction-time at a low cost level must be ensured and this has led to some key targets for product development (Bullinger and Warschat, 1995):

– Reduction of the Time to Market to increase market share.

- Improvement of the overall quality, which meets the needs and wishes of the customers.
- Reduction of product and process development costs to decrease the pay-off period.

The development of new products and processes is a focal point of competition. Especially, there is an increasing need for firms to get to the market quickly and efficiently with products that are well matched to the customers' needs and expectations. Wheelwright and Clark (1992) have written about three forces in particular that drive the product and process development forward:

- Intense international competition
- Fragmented, demanding markets
- Diverse and rapidly changing technologies

Ulrich and Eppinger (2004) describe the product development process as a set of activities beginning with the perception of a market opportunity and ending with the production, sale, and delivery of a product. In this definition, the market introduction and disposal of the product is not included and, instead, the definition of the product development process in this research project is the one according to Bullinger and Warschat (1995) which reads:

> *"The product development process refers to the entire product life cycle time. It covers the process from the idea for a product and its production through to its market entry and disposal. The process is a defined order of specific tasks which is required to generate the necessary information for every stage of the process.*

This definition has been chosen since it concludes the whole life cycle of the product. It covers the whole process of developing a product, starting with an idea, and does not stop when the product is developed; it also includes bringing it to the market. Also, the disposal of the product is covered, which the author believes is essential today with the environmental stresses we have. This is not the case in, for example, Ulrich and Eppinger´s (2004) definition of the product development process.

With the complex nature of modern technology we have today, it is rarely possible for an individual to tackle the design and development of a major new product single-handed. Often a large team is required. When you have a large team involved, you introduce problems with organization and communication. This implies that the design process must be planned carefully and executed systematically and there is a need of describing the product development in different phases, (Pahl and Beitz, 1996). There are many authors that have described the typical phases in the product development process: Pahl and Beitz (1996), Andreasen and Hein (1986), Wheelwright and Clark (1992), Bullinger and Warschat (1995), and Ulrich and Eppinger (2004). There are some differences, but in many respects the descriptions of the product development process are pretty similar to each other. For example, according to Wheelwright and Clark (1992), the typical phases of the product development process are:

- Concept Development
- Product Planning
- Product/Process Engineering

– Pilot Production/Ramp-up

In the two first phases – concept development and product planning – information about market opportunities, competitive moves, technical possibilities, and production requirements must be combined to lay down the architecture of the new product. This includes its conceptual design, target market, desired level of performance, investment requirements, and financial impact. The primary activity in the next phase – product/process engineering – is the design and construction of working prototypes and the development of tools and equipment to be used in commercial production. The conclusion of the detailed engineering phase of development is marked by an engineering "release" of "sign off" that signifies that the final design meets requirements. In the last phase – pilot production/ramp-up – the individual components (which have been built and tested on production equipment) are assembled and tested as a system in the factory. At this stage, all commercial tooling and equipment should be in place and all parts' suppliers should be geared up and ready for volume production. This is the point in development at which the total system – design, detailed engineering, tools and equipment, parts, assembly sequences, production supervisors, operators, and technicians – come together (Wheelwright and Clark, 1992). These phases can also be illustrated in a process figure, as in Figure 4.

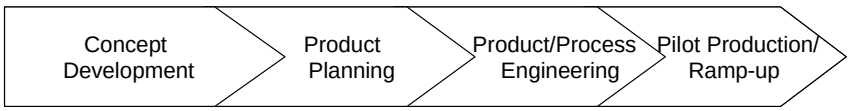

Figure 4 - The different phases in the product development process. The figure is an adoption and modification from Wheelwright and Clark (1992).

3.2.1 Concurrent Engineering

In earlier times, a sequential process of developing products with different phases in the process carried out without collaboration or insight from other activities was more common. It was usual that the industrial engineering work was started when all the product development work was finished. This resulted in long development times and that the coordination between product development and industrial engineering failed (Olsson, 1997). In the sequential process of developing products, the constructors seldom have contact with the users, the sequential process is very slow with a lot of waiting times between the activities, and the communication between constructors, production personnel, and marketing/selling personnel is poor (Ottosson, 1999). The Japanese car industry serves as a model to leave the sequential process of developing products when they started their resource-effective product development (lean product development). The Japanese approach was to start the next step of development before all parts in the earlier step were completely finished (Womack et al. 1990).

In the age of more heterogeneous markets, more specific customer demands, complex technologies, and reductions in product life cycle, the need of concepts as concurrent engineering (Prasad, 1997), integrated product development (Andreasen and Hein, 1986) and simultaneous engineering (Hartleey, 1991) has increased and has now been recognized as strategies for product development. In this licentiate thesis only the concept concurrent engineering has been chosen to be discussed since this is a well established concept and is the most frequently referred concept by logistics researchers (Klevås, 2005). Example on

logistics researchers within this area are for example Gupta and Dutta (1994), Johansson (2006), Dowlatshahi (1996). According to Bullinger and Warschat (1995) the idea of Concurrent Engineering is to develop high quality products and offer them at a lower price and in significantly shorter time to the competitive global market.

There is no definitive definition of what should be included in Concurrent Engineering, but a definition often used for Concurrent Engineering was developed in 1986 by the Institute of Defense Analyses (IDA), which reads (Carlson-Skalak, 2002):

> *"Concurrent engineering is a systematic approach to the integrated, concurrent design of products and their related processes, including manufacture and support. This approach is intended to cause the developers, from the outset to consider all elements of the product life cycle from conception through disposal, including quality, cost, schedule, and user requirements."*

One drawback of the parallel methods is that it is easy to loose the radical innovations, which are more common in the sequential process of developing. The radical innovations do not have a demand from the market until they are introduced on the market and a bigger part of the market has realized the possibilities of the product (Ottosson, 1999).

There are different ways of describing product development and different views are described in the literature. For example, Thomke and Fujimoto (2000) describe product development as a number of problem-solving cycles. With their view of the product development, they suggest that faster product development can be achieved if identification and solving of design problems are made earlier in the product development process. In the product development phase when the engineering details are designed, the production methods which can be used when producing the item are decided in a very big extension. It is essential that persons with knowledge about processes and assembly from the production are involved in these early product development phases before the drawings are ready and there is time to have influence (Andreasen and Hein, 1986).

Most of the methodologies for concurrent engineering ignore a critical element – the logistics. Traditionally, logistics design usually comes into focus after the product has been engineered. This is too late, because by this time a significant portion of the total product lead time has been used and there is little time left for developing a proper strategy for manufacturing the product (Gupta and Dutta, 1994).

In the past, designers have tried to involve only marketing and manufacturing requirements in the design instead of including the logistics requirements as well. The consequence is inefficiency in the overall product and system performance. The design decisions made in the early phases of the product development process will have significant impact upon future manufacturing and logistics activities (Dowlatshahi, 1996).

3.2.2 Summary of the product development process discussion

This theoretical chapter has mentioned some relevant theory for this research project within the product development process. Tendencies of the competitive situation affecting the product development process and key targets for the product development process have been mentioned. The chosen definition of the product development process according to Bullinger and Warschat (1995) can be read in this chapter. The different phases in the product development process are brought up and the described phases in this licentiate

thesis are according to Wheelwright and Clark (1992). Some theory about Concurrent Engineering is put forth in chapter 3.2.1 and the chosen definition of Concurrent Engineering in this project is presented.

According to Nilsson and Jackson (2004), the main purpose of Concurrent Engineering is to increase the collaboration between different departments in the product development process. This, together with the statement by Gupta and Dutta (1994) above, makes the fields collaboration and interfaces between the logistics- and the product development process essential to consider.

3.3 Collaboration and interfaces within logistics

Almost all processes and products must be designed before they can be implemented or manufactured. This is mainly because two groups of people with different knowledge and tools will be involved. One designs and the other implements or produces, (Hubka and Eder, 1996). With two groups of people involved there is a need for collaboration and an interface exists between the two groups.

The main filed for this licentiate thesis is the logistics field and for this reason the chosen literature about collaboration and interfaces is mainly from the logistics research e.g. Wynstra et al (2001), Gupta and Dutta (1994).

3.3.1 Collaboration

The success of project work depends on the collaboration and participation of staff. Teamwork is a kind of collaboration and is characterized by a group of people who are responsible for the execution of their tasks, allocation of the tasks to the team members, for solution of occurring problems, and for communication with other organizational units. Advantages of teamwork can be seen in the shortest possible closest loops which give more work in parallel processes, integration of knowledge, and motivation and performance. Collaboration and communication are significant performance factors (Bullinger and Warschat, 1995).

According to Cousins (2002), the central concept of a relationship approach is concerned with the collaboration and sharing of resources, either physical or intangible, for example intellectual know-how or technological processes, as well as the primary goal of gaining competitive advantage through improvements in product and process redesign to be more efficient in the supply of the end product. It is essential that relationships and collaboration focus on giving definable deliverable outcome and delivering value.

The demands for many companies today are good liquidity, high flexibility, short delivery times, and many product variants. At the same time, material flows without intermediate storing are more common. In these situations, the dependency between the increase of functions and the demand for collaboration between the different fields of responsibilities increases. Instead of a functional organization, a more flow-oriented or process-oriented responsibility allocation and organization, with focus on adding value to the customer instead of optimizing the use of resources within an organization, is needed. This focus normally needs more collaboration from several of the traditional functions; see Figure 5

(Jonsson and Mattsson, 2005). The figure illustrates a focus on processes which cut across the functions.

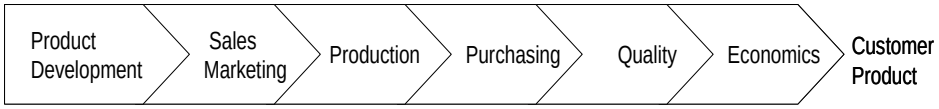

Figure 5 - Process oriented organization structure. The figure is an adoption and modification from Jonsson and Mattsson (2005).

Today there are a lot of discussions in the logistics context about how different companies and organizations, in the best way, are able to collaborate to achieve higher competitiveness together. Traditionally, the focus has been on individual companies, individual functions, and individual machines. It gives entirely new dimensions and opportunities if you instead look towards what is between the companies, functions, and machines (Storhagen, 2003). NUTEK (2002) has written that research indicates that geographical closeness between actors in different forums for collaboration is able to create competitiveness in the international market. Regions who realize this are able to develop their competitiveness and development ability, which leads to sustainable growth. For this kind of development, it is necessary that the industry in the region and the organization for research and education together with politicians and society co-operate and coordinate their resources efficiently.

Storhagen (2003) writes about two driving forces which are the basis for the acceleration of logistics today, and they are, according to him, a very strong focus on customers and a development towards collaboration within and between organizations. The development is consequently going towards increased collaboration.

Mattsson (2002b) has mentioned some motives behind the increasing need for collaboration within logistics and they are:

- Increased dependency on suppliers
- Outsourcing – value from sub-suppliers is increasing which increases dependency of transportation
- Self-support within the industry has been replaced by the value-added networks
- An increasing amount of deliveries directly into production, instead of to stock
- The technical development of new IT-system for logistics creates new requirements and opportunities for efficient logistics solutions, both internally and externally
- Shorter product life cycles, more product introductions, and more product variations

3.3.2 Interface between the logistics- and the product development process

Product development has influences on all parts of the business. As a firm develops a new product, it is basically simulating the entire business. It is meaningful to think about how the product will be manufactured, what sourcing will be involved, what the supplier chain will look like, who will be involved in distribution, and how the new product will be promoted and serviced (Wheelwright and Clark, 1995). Consequently, product development has interfaces to many different fields, and one of them is logistics.

The market trend today is an increasing need for getting to the market faster and more efficiently with products (Wheelwright and Clark, 1992). This has led to a need for working with more overlapping activities in product development projects, which is called

Concurrent Engineering. This involves decisions being made regarding, for instance, the assembly system and logistics before the product is completely developed (Johansson and Medbo, 2004). Already when the character of the product has been defined, true product and logistics design can begin. Product character and basic product features have a significant role to play in the determination of internal as well as external logistics (Gupta and Dutta, 1994). According to Klevås (2005), one way of integrating the logistics considerations in the product development process is to include logistics competence in the cross-functional teams when working with Concurrent Engineering.

It is pointed out in the theory above that it is important to involve the logistics department in the product development process. Wynstra et al (2001) have found three critical issues for managing supplier involvement in the product development process, which, according to the author of this licentiate thesis, is comparable with integrating the logistics department in the product development process. These issues are according to Wynstra et al (2001):

- Identifying specific processes and tasks that need to be carried out, aimed at the integration of product development and sourcing processes.
- Forming an organization that supports the execution of such tasks.
- Staffing the organization with people that have the right commercial, technical, and social skills.

The first issue implies to identify the kind of managerial activities that need be organized and carried out to support the involvement of suppliers in developing new products. The second issue is to have an internal organization that supports the execution of the various activities and the third issue means to have adequate human resources involved. These three issues are the most significant problems for supplier involvement in product development when they occur at the manufacturer. Wynstra et al (2000) point out that it is essential to differentiate between different management areas when considering purchasing involvement in product development. According to Wynstra et al (2001) involvement activities are performed at different hierarchical levels in the organization. Engineers and operative persons (for example buyers) discuss the design of a new part, managers evaluate past collaboration and discuss potential new projects, directors draw guidelines for their department's role in accordance to the product development department, and the general management make strategic outsourcing decisions. A critical requirement for successful supplier involvement is adequate human resources. Participation of representatives from purchasing in the product development process means that the representatives are better informed about the project and they are able to influence the product development decisions that are made in the project.

Other researchers who have written about the integration of the logistics in the product development process are for example Johansson (2006), Klevås (2005), Bramklev (2003), and Peter (1996). Klevås (2005) has presented a model for integration of logistics and packaging considerations in the product development process, The Design for Packaging Logistics approach.

3.3.3 Summary of interfaces and collaboration

The theoretical chapter about interfaces and collaboration has stated the increased importance of collaboration both within and outside the company. It has been pointed out that there is an interface between the logistics- and the product development process and the

involvement of the logistics department in the product development process is of great importance. The human resources involvement and different management areas of the involvement in the product development process, according to Wynstra et al (2000), are mentioned in the chapter about interfaces between the logistics- and the product development process.

Some motives behind the increased need of collaboration within logistics, according to Mattsson (2002b), were mentioned in this chapter. The last motive is about shorter product life cycles and this shows the connection to the product development process and shows the importance of the interface between the logistics- and the product development process.

3.4 Summary of the theory introduced

The theoretical framework chapter has summarized literature about logistics, product development, collaboration, and interfaces within these two fields. The most essential issues from these fields will be pointed out and the chosen definitions that have been made for some key terms in this research project will be summarized in this last chapter of the theoretical framework. Also some own comments from the author on the literature within these fields are made in this chapter.

Logistics can be described in several ways and in this licentiate thesis the following definition of the term logistics has been chosen:

> *"Logistics is the process of planning, implementing, and controlling the efficient, cost-effective flow and storage of raw materials, in-process inventory, finished goods and related information from point of origin to point of consumption for the purpose of conforming to customer requirements."*

This definition of logistics originates from the Council of Logistics Management (CLM), a professional organisation of logistics managers, educators, and practitioners formed in 1962 (Ballou, 1992). It includes the whole flow of goods from raw material to the end user and is, therefore, chosen to define the term logistics in this licentiate thesis.

Logistics is a wide field and it cuts across a number of the different fields within a business and, according to Dowlatshahi (1996), these fields are product design, marketing, manufacturing, procurement, quality control, and finance.

Examples of parameters that affect the efficiency of the logistics process have been mentioned in the chapter about efficient logistics. Some of the parameters are the same and some are different between the authors. Aronsson et al (2004) has three parameters describing the tied capital, which Mattsson (2002a) has seen as one parameter (tied-up capital). In Table 6 all parameters from the theoretical framework are summarized and the parameter tied-up capital includes the three parameters average value in stock, work in progress, and product value, according to Aronsson et al (2004).

Table 6 - Summarization of the parameters affecting the efficiency of the logistics process from the theoretical framework.

Parameters affecting the efficiency of the logistics process (from theoretical framework):	Short description:
Throughput time	The time it takes for a product to pass a certain part of the flow.
Inventory turnover	How often you change your inventory, based on the average item (based on the average inventory).
Tied up capital	Capital which is tied up and can not be used in a better way. The parameters average value in stock, product value and work in progress (parameters according to Aronsson et al (2004)) are examples of tied up capital.
Capacity utilization	Capacity is here an expression for production- and material flows resources from a volume perspective. This means that it is a performance measure for the resoruces that exist within a company.
Logistics costs	May be splitted in costs related directly to the material flows and costs related to production/working up value. For example transportation and inventory cost.
Flexibility	The ability to create prerequisites to handle unplanned circumstances irrespective of if it is the customers or the markets that is changed. This paramater flexibility includes both delivery, volume and product mix flexibility.
Customer adoptions	Needs from customer to get the products delivered in a way which differ from the company's normal way to deliver, for example faster transportations or other packages.
Percent of fill from stock	How big part of the order is available from stock when the customer put the order (only for items in stock).
Delivery capacity	Ability to deliver according to time agreed with the customer.
Delivery dependability	If the correct products are delivered in correct quantities.
Delivery time	Time from customer order to delivery of the order.
Information	Exchange of information between suppliers and customers. Important information for the supplier might be the demand from the customer and important information for the customer might be which customer service the supplier is able to offer.
Logistics service	Supply services as complement to the physical product as for example bar-code on products for faster and more secure identifying of supplied products or to take the responsible for controlling the customer's inventory.

The definition of the product development process that has been chosen in this research project includes the market introduction and the disposal of the product and reads (according to Bullinger and Warschat (1995)):

"The product development process refers to the entire product life cycle time. It covers the process from the idea for a product and its production through to its market entry and disposal. The process is a defined order of specific tasks which is required to generate the necessary information for every stage of the process."

The literature mentions the importance of collaboration both within the company and outside the company. The predominating way of working in the product development process today is according to the ideas of Concurrent Engineering, which means working with more overlapping activities. A common definition of Concurrent Engineering was developed in 1986 by the Institute of Defense Analyses (IDA) (Carlson-Skalak, 2002), and it is the chosen one also in this project.

> *"Concurrent engineering is a systematic approach to the integrated, concurrent design of products and their related processes, including manufacture and support. This approach is intended to cause the developers, from the outset to consider all elements of the product life cycle from conception through disposal, including quality, cost, schedule, and user requirements."*

Andreasen and Hein (1986) point out the importance of involving persons with knowledge about processes and assembly early in the product development phases when there still is time to have influence. This confirms that the collaboration between the product development process and other parts of the company is essential. In this licentiate thesis, the chosen focus has been the collaboration between the logistics department and the product development process and the interface between the logistics- and the product development process.

The literature states that the product character and product features have a lot of influence on the design of both the internal and external logistics, according to Gupta and Dutta (1994). The design of logistics can start straight away once the character of the product has been defined. Consequently, the literature says that the product development process has an influence on the logistics process and that it is essential to involve the logistics department early in the product development process. This raises the need for analysing the interface between the logistics- and the product development process and to integrate the logistics department early on in the product development process.

A lot of literature exists within the logistics field, but most of the literature focuses only on this field and does not look at the interfaces to other fields that logistics is influenced by and also exerts influence on. Some literature about interfaces exists, as logistics being involved too late in the product development process is not a new problem. But what still is missing is literature describing how companies should act and do something to really integrate the logistics process in the product development process. What is needed is a definite set of rules that companies can use and transform to their own businesses.

4 Summary of papers

This chapter includes the empirical results from the research project. Hence, the chapter includes contributions from the papers published from this research project and a summary of the results from those papers. The chapter also contains a summary of case study 1.

IN THIS RESEARCH PROJECT three papers have been published. Results from the performed case studies are presented in these papers. This is the contribution from this project, summarized in the chapter below.

4.1 Paper A: Efficient logistics development through regional collaboration

The objective of this paper was to investigate how regional collaboration may contribute to improve logistics development within the manufacturing industry. Case study 2 has been the main input in this paper. Paper A gives a contribution to answer research question 3: *How may the logistics department be integrated earlier in the product development process?*

The case study investigated examples of regional collaboration and co-ordination within logistics development between the industry, the public, and the university. The case study investigated the effect of two initiatives regarding regional collaboration – PLC (Production- and Logistic Center at Mälardalen University) and ELN (Eskilstuna Logistic Network).

The case study indicates that the network and the arena have had an impact on the region regarding creating contacts and increasing knowledge within logistics. They will definitely, in the long run, have an influence on the logistics efficiency in the region. More knowledge increases the ability to develop and the ongoing logistics activities will increase the logistics efficiency. Direct effects from the network and the arena are new education programs, a personnel pool, a container terminal, projects initiated, activities to increase interest for logistics, new contacts initiated, and more research within the logistics field. These kinds of networks and arenas in a region will contribute to highlight the region as having a positive climate which will facilitate new establishments in the region.

The best strategy to grow via alliances may be to move slowly, and start with simple alliances and then move towards more complex ones as alliance experience and talent are acquired (Elmuti and Kathawala, 2001). This emphasizes that PLC and ELN can be embryos for more complex strategic alliances between companies, which will lead to more efficient logistics solutions for companies involved.

A result from the case study is that it is not the participation in regional collaboration in itself that will give more efficient logistics in a company. As the case study indicates, the network

and the arena constitute forums for collaboration where you have seminars, evoke project-ideas, create contacts, and raise meaningful questions. It is the logistics activities; initiated in these forums, which lead to more efficient logistics in the companies involved, see Figure 6. This is one way of working to obtain a more efficient logistics through collaboration. This can also be applied to the interfaces between different departments and processes within a company, as for example the interface between the logistics- and the product development process. It is essential that the logistics department is involved in the product development process. Forums for collaboration, where people can meet, are of importance to form. But it is not enough only to be involved and present in different forums, as for example meetings. It is also essential that the logistics department is active in the work and in the different decisions that are made, through different activities. The way of working presented in Paper A and Figure 6 below offers a suggestion for how to integrate the logistics department earlier in the product development process.

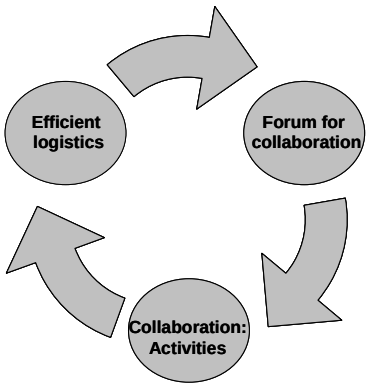

Figure 6 - It is the logistics activities, created in the forums, which assume to contribute to more efficient logistics.

4.2 Paper B: The impact of outsourcing on logistics

The aim of this paper was to identify critical parameters that affect the efficiency of companies' logistics. The objective was also to investigate which of the logistics parameters should be considered before making sourcing decisions. Two research questions were formulated in this paper:

- Which critical parameters affect the efficiency of companies' logistics and how?
- How and which parameters need to be regarded when making outsourcing decisions?

This paper relies on input from case study 3 and mainly gives input to the answer of research question 1 in this research project: *Which parameters influence the efficiency of the logistics process?*

The case study was performed at a company within the Volvo group. The interviews were conducted with persons within the functions logistics, purchasing, and production. They were mostly performed with people in managerial positions, due to the increased need of focusing these questions on a managerial level. The case study investigated the influence on

the efficiency of the logistics process when outsourcing. The objective was to define which parameters are essential to pay attention to for obtaining a more efficient logistics process and which of these parameters should be considered when making outsourcing decisions?

An indication in the case study is that it is essential to have **correct input** and data in the logistics process, as for example correct forecasts, reliable and long-term delivery plans, correct data in the systems, and efficient communication. Correct input can be seen as a fundamental parameter, to be able to reach an efficient logistics process and good sourcing relations. Without correct input there will be errors and unnecessary uncertainties in the company's system, which lead to an inefficient logistics process. When you have correct input there are some parameters that are essential to follow up, measure, and develop to reach a more efficient logistics process. To be competitive and reach an efficient logistics process the two parameters **delivery capacity,** ability to deliver when the need arises, and **delivery dependability**, capability to deliver the correct products in the correct quantity, are significant, according to the case study, since the deliveries at the right time are significant to get the production running. It is essential for the case study company that the **supplier has sufficient capacity** for the company's volumes and that the supplier has the **correct technical equipment**. This is because it is essential to be able to secure the deliveries from the supplier. The **transportation cost** is a part of the total cost and should be regarded when discussing an efficient logistics process, according to Volvo. The transportation time is crucial for the lead time and will affect the ability to deliver to the customers. The **physical distance and localization of the supplier** will, for example, put more requirements on the transportation system, the quality of the articles, and the safety stock. The **quality** of the products and information handled within the logistics process are central. Poor quality of articles will, for example, put requirements on the supplier's capacity to make replacement articles and also the levels of stock are affected. How flexible the logistics process is, for example the ability to change fast to increased volumes, is a significant factor for Volvo, i.e. **flexibility**. If Volvo's suppliers do not use the special Volvo packages it will cause extra costs and it is, therefore, central to take **packaging** into consideration when dealing with the logistics process. **Planning and control** of the activities in the logistics process are essential, depending a lot on correct input into the system. Planning and control safeguard deliveries and internal capacity and will affect delivery quantities and frequencies and thus the transportation and stock cost. **Total cost** is a parameter which is influenced by a number of factors in the logistics process and, therefore, the respondents consider the total cost as an essential parameter to follow up and work on. These parameters are summarized in Table 7 below.

Table 7 - Parameters that are essential for the efficiency of the logistics process from case study 3.

Parameters affecting the efficiency of the logistics process (from case study 3):	Short description:
Deliviery capacity	Ability to deliver when the need arises.
Delivery dependability	Capability to deliver correct products in correct quantity.
Capacity and correct technical equipment at the supplier	Some different parameters are important to secure at the chosen supplier.
Total cost	The total cost in the logistics system.
Quality	Stock levels are affected by quality, for example poor quality takes capacity to make re-place items both in production and at supplier.
Transportation cost	Transportation cost of material from supplier to company.
Physical distance and localization of the supplier	Some different parameters are important to secure at chosen supplier.
Flexibility	For example the ability to rapid change to increase/decrease volumes.
Planning and control	Secure deliveries and internal capacity and affect delivery-quantities and delivery-frequencies.
Packaging	For example extra costs if suppliers are not using standard packages.
Correct input	For example correct data in the system, forecast accuracy, correct forecast in to the system, reliable and long-term plans out from the company, written and spoken communication.

The case study also analyzed which of these logistics parameters that should be regarded when dealing with sourcing decisions. The case study showed that all the parameters except for packaging should be regarded when making sourcing decisions. This means that the following logistics parameters are essential to take into consideration for sourcing decisions: delivery, total cost, transportation costs, transportation time, flexibility, capacity, and correct technical equipment at the supplier, quality, and planning and control.

The case study also shows the importance of collaboration and working cross-functionally. Both internal and external collaboration are mentioned as meaningful. Internal collaboration is collaboration within the company, between different functions or departments, where the logistics- and the product development process might be one example. Examples of external collaboration are with other Volvo companies, the academy, suppliers, or the local authorities.

4.3 Paper C: The interface between the logistics and the product development process

In this paper the objective was to investigate the interface between logistics- and the product development process within the manufacturing industry. The input for this paper has been generated through case study 4. The result from this paper has given information which has

been used to answer research question 2: *What is the interface between the logistics- and the product development process?*

The case study was conducted at a company within the Volvo Group in Sweden. The case study was performed to answer the overall objective of the paper: investigate the interface between the logistics- and the product development process, through at the study of decisions in the product development process that affect the logistics process and which problems today exist at this interface. It is important to define the interface and questions as, for example what type of control and management should be used, what type of dependencies exists to other tasks, how may efficient communication between provider and recipient be achieved, how should the interface be monitored, measurable and evaluated are interesting (Browning, 1997).

The result from this paper is that today there are several problems at the interface between the logistics- and the product development process, for example, there is a need for a more narrow focus of logistics activities and communication needs to be improved. The focus of the logistics activities also need to be in the early phases of the product development process. Good communication within a system can be a key source to competitive advantage (Lambert et al, 1998). But the logistics department also needs to elucidate its needs and demands. These problems are summarized in Table 8. In the product development decision process, there are different decisions which affect the logistics process, for example the make-or-buy decisions, the supplier selection, and the different product development solutions, see Table 8. The make-or-buy decisions may appear on both a strategic and a more operative level. It is a strategic decision if it concerns producing something outside or inside the company which has a big impact on the company. An operative make-or-buy decision is more one concerning whether a specific and smaller item should be produced inside the company or be bought externally. To be able to integrate the logistics department earlier in the product development process, it is essential to focus and find solutions to the identified problems in Table 8.

Table 8 - The problems at the interface between the logistics- and the product development process and the decisions in the product development process that affect the logistics process.

Problems in the interface between the logistics- and the product development process:
Communication.
Logistics is not discussed in the product development project reviews.
The logistics department has not specified their demands and needs.
The logistics department involved too late to have influence.
Commonality (poor system for calculation).
"Status": Product development projects have never been delayed because of logistics. The logistics department needs to be better at pointing out the logistics consequences when product development projects are delayed.
Product development decisions which affect the logistics process:
Make-or-buy
Supplier selection
Product development solutions
Choice of material

4.4 Case study 1: Logistics design at companies in Mälardalen

Case study 1, Logistics design at companies in Mälardalen has not been presented in any published paper. Instead, the case study is summarized in this chapter. The case study is also documented and summarized in a technical report: *Logistikutformning på företag i Mälardalen*, Andersson (2002). The objective of this study was to investigate which methods and tools that are used within producing companies today and to understand which parameters affect the efficiency of the logistics process in the companies studied. The results from this case study have mainly given input to the answers to research question 1: *Which parameters influence the efficiency of the logistics process?*

4.4.1 Case study companies

The case study has been performed at two producing companies with similar products with about the same complexity, and this was the reason why these two companies were chosen. Also, another company, within the same group of companies as one of the producing companies, participated in the case study. The reason for this was that this company is the main supplier of logistics services to the producing company. Both companies are geographically situated in the region of Mälardalen. The companies were chosen since the answers from these companies are assumed to be representative for other similar companies.

4.4.2 Data collection

The data was collected mainly through semi-structured interviews. A literature study has also been conducted and data has, to a smaller extent, been collected through direct observations. In the semi-structured interviews, eight persons in total were interviewed at the three companies. They were chosen because of their different positions within the companies, because they were working with logistics questions on different levels within the companies, and they have competence within the logistics field. For further details on how the interviews were carried out and the interview questions, see Appendix 1.

4.4.3 Summary of results

The case study shows that there is a lack of methods and tools on an overall level for the design of logistics. There are some systems and tools being used, but only within limited fields of the logistics process.

A lot of parameters have presented themselves in the case study, essential to consider in the design of the logistics process. In the technical report they were summarized in 28 bullet points. Some parameters are mentioned by more than one person and they are: precision, delivery at the right time, tied-up capital, correct input, and cost. Several parameters which affect the efficiency of the logistics process have been highlighted in the case study and they are summarized in 26 bullet points in the technical report. The parameters supplier delivery frequency, forecast accuracy, correct input, and cost have been mentioned by more than one person. Correct input is defined as, for example, correct forecasts and correct technical information in the systems, such as transportation times, operation times, and lead times. The parameter affecting the efficiency of the logistics process mentioned by most persons was forecast accuracy. Correct forecast and forecast accuracy are similar parameters and consequently forecast accuracy can be included in the parameter correct input. Other parameters which appeared in the case study as essential for the logistics process efficiency were: the supplier (for example the relation to the supplier and the attitude at the supplier),

transportation (from the supplier to the manufacturing plant and the distribution from the manufacturing plant), and the flexibility in the logistics process (how fast you are able to increase or decrease the produced volume at the manufacturing plant). There are a few different precision concepts which are included in the parameter precision. For example departure precision (the carrier departs from the supplier on time), arrival precision (the carrier arrives on time), transport precision (the carrier keeps the transportation time), and delivery precision (the supplier's ability to deliver the correct quantity at the correct time to the supplier's shipping dock). Some of the parameters to consider for the design of the logistics process and the parameters affecting the efficiency of the logistics process are in accordance with each other: cost and correct input. This means that these are examples of the parameters that affect the efficiency of the logistics process to be considered when designing the logistics process. Also the parameters precision and deliveries at the right time and forecast accuracy have a connection with each other. The forecast accuracy is the first input in the chain of data input. If this data input is wrong, it will have consequences in the whole subsequent chain of activities. This may lead to it being more difficult to reach high precision and receive deliveries at the right time. In some way tied-up capital and frequency also have a connection. The delivery frequency is how often you receive materials from your suppliers. Lower frequency of taking home your materials will give lower costs for transportation, but higher costs for tied-up capital. This implies a need for a compromise between these two parameters.

The case study also shows that product development and purchasing departments at an early stage of product development decide how the logistics process will be set up. This is made with insufficient consideration to the logistics aspects. The effect will be that the logistics process structure does not depend on the structural design of the logistics process; instead it depends on work performed at the product development- and the purchasing department.

4.5 Summary and discussion of the results from the papers

The empirical studies in this research project consist of four case studies and three of these have been presented in published papers. Case study 1 has been presented in a technical report and is summarized in the chapter above. The empirical results from the papers and case studies in this project may be summarized in some bullet points:

- There is a lack of methodologies and tools (and application of methodologies and tools existing) for developing efficient logistics processes in manufacturing industry.
- The product development process affects the logistics process efficiency:
  - There are several decisions in the product development process which affect the (efficiency of) the logistics process.
  - There are several parameters which affect the efficiency of the logistics process, many of these parameters can be influenced at an early stage of the product development process.
- Integration of the logistics department in the product development process:
  - The logistics department needs to be integrated earlier in the product development process than today.

    - It is essential to involve the right persons from the logistics department early on in the product development process.
- Evaluation of the demands and needs:
    - The logistics department needs to evaluate their demands and needs.
    - The logistics department needs to express their demands and needs to the product development department in an early phase of the product development process.
    - The product development department is open to develop the products to be more designed for logistics, but often the demands from the logistics department are missing.

One thing to underscore is that it is important for the logistics department to identify their demands and needs. It is a condition that the demands and needs are identified so as to be influence product development. If the demands and needs are not identified, it is hard to know what to influence and how to make the product development design for logistics.

In chapter 4.2 and 4.4 above, parameters which affect the efficiency of the logistics process were presented. In case study 1, chapter 4.4 above, the parameters frequency, correct input, cost, the supplier, transportation, and flexibility were mentioned. From case study 3 the parameters delivery capacity, delivery dependability, capacity and correct technical equipment at the supplier, total cost, quality, transportation cost, physical distance and localization of the supplier, flexibility, planning and control, packaging, and correct input came out as parameters affecting the efficiency of the logistics process. All the parameters affecting the efficiency of the logistics process from both case studies are summarized in Table 9 below.

Table 9 – Summary of the parameters affecting the efficiency of the logistics process from the empirical results (case study 1 and 3).

Parameters affecting the efficiency of the logistics process (from the empirical results):	Short description:
Delivery capacity	Ability to deliver when the need arises.
Delivery dependability	Capability to deliver correct products in correct quantity.
Supplier: *Capacity and correct technical equipment at the supplier *For example the relation to the supplier and the attitude at the supplier *Physical distance and localization of the supplier	Some different parameters are important to secure at chosen supplier.
Total cost	The total cost in the logistics system.
Quality	Stock levels are affected by quality, for example poor quality takes capacity to make re-place items both in production and with supplier.
Transportation cost	Transportation cost of material from supplier to company.
Flexibility (volume)	For example ability to fast change to increase/decrease volumes.
Planning and control	Secure deliveries and internal capacity and affect delivery quantities and delivery frequencies.
Packaging	For example extra costs if suppliers are not using standard packages.
Frequency (of incoming material)	With which frequency does the company receive material from suppliers.
Correct input	For example correct data in the system, forecast accuracy, correct forecast in to the system, reliable and long-term plans out from the company, written and spoken communication.

5 *Proposed framework*

This chapter summarizes the results from chapter 3, Theoretical framework and chapter 4, Summary of the published papers, the empirical results, in a proposed framework.

THE OBEJCTIVE OF this research has been to develop a framework supporting collaboration between the logistics- and the product development process. The results of the case studies and the theoretical framework form the basis for the framework proposed in this chapter.

It has been deduced that the parameters and decisions made in the early phases of product development process have an influence on the efficiency of the logistics process. This research project has also shown that there are problems at the interface between the logistics- and the product development process, see Paper C. This means that one way to achieve a more efficient logistics process is to improve the collaboration between the logistics- and the product development process. According to Wheelwright and Clark (1995), as mentioned in the theoretical framework, the product development process affects everything the manufacturer does and, when developing a new product, you need to consider how the product will be manufactured, sourcing questions, what the supply chain will look like, and so on. The conclusion is that it is essential to support collaboration between the logistics- and the product development process. The question is how to support collaboration and how to integrate the logistics department earlier in the product development process.

5.1 Product development process

According to Wheelwright and Clark (1992), the typical phases in the product development process are **Concept Development** (information about market opportunities, competitive moves, technical possibilities, and production requirements must be combined to lay down the architecture of the new product), **Product Planning** (as in the first phase information about market opportunities, competitive moves, technical possibilities, and production requirements must be combined to lay down the architecture of the new product), **Product/Process Engineering** (the design and construction of working prototypes and the development of tools and equipment to be used in commercial production), and **Pilot Production/Ramp-up** (the individual components are assembled and tested as a system in the factory). Many authors have written about the different phases in the product

development process. In many respects, the product development process is described in a similar way by the different authors. In the theoretical chapter, the product development process presented by Wheelwright and Clark (1992) was chosen as one meriting to be introduced and used as a reference in this project: here is the description of the product development process according to Wheelwright and Clark (1992), see Figure 7.

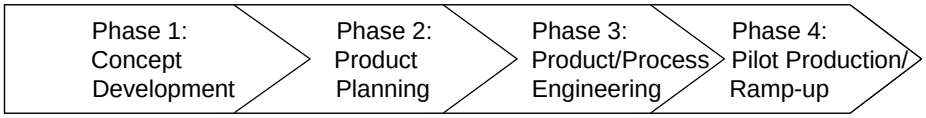

Figure 7 - The phases in the product development process. The figure is an adoption and modification from Wheelwright and Clark (1992).

As presented in Paper C, the empirical results, which have served as the input to this part of the framework, is from a case study performed at a company within the Volvo group. The product development process at this specific company was analyzed and the different phases in the product development process at this company are:

- **The Pre-study phase**, where several product concepts are discussed, market analysis is made, and the prerequisites from customers are collected.
- **Concept study phase**, where the first design is done and in this phase there are a lot of discussions about what the product will look like.
- **Detailed Development phase** is the phase where a lot of the design is done and, for example, calculations on the dimensions are made.
- **Final Development phase** is the phase where the design on the lowest level is done, for example strength of screws and surface roughness.
- **Industrialisation phase,** where the pre-series production is done (the first order from the customer).
- **Follow-up phase** is the phase when different follow-ups are done, for example the actual costs in comparison to the calculations made earlier.

The phases at the Volvo company studied are possible to match to the typical phases in the product development process which was chosen as a reference in this project, and was described in the theoretical chapter: the product development process according to Wheelwright and Clark (1992). This confirms that the theoretical product development process according to Wheelwright and Clark (1992) is applicable in industry and the match between these two product development processes is seen in Table 10 below.

Table 10 - Phases in the product development process according to Wheelwright and Clark (1992) matched to the phases in the product development process used at the case study company.

Wheelwright and Clark (1992):	Case study company:
Concept Development and Product Planning	Pre Study and Concept Study
Product/Process Engineering	Detailed Development and Final Development
Pilot Production/Ramp-up	Industrialisation and Follow-up

The analysis of the product development process at the Volvo company showed a number of decisions made in the different phases of the product development process which have an influence on the logistics process. These decisions are, presented in Table 8: the make-or-buy decision (which can be both on a strategic and an operative level), the supplier selection, the

choice of material, and the decisions connected to the different product development solutions. According to Table 10 above, it is possible to translate the phases at Volvo to the different phases in the product development process according to Wheelwright and Clark. Figure 8 below shows in which phase of the product development process the different product development decisions, which have an influence on the logistics process, are made. According to Johansson (2001), it is essential to investigate what decisions should be made early in the product development process and what decisions can be postponed.

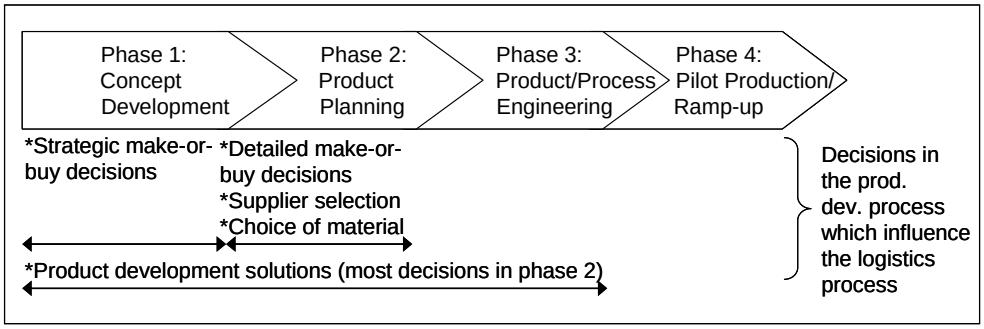

Figure 8 - The decisions made in the product development process which affect the logistics process mapped to the phases in the product development process where they are made.

In summary, the objective of this part of the framework is to highlight the importance of involving the logistics department early in the product development process. It is shown, both at Volvo and also confirmed by the theoretical framework, that the product development decisions made early in the product development process will have a significant impact on future manufacturing and logistics activities (Dowlatshahi, 1996). As mentioned in the theoretical framework, the logistics should be considered already in the earlier design phases of the product to gain the system later in the process (Storhagen, 2003). Figure 8 shows the product development decisions that have an influence on the logistics process and in which phase of the product development process they are made.

5.2 Parameters affecting the efficiency of the logistics process

The empirical results from case study 1 and 3 resulted in a number of parameters which affect the efficiency of the logistics process. These parameters can be seen in Table 9, chapter 4.5. The theoretical framework also resulted in a number of parameters which influence the efficiency of the logistics process and were presented in Table 6, chapter 3.4. The results from the case study confirm, to some extent, the theoretical framework as to, for example, flexibility, delivery capacity, and delivery dependability. Then there are some parameters mentioned in the theoretical framework which did not come up in the case studies and vice versa. Total cost is mentioned in the case studies but is seen as one of the superior terms in the theoretical framework, according to Mattsson (2002a) and Aronsson et al (2004) and is, therefore, not mentioned as one of the parameters affecting the efficiency of the logistics process. In the case studies, correct input has also been brought up as essential to the efficiency of the logistics process. In the theoretical framework, the parameter information is

mentioned, which is considered to be included in the parameter correct input, provided that the correct input parameter includes correct input both within the own company, to the own company, and also out to customers and suppliers from the own company. In the parameter logistics costs from the theoretical framework transportation cost is included, which was one parameter from the case studies. Planning and control is a parameter which is a result from the case studies. The parameters inventory turnover and percentage of fill from stock are parameters from the theoretical framework which are considered to be dependent on the planning and control activities and, therefore, the planning and control is considered to be the main parameter, including the other two parameters. This results in a total list of parameters affecting the efficiency of the logistics process, which is presented in Table 11 below.

It has been mentioned in the theoretical framework that the decisions made in the product development process have impact on the logistics activities (Dowlatshahi, 1996). This implies that there is a connection between the identified product development decisions and the identified parameters which affect the efficiency of the logistics process. Each of the parameters in Table 11 is influenced by one or more of the product development decisions. A suggestion as to the interface between the parameters and the product development decisions is presented in Table 11 below. When you have the input about which product development decision has influence on which parameter and know in which phase the different product development decisions are made (see Figure 8, chapter 5.1), it is possible to analyze in which product development phase it is possible to have an influence on the different parameters which affect the efficiency of the logistics process. This is seen in Table 11 below.

Table 11 - Parameters affecting the efficiency of the logistics process from the theoretical framework and the case studies, and the connection to the different product development decisions which influence the parameters. The last column shows in which phase of the product development process it is possible to influence the parameters affecting the efficiency of the logistics process.

Parameters affecting the efficiency of the logistics process:	Product development decisions influencing the parameters for an efficient logistics process:	Where in the product development process the parameters for an efficient logistics process might be influenced:
Delivery capacity	Supplier selection, make or buy decision	Phase 1-2
Delivery dependability	Supplier selection, make or buy decision	Phase 1-2
Delivery time	Supplier selection, Product development solutions	Phase 1-3
Frequency (of incoming material)	Supplier selection	Phase 2
Capacity utilization	Product development solutions	Phase 1-3
Throughput time	Product development solutions	Phase 1-3
Tied up capital	Supplier selection, make or buy decision	Phase 1-2
Customer adoptions	Product development solutions	Phase 1-3
Supplier: *Capacity and correct technical equipment at the supplier *For example the relation to the supplier and the attitude at the supplier *Physical distance and localization of the supplier	Supplier selection, choice of material and make or buy decisions	Phase 1-2
Packaging	Product development solutions	Phase 1-3
Flexibility	All decisions	Phase 1-4
Quality	All decisions	Phase 1-4
Planning and control	Product development solutions and supplier selection	Phase 1-3
Correct input	Depending on communication between the logistics and the product development process	
Logistics costs	All decisions	Phase 1-4
Logistics service	None of the decisions in the product development process	

In which product development process it is possible to influence the different parameters which affect the efficiency of the logistics process can be illustrated in a figure describing the product development process, see Figure 9.

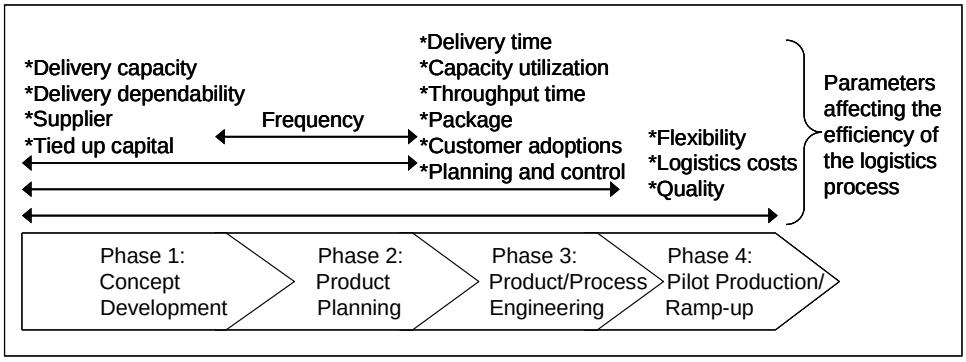

Figure 9 - The product development process phases where it is possible to influence the different parameters affecting the efficiency of the logistics process.

The objective of this framework is to show in which product development phases it is possible to influence the different parameters which affect the efficiency of the logistics process. As can be seen in Figure 8, it is possible as early as in the first product development phase to influence the logistics process. This means that it is meaningful to integrate the logistics department as early as in the first phase of the product development process. Also, it is worth to notice that all parameters which affect the efficiency of the logistics process, except for two, are influenced, more or less, by the decisions made in the product development process. These two parameters are correct input and logistics service which are considered not to be affected by the produce design.

5.3 How to integrate the logistics department earlier in the product development process

Paper A gives a discussion about how to reach efficient logistics through regional collaboration. The paper concludes that it is not the collaboration but the performed activities, which are a result of the collaboration, which will result in more efficient logistics. This is also confirmed in the theoretical framework by Cousins (2002), who points out that it is essential that relationships and collaboration focus on giving tangible outcomes and delivery value. A way of working was presented in Figure 2, Paper A, which is a suggestion of how to work with different forums for collaboration and the activities believed to contribute to more efficient logistics. This mode of working may be applied in other interfaces, as for example between the logistics- and the product development process. An application of the way of working presented in Paper A is presented in Figure 10, describing the interface between the logistics- and the product development process. This proposed mode of working consists of three stages in a closed loop. The loop shows that this is ongoing work during the whole product development project.

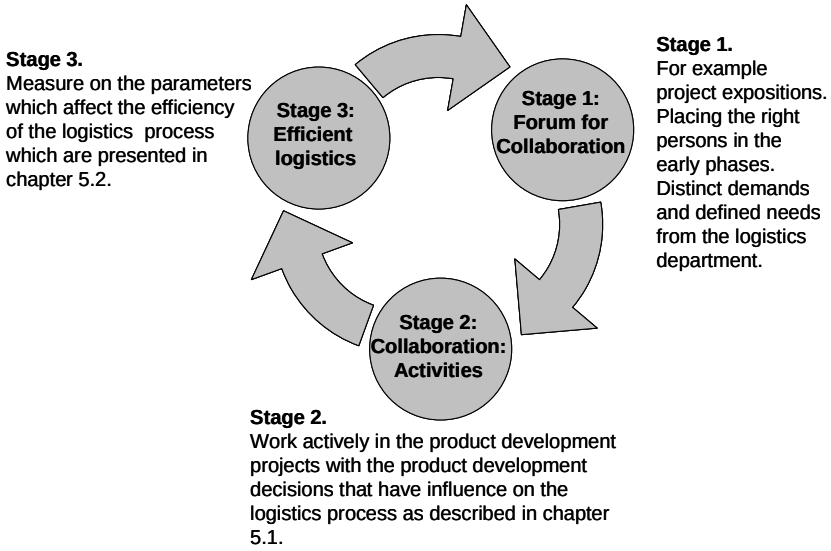

Figure 10 - Proposed way of working at the interface between the logistics- and the product development process. The figure is an adoption and modification from Andersson and Jackson (2004).

The content of the following stages is indirectly based on the case studies and developed by the author.

Stage 1: Forum for collaboration

It is essential that logistics' aspects are present in the early phases of the product development process. Placing the right person in the right phase is of importance and these involved persons should be persons in different positions in different phases. In the early phases there is more strategic work and in the later phases questions of a more operative character are essential. It is significant that the person with the appropriate position is present for the different types of questions in the different phases. The participation can be in the project reviews or in the meetings where the projects are discussed. Below the input and output to stage 1 is described and also why stage 1 is needed and what kind of forums there should be in stage 1.

- INPUT: Specification of requirements with needs and demands from the logistics department.
- WHY: One identified problem at the interface between the logistics- and the product development process is communication. One way to overcome this is to meet and have discussions. It is essential for the logistics department to be present when the product development decisions are made to be aware of which decisions that are made, since the decisions affect the logistics process. If the logistics department is not present and not aware of the decisions made, there is no possibility to affect the decisions and be able to adapt the logistics process in the best way for new products and solutions.

- WHAT kind of forums for collaboration: In the early phases, the logistics department needs to be present in the strategic dialogues and, when the product development project is running, one forum for collaboration might be the project reviews and regular meetings. Logistics workshops with time spent discussing only logistics in the product development projects is another kind of collaboration. If the physical distance is short between the location of the logistics- and product development department there is more informal communication, which is valuable.
- OUTPUT: The output from the forums for collaboration is an activity list with activities that need to be started. These activities describe what needs to be developed and taken care of within the logistics field to develop the logistics process and make the total logistics process appropriate for the new product/products and the existing products in the company. Examples of activities might be to design new packaging, to investigate a new supplier, or to investigate in or outsourcing for an item within the new product.

Stage 2: Collaboration - Activities

It is not enough to participate in the different forums. It is also important that the logistics department have formulated their demands and they need to know what to focus on and what to influence. It is important to be an active part in the product development work and be active and influence the decisions that affect the efficiency of the logistics process. The decisions made in the product development process that affect the logistics process are presented in Paper C. The logistics department needs to show the logistics consequences of the different decisions made and also be clear about which the logistics consequences are if the product development is delayed. The input and output of this stage are presented below. Also, the reason of stage 2 (why) and examples of what kind of collaborative activities there are in this stage are described.

- INPUT: The activity list that was output from stage 1.
- WHY: To be able to design a logistics process which is suitable for the new product/products and also an efficient logistics process totally and, for the existing products in the company, the identified activities in stage 1 need to be performed.
- WHAT kind of collaborative activities: Start projects (or activities with responsible persons) for the identified activities to guarantee that the activities are realized.
- OUTPUT: The output is the result from the activities started in stage 2, which might be new packaging, a change to another/new supplier, or something else.

Stage 3: Efficient logistics

The parameters that affect the efficiency of the logistics process were presented in chapter 5.2 and these parameters are connected to the decisions made in the product development process that influence the logistics process. Through these parameters, it is possible to measure if the logistics process has been more efficient. Below are the input and output from stage 3 and an explanation of why this stage is involved in the proposed way of working and what to measure in stage 3.

- INPUT: A summarized list with the realized changes, which are the results from the performed activities in stage 2, e.g. the output from stage 2.
- WHY: To show and verify that the activities performed in stage 2 have given a more efficient logistics process; it is of importance to measure these changes. The changes

are measured in accordance with the identified parameters for efficiency of the logistics process, see Paper B.

- WHAT to measure: A number of changes have been made through the projects and activities performed in stage 2, for example: new ways of transportation, new supplier, new packaging, and so on. To verify that the logistics process has been more efficient, the performed changes need to be measured.
- OUTPUT: A more efficient logistics process is hopefully an output from stage 3.

The forums for collaboration are active during the ongoing product development projects. The specification of requirements includes needs and demands that are addressed at different times and phases in the product development process. Therefore, new activities are raised continuously during the product development project and the loop starts over again with stage 1 and makes a closed loop. This type of participation of involving representatives in development teams is also described by Wynstra et al (2001). They state that the output of the participation is better information between the departments and there is an ability to influence certain decisions, which is what is wanted to be achieved also with this proposed way of working. This proposed way of working, which has been described above, should be applied in all the four phases in the product development process, according to Wheelwright and Clark (1992), which was presented in chapter 5.1 and is illustrated in Figure 11 below.

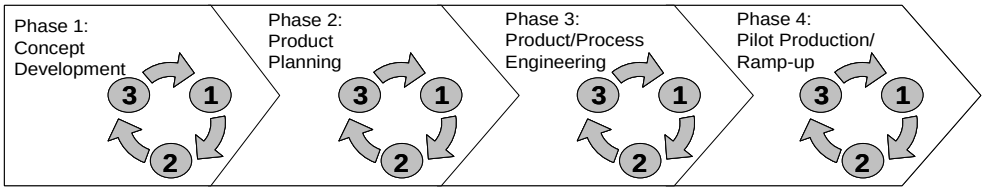

Figure 11 - The proposed way of working should be applied in all four phases of the product development process.

The part of the framework presented in this sub-chapter can finally be summarized by having described a proposal of a way of working in the phases of the product development process to be able to integrate the logistics department earlier in the product development process. The next chapter will discuss a suggestion of which persons from the logistics department should be involved in the different phases in the product development process.

5.4 Human resources from the logistics department in the product development process

It has been pointed out in this licentiate thesis, both in the theoretical framework (Andreasen and Hein, 1986) and in the empirical results, that it is essential that the right person from the logistics department is involved in the right product development phase. This is also confirmed by Wynstra et al (2001) in the theoretical framework who say that the most critical requirement for successful involvement is adequate human resources. They write about supplier involvement in product development, but the same should be valid for the involvement from the logistics department. As mentioned in the theoretical framework, Wynstra et al (2000) point out that it is meaningful to differentiate between different

management areas when considering purchasing involvement in product development, which also should be the case for logistics involvement. In the earliest phases of product development the strategic decisions are made and it is essential to involve strategic competence from the logistics department and, therefore, the overall manager for the logistics department should be involved in the first product development phase. In the next phase, a lot of significant decisions about more detailed product development solutions and supplier selections are made. The most suitable persons to be involved in this phase are the managers for material control, planning, transportation, and so on. When the detailed design is made and the questions are getting closer to production and manufacturing, it is meaningful to involve the persons from the logistics department who work with operative logistics questions and the day to day problems within the logistics process, for example planners and material controllers. It is hard to give a general explanation of which positions and persons should be involved in which phase because it depends on the organization of different companies. Wynstra et al (2001) have made a different but pretty similar split of the tasks for the different management levels, which was presented in the theoretical framework. Figure 12 below shows in which product development phase the different positions and management areas from the logistics department are recommended to be involved.

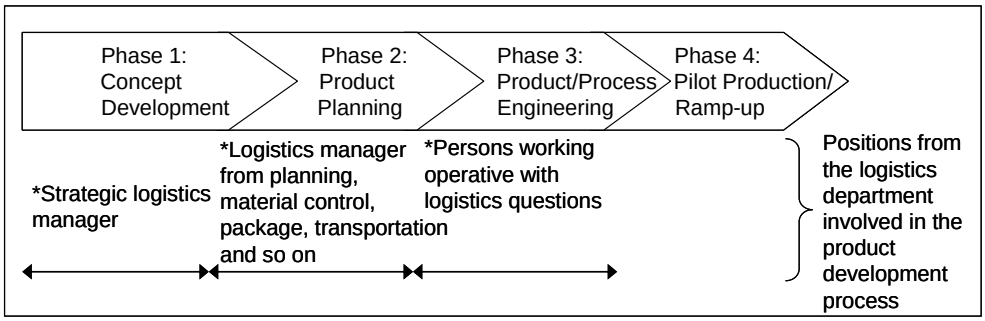

Figure 12 - Suggestion of which representatives from the logistics department should be involved in the different described phases in the product development process.

In this sub-chapter a suggestion of which representatives from the logistics department that might be suitable in the different phases of the product development process has been presented. The next chapter will describe the total framework and briefly describe who to involve, how to collaborate, and what to focus on in the four different phases in the product development process.

5.5 The proposed framework

Earlier in this chapter the product development process and the different decisions made in product development which have an impact on, and interface to, the logistics process have been presented. A set of parameters which affect the efficiency of the logistics process have been brought up and they have been connected to the different phases in the product development process where they can be influenced. Also, a suggestion of a way of working to facilitate the collaboration between the logistics- and the product development process has been discussed. Chapter 5.4 includes a suggestion of which representatives from the logistics

department that should be involved in the different phases described in the product development process. All the pieces from chapter 5.1 to 5.4 can be summarized in a total framework supporting the collaboration between the logistics- and the product development process, which is done in Figure 13 below. To make it easier to implement this framework in a company, a description is summarised below over the four phases in the product development process with who to involve, examples on how to collaborate, and what to focus on in the different phases.

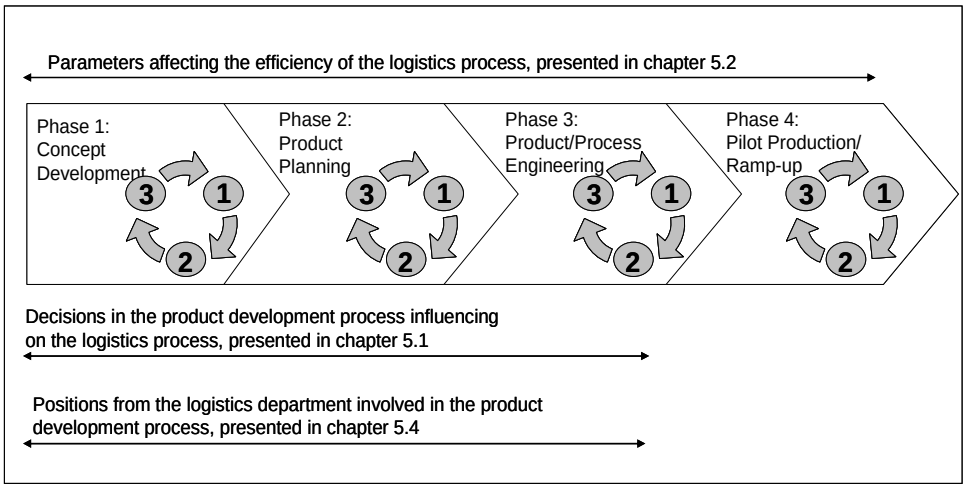

Figure 13 - Proposed framework for supporting the collaboration between the logistics- and the product development process.

Phase 1 – Concept Development:

In this phase it is most suitable that the strategic logistics manager is involved, since the questions discussed in this early phase are on a strategic level. The persons involved from product development are not too many and the preferred way of collaboration in this phase is through regular physical meetings. The focus in this phase is, for example, strategic make-or-buy decisions and their impact on the logistics process. For example, if there is an item constituting the difference between two variants of the product, it is not suitable to have a supplier far away with maybe several weeks of lead time. It is also essential to focus on strategic product development solutions which may have an impact on the logistics process. Logistics efficiency parameters to measure and focus on in this phase are delivery capacity and dependability, tied up capital, how complex planning and control activities are/will be, cost for packaging, information about the supplier, different parameters in the production (capacity utilization and throughput time), delivery time, and customer adoptions.

Phase 2 – Product Planning:

In this phase, the logistics manager within for example planning, materials control, or packaging and transportation should be involved. Forums for collaboration in this phase are, for example, workshops with a logistics agenda where the logistics questions are discussed. Depending on the size of the product development project, it might be necessary to have

several workshops. Significant product development decisions to focus on in phase 2 are make-or-buy decisions on a more operative level, the supplier selections, the choice of material, and the different product development solutions which might affect the logistics process. At the workshop brainstorming might be one activity to use in order to identify, for example, product development solutions that affect the logistics process, since in this phase the majority of the product development decisions are made. At a workshop it is a good idea to involve some key persons who are involved in operative logistics questions. The logistics efficiency parameters to measure and focus on in this phase are the same as in phase 1 with the additional suggestion to focus on the frequency of incoming material.

Phase 3 – Product/Process Engineering:

In phase 3 it is essential to involve the persons from the logistics department who work on an operational level with logistics issues and with the day-to-day activities within the logistics process. Workshops, as mentioned in phase 2, is one way to focus on the logistics but also close collaboration between the people in the logistics- and the product development process in the form of working with activities (as explained in chapter 5.3) together; not only participating in meetings. It is meaningful to focus on the time schedule for the product development project and also to ascertain that logistics representatives have the authority to point out the logistics consequences if the time plan is not followed. In this phase, some product development decisions might be made which have impact on the logistics process and are essential to focus on. Logistics efficiency parameters to measure and focus in this phase are how complex planning and control activities are/will be, cost for packaging, different parameters in the production (capacity utilization and throughput time), delivery time, and customer adoptions.

Phase 4 – Pilot Production/Ramp-up:

In the last phase, the main activity is to follow up. It has been claimed that the parameters logistics costs, quality, and flexibility were essential in all the four phases, but it is in this last phase that they are focused on by being measurable and followed up. In the earlier phases they have been focused on by performance of activities, which make these measurable values better (for example: lower logistics costs, better quality, and higher flexibility). It is also essential to follow up the collaboration between the logistics- and the product development process to see how well it has worked and what can be improved in the next product development project.

This framework is not a complete methodology to work from, but it is a support for the collaboration between the logistics- and the product development process, which was the objective for this research project. This framework has not been tested in industry and should be seen as a suggestion for supporting collaboration. The framework needs to be developed further into a complete methodology and also tested in industry. Among other things, this framework needs to be complemented with, for example, more detailed needs and demands from the logistics department, checklists for the different phases, and further analysis on the interface between the logistics- and the product development process at more companies.

6 Discussion and conclusions

This chapter brings up the objective of this research project and the three research questions and summarizes the results pertaining to each of the research questions. There is also a discussion about relevance and generalization. Future research is also brought up at the end of the chapter.

THE OBJECTIVE OF this research project was to develop a framework supporting the collaboration between the logistics- and the product development process. On the way to try to reach this objective, three research questions have served as underpinning. The conclusions from these research questions and discussions and reflections in relation to the suggested framework are described in this last chapter.

6.1 Objective of this research project and the research questions

The objective of this project has been to try to develop a framework supporting the collaboration between the logistics- and the product development process. To fulfil this objective, three research questions were formulated. These research questions have been investigated through the literature study and the case studies and the result from these two parts have been presented in chapter three and four of this licentiate thesis. Below is a summary of the conclusions for the three research questions.

RQ1: Which parameters influence the efficiency of the logistics process?

The overall goal for logistics is to contribute to the company's profitability and to do this there are two targets for logistics: to decrease the company's costs and to increase the company's receipts through serving the customer better. This leads to two essential items for logistics, costs and customer service (Aronsson et al, 2004). Efficient logistics processes can be understood as performing the logistics activities in such a way that the logistics process contributes the most possible to the company's overall profitability through the two terms customer service and costs. In the theoretical framework and the case studies presented earlier in this licentiate thesis, a number of parameters within customer service and costs have been presented influencing the efficiency of the logistics process and contributing to the company's overall profitability. According to the theory, the problem with increasing the efficiency of the logistics process is that improving some parameters might have a negative effect on other parameters. This means that it is essential to look at the logistics process in it's entirely and it might be necessary to give priority to the actions which, in the largest

extension, support the company's competitiveness. Table 12 below summarizes the parameters which influence the efficiency of the logistics process from both the empirical results and the theoretical framework.

Table 12 - Parameters which influence the efficiency of the logistics process, from both the empirical studies and the theoretical framework.

Parameters affecting the efficiency of the logistics process:	Short description:
Delivery capacity	Ability to deliver according to time agreed with the customer
Delivery dependability	If the correct products are delivered in correct quantities.
Delivery time	Time from customer order to delivery.
Frequency (of incoming material)	With which frequency does the company receive material from suppliers.
Capacity utilization	Capacity is here an expression for production- and material flows resources from a volume perspective. This means that it is a performance measure for the resoruces that exist within a company.
Throughput time	The time it takes for a product to pass a certain part of the flow.
Tied up capital	Capital which is tied up and can not be used in a better way. The parameters average value in stock, product value and work in progress (parameters according to Aronsson et al (2004)) are examples of tied up capital.
Customer adoptions	Needs from the customer to get products delivered in a way which differ from the company's normal way to deliver, for example faster transportations or other packages.
Supplier: *Capacity and correct technical equipment at the supplier *For example the relation to the supplier and the attitude at the supplier *Physical distance and localization of the supplier	Some different parameters are important to secure at chosen supplier.
Packaging	For example extra costs if suppliers are not using standard packages.
Flexibility	The ability to create prerequisites to handle unplanned circumstances irrespective of if it is the customers or the markets that are changed. This paramater flexibility includes both delivery, volume and product mix flexibility.
Quality	Stock levels are affected by quality, for example poor quality takes capacity to make re-place items both in production and with supplier.
Planning and control	Secure deliveries and internal capacity and affect delivery-quantities and delivery-frequencies.
Correct input	For example correct data in the system, forecast accuracy, correct forecast in to the system, reliable and long-term plans out from the company, written and spoken communication.
Logistics costs	May be splitted in costs related directly to the material flows and costs related to production/working up value. For example transportation and inventory cost.
Logistics service	Supply services as complement to the physical product as for example bar-code on products for faster and more secure identifying of supplied products or to take the responsible for controlling the customer's inventory.

RQ2: What is the interface between the logistics- and the product development process?

There are several decisions in the product development process that affect the logistics process, which is a result of Paper C. It is also a result of the theoretical framework that the decisions made in the product development process impact upon the logistics activities (Dowlatshahi, 1996). The decisions in the product development process will consequently affect the outcome of the parameters affecting the efficiency of the logistics process. It is possible to connect the different parameters to one or more of the different decisions identified in the product development process, which also was done in chapter 5.2, Table 11. An example is that a specific product development solution may lead to a special way of producing the item, which the company does not have machines and/or competence to perform in-house. Thus this operation needs to be done somewhere else as a kind of subcontract work. Because of this outside operation, the logistics flow is a lot more complicated, which requires, for example, more advanced planning, more buffer stock, transportation, and increased lead-times. This means that the product development process will influence the efficiency of the logistics process. The influence is at the interface between the logistics- and the product development process, which is the connection between the different parameters affecting the efficiency of the logistics process and the decisions in the product development process. This was presented in Table 11 in chapter 5.2.

RQ3: How may the logistics department be integrated earlier in the product development process?

As presented in chapter 4, in the case studies, the logistics department needs to be involved earlier than today in the product development process. There needs to be increased communication between the logistics department and the product development department. It is also confirmed in the theoretical framework that logistics usually comes into focus after the product has been engineered, which is too late since then there is little time left for developing a proper strategy for manufacturing the product (Gupta and Dutta, 1994). It is also essential that the right persons from the logistics department are involved in the right product development phase. It is meaningful to have knowledge about which demands are important in the different phases. In the theoretical framework, the importance of involving adequate human resources is also mentioned (Wynstra et al, 2000). The question is how the logistics- and product development process will be integrated and the logistics department having an influence on product development decisions. Then the lines written above are the first prerequisites but it is also important that the logistics department has identified their demands and needs in the different product development phases and that there is a methodology to work from. The proposed framework in chapter 5 is a start for helping the logistics department to be an active part in the product development process. The framework in chapter 5 supports the logistics department in choosing what to focus on in the different phases of the product development process. The framework also gives an indication of which persons to involve and a suggestion for different forms of collaboration in the different phases. With this support there is more of a possibility for the logistics department to be involved in the earlier phases of the product development process, thus allowing for an

integration of the logistics department earlier in the product development process than without this supportive framework.

> Objective of this research project:
> Develop a framework supporting the collaboration between the logistics- and the product development process.

At the very beginning of this licentiate thesis three research questions were presented. In the chapter above three research questions have been discussed. Together these three research questions have ended up answering the overall objective of this research project: developing a framework supporting the collaboration between the logistics- and the product development process. The result is the framework presented in chapter 5. With the support of the framework for the logistics department there is a bigger possibility for the logistics department to be involved in the earlier phases of the product development process. The framework gives support as to what to focus on, how to collaborate, in which phases collaboration is meaningful, and which persons need to be involved in the different product development phases. Working as the framework suggests will, hopefully, give closer collaboration between the logistics- and the product development process than without this supportive framework. The expectation of the collaboration is an earlier integration of the logistics department in the product development process and therefore to influence and be able to increase the efficiency of the logistics process.

6.2 The proposed framework put in perspective

In chapter 3, three critical issues for managing supplier involvement in product development, according to Wynstra et al (2001), were presented. These issues can be compared to this project where, instead of supplier involvement, there is a need for more logistics involvement in the product development process. The first issue is to identify specific processes and tasks that need to be carried out and the second issue is to form an organization that supports the execution of the tasks in the first issue. Most of the content in these three issues are taken care of in this research through the proposed framework which suggests a way of working, areas focused, and persons involved in the different product development phases.

As mentioned in the theoretical framework, there are several ways by which business processes may be made more efficient, and among these also the logistics processes (Mattsson, 2002a). These strategies are simplification and rationalization, exchange of information, automation, reconfiguration, and collaboration. At least three of these strategies will be supported by the proposed framework in this licentiate thesis. Through avoiding, for example, outside operations in production through influencing product development solutions early in the product development process, the complexity of the flows and processes is reduced and unnecessary activities are eliminated. This affects the strategy simplification and rationalization. The strategy exchange of information means to make the process more efficient through faster communication and information. The proposed framework in this licentiate thesis suggests a way of involving the logistics department in the product development process, and with increased collaboration and involving of persons

and working together with activities the communication will increase and the information will be shared earlier in the product development projects.

Collaboration is the last strategy, according to Mattsson (2002a), which is also considered to be supported by the proposed framework. The objective of the suggested framework is to support the collaboration between the logistics- and the product development process. By working according to thisframework, the expectation is that the logistics department will be integrated earlier in the product development process and the collaboration between the logistics- and the product development process will increase.

This framework is not finished and there is more to do. It is a skeleton which a more complete methodology may build upon. But still, the framework points out the need for early logistics integration and what to focus on in the different phases in the product development process. Hopefully, this framework will lead to an active involvement from the logistics department and enable it to have more influence on product development through closer collaboration. The result of the logistics department's involvement is to be aware earlier of the problems that can arise in the later logistics process. Thereby, it is possible to avoid the problems mentioned in the introduction chapter with the metal sheet which could not be transported and the redesign of an item which needed one pallet per item instead of three items per pallet.

A lot of the empirical results are from one company within the Volvo group. This is due to the access the researcher has to the company as an industrial Ph. D. student. To what extent the results may be generalized can be discussed. It is the belief that the company in the case studies is representative for the manufacturing industry and the situation at the company is not unique in any way for this industry. Therefore, the results are arguably representative for the manufacturing industry. However, it is always important to pay attention to the current situation at a specific company when applying a framework or method. The suggested framework needs to be adapted to fit any specific organization and company.

The validity is of importance if another researcher repeats the presented research in this licentiate thesis. In case studies this is problematic since every case is dependent on the persons interviewed and the companies, which are changed and developed over time. The current environment affecting the companies is also changed. To avoid this problem the empirical results are used for getting practical insight in parallel with the literature studies and the theoretical reasoning is the basis for the conclusions in this licentiate thesis.

6.3 Industrial and academic relevance

It is not an unknown problem that the logistics department, quite often, is involved too late in the product development process. The problem has been known for a long time, but still the problem exists in the industry and there is a need for support for integrating the logistics department earlier in the product development process. The problem has been raised in the industry, especially at the company within the Volvo group where the fourth case study was performed. The research has been performed in close co-operation with the industry and the relevance for the industry has been discussed throughout the whole project.

The focus of this research has been the question of how to manage the involvement of the logistics department in the product development process. There is a need for support for the

logistics department to become more involved in the product development process and to increase collaboration. Johansson (2006) points out that, despite the importance of integrating the logistics department in product development projects, there is little research made on its management represented in the literature.

The contribution of this licentiate thesis is the framework in chapter 5. With this suggested framework, the manufacturing industry will hopefully have a support to integrate the logistics department earlier in the product development process. All the different components presented together in the proposed framework, in chapter 5, serves as an industrial and academic contribution from this research project.

6.4 Future research

The presented framework is not yet fully tested in industry, something that has to be done to develop a methodology further. Activities which need to be carried out to develop a methodology are, for example, defining the forums for collaboration and activities to collaborate around more in detail, designing checklists for the logistics department, and identifying and defining the logistics development process.

Something else that would be of interest in a next phase would be to make a broader study and look at several more companies. This first research has been focused on Volvo mostly, but it would be of interest to look deeper into other companies.

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Appendix 1 - Interviews in case study 1

Choice of companies

The companies were chosen because they are companies where logistics is of big importance. Three companies were chosen; two producing companies and one company which is the main supplier of logistic services to one of the producing companies (and is in the same group of companies as the producing company). The two producing companies were chosen because they have similar products with about the same complexity. Both companies are situated in the region of Mälardalen. The companies were chosen as the answers from these companies can be considered to give a picture of how it looks in other similar companies. In chapter 1.5 more details about the region Mälardalen are found.

How the interviews were carried out

The interviews began with an explanation about the purpose of the case study and the interviews. They were performed face to face with all the respondents. The interviews were of the semi-structured type with formulated questions and free discussions during the interviews. All interviewed persons received the notes taken during their interview and accepted the construed answers or the answers were discussed and rewritten until the interviewed person were satisfied.

Choice of respondents

The respondents were chosen because of their different posts within the companies, because they are working with logistic questions on different levels within the companies, and because they have competence within logistics (within the areas where they are working). In total eight persons were interviewed. Persons with the following posts at the different companies have been interviewed:

Producing company 1:

- One person working as the Manager for logistics (the logistics for the all of the production)
- One person working with materials control (supplier contacts, supplier development, and operative purchasing)

Producing company 2:

- One person working with materials control and the MPS-system (Material Planning System) within the assembly unit
- One person working with the planning of the materials and the MPS-system within one of the producing units.
- One person working as the manager for receiving goods and the chairman of the administration group for the MPS-system.
- One person working as the manager for purchased materials, materials control, and shipping of products.

Logistics company (delivers logistics services to producing company 2:

- One person working as a project manager at the department for logistics development.
- One person who is responsible for customers (the customer is producing company 2) and also working with logistics development.

Analysis of the answers

The analysis of the interviews in this research project has been made according to the analysis methods which Kvale (1997) describes. First of all, the material from all the interviews in case study 1 was structured. To make the interview material accessible for analysis all repetitions and unessential parts (depending on the actual study's purpose) were deleted. Then the material was ready for analysis, which was made through two of the five methods for sentence analysis that Kvale (1997) mentions: concentrating and categorizing.

Questions

The following questions were the base in the semi-structured interviews:

1. Which demands control the company when designing the logistics system?

    a) Demands on incoming materials? (Supply)

    b) Customer demands, deliveries per day/per hour? (Distribution)

2. How do you meet the demands from the customers?

    Correct quantity, in right time

3. Which parameters are important to consider when designing logistics?

4. Which parameter do you consider affects the efficiency of the logistics?

5. Are there any projects going on right now to develop the logistics system?

6. Are you involved in any logistics projects?

7. Have there been projects which have developed the logistics system?

    Often, seldom, or occasionally

8. How has the logistics system you have today been designed (For example by random, out of a strategy, by projects, or by development in small steps)?

9.
a) Are there any methods, tools, or other assistance to design the logistics system at the company, or to develop the logistics system further?
b) Are there any methods, tools, or other assistance to decide, for example, which type of transportation, frequency of taking home material, and so on?

10. Which methods, tools, or other assistance do you use in your daily work with logistics?

11. Are there any methods, tools, or other assistance to analyze the logistics system at the company?

Appendix 2 - Interviews in case study 2

Choice of network and arena

Mälardalen is the region focused upon in this research project. The studied companies in case study 1, 3, and 4 are situated in Mälardalen and, therefore, it is interesting to study networks and arenas in the same region. One arena and one network which are active in this region wanted to be studied and, for this reason, the arena and the network of this study were chosen. For more details about the region Mälardalen, see chapter 1.5.

How the interviews were carried out

The interview questions were sent electronically to the respondents in advance. The respondents answered electronically and the answers were followed up by an interview by telephone or by a personal meeting. The form with questions began with the purpose of the case study and the interviews.

Choice of respondents

The condition when the respondents were chosen was that they were currently participating in some kind of regional collaboration (in this case the chosen arena and network). Three persons from the chosen arena and three persons from the network were selected. These persons were chosen because they had been active in the arena/network from the beginning or had a deep involvement in the arena/network. One person outside the studied arena and network was interviewed and the answers were used as extra information.

Analysis of the answers

The interviews have been analyzed by the methods for analysis described by Kvale (1997). First the entire interview material was structured and then all material was made clear to be accessible for analysis. For example all repetitions and unessential information, depending on the purpose of the study, were eliminated. After this the analysis could be made. Kvale (1997) mentions five methods for sentence analysis and out of these five methods two have been used: concentrating and categorizing. For the questions with a four-graded scale the mean value was calculated.

Questions

1. How important do you consider it to be that your company (or local authority) is participating in a network/arena?

   1 2 3 4

   ☐ ☐ ☐ ☐

   Not important at all Very important

2. What do you consider to be the most important task for a network/arena? (For example to create projects, to create contacts, "networking", and so on)
3. Are there any negative aspects of participating in a network/arena?

4. Which different parties do you think are important to partake in a network/arena?
5. Which network/arenas are you involved in, that your answers in this interview study are valid for?
6. How much do you think the network/arena you participate in contributes to drive the logistics development forward in the region of Mälardalen?

   1 2 3 4

   ☐ ☐ ☐ ☐

   No contribution A lot of contribution
7. How much do you think the network/arena contributes to the (economical) growth in the region of Mälardalen?

   1 2 3 4

   ☐ ☐ ☐ ☐

   No contribution A lot of contribution
8. How much does the network/arena contribute to increased knowledge within logistics in the region of Mälardalen?

   1 2 3 4

   ☐ ☐ ☐ ☐

   No contribution A lot of contribution
9. Which effects can you see that the network/arena gives in the region of Mälardalen?
10. Which concrete effects has the network/arena given?
11. Do you know if this type of network/arena you are involved in is usual?
12. Is there something you miss in the network/arena you are involved in?
13. What would get you even more involved in a network/arena?

Appendix 3 - Interviews in case study 3

Choice of company

The company was chosen on the basis that it is a rather big company with about 1000 employees. It is situated in the Mälardalen region which is an interesting and important region in Sweden that has been focused on in this research. See chapter 1.5 for further details about the region of Mälardalen. The deep access to the company which had not been possible at other companies has been a strong motive for the choice of this company. The deep access to the company depends on the researcher's role as an industrial PhD student at the company.

How the interviews were carried out

The interviews were of the semi-structured type and the questions were sent in advance by e-mail to the respondents. The interviews were carried out face to face. The questions were sorted in a matrix (see below). When all the interviews had been performed, all the answers were summarized in a total matrix and sent to all respondents. The respondents were asked to answer how important the parameters are and if the parameters should be considered when making sourcing decisions (for the parameters the other respondents had brought up). All interviewed persons received the notes that had been taken during their interview and accepted the construed answers or the answers were discussed and rewritten until the interviewed persons were satisfied. The interviews began by explaining the purpose of the case study and the interviews.

Choice of respondents

The respondents in the interview study were selected with regard to management level, experience, and post in the company with the purpose to try to avoid sub-optimizing and to cover the whole company. Four persons were interviewed with the following posts within the company;

Person 1: Purchaser and responsible for contacts with the (internal) company which handles the external transportations

Person 2: Planner for the manufactured materials

Person 3: Manager of materials control and works with sourcing questions

Person 4: Manager of the logistics department

Analysis of the answers

All the interview material was first of all structured before it was accessible for analysis. This was done by, for example, eliminating all repetitions and unessential information (depending on the purpose of the study). The next step was to analyze the interview material and two methods for sentence analysis were used: concentrating and categorizing. This way of analyzing interviews is described by Kvale (1997) and has been used for all interviews in this research project. The questions were sorted in a matrix and the answers were summarized in this matrix. The answers on how important

the parameters were on a scale from 1-4 were used to point out the most important parameters.

Question matrix

Which parameters affect the efficiency of the logistics?	How important is this parameter on a scale 1-4? (4=very important)	Comments:	Should this parameter be considered for a outsourcing-decision? (Yes/No)	Comments and reasons why the parameter should be considered at outsourcing-decisions:

Appendix 4 - Interviews in case study 4

Choice of company

The chosen company is located in Mälardalen which has been an interesting region for this research project. See chapter 1.5 for more details about the Mälardalen region. The size of the company is about 1000 employees and it is regarded as a big company which has influence in the studied region. The access to this company is deeper than it would have been at other companies because of the author's role as an industrial PhD Student at the company. These reasons made this company a suitable company to perform the interviews in case study 4 at.

How the interviews were carried out

The interviews were of the semi-structured type, with discussions around questions written in advance. The interviews were carried out face to face. All interviewed persons received the notes that had been taken during their interview and accepted the construed answers or the answers were discussed and rewritten until the interviewed person was satisfied. The interviews began by explaining the purpose of the case study and the interviews.

Choice of respondents

Two product development projects running in the company were chosen to be studied. The persons who were chosen to participate in the interviews were persons involved in these two projects within the areas product development, industrialization of product development projects, purchasing, and logistics. The project managers for the whole product development project and the project managers for the industrialization sub-projects for these two projects were chosen as respondents. The respondents were complemented with the logistics manager, the manager of materials control, the responsible person at the purchasing department for these projects, and the logistic representative in these projects. Altogether eight persons were interviewed.

Analysis of the answers

Kvale (1997) describes methods for analyzing interviews, which has been the base in the analysis of the interviews in this research project and also in the interviews in case study 4. The first step was to structure the entire material. When this was done the material was gone through to eliminate all repetitions and unessential information, depending on the purpose of the study. Then the material was ready for analysis. The analysis methods for sentence analysis that were used were concentrating and categorizing.

Questions

The interview study consisted of two main questions:

1. How does the company work with logistics in the product development process today?
2. How should the company be working with logistics in the product development process?

Within these two main questions, some areas for discussion were put up and these areas were discussed for every phase in the product development process, according to the decision model used in the product development projects at the case study company. Some questions had been formulated for the different areas for discussion. The interviews were of a semi-structured nature and there were conversations in the areas for discussion and the questions were used as a support during the interviews.

Main question 1:

The areas for discussion were for main question 1 (the word "phases" refers to the different phases in the decision model used in the product development projects at the case study company):

- Important logistics questions and parameters in the different phases
    - Which logistic questions were discussed (and decided on) in the different phases?
    - Were some logistic parameters in focus in the different phases?
    - Were the logistic questions discussed (decided on) in the right phase?
- Important persons to involve
    - Which representatives from the logistics (posts) participated in the different phases?
- Influence on the logistics of the decisions taken in the product development process (which and when taken)
    - Were any decisions taken early in the project which you think affected the logistics and how the logistics would look like in the Order To Delivery Process?
    - If yes, do you think people were aware of that the logistics would be affected?
    - Which product developments questions do you think are made without people being conscious of that they affect the logistics?
- Problems today
    - Which problems do you see that there are today between the product development process and the logistics?

Main question 2:

The areas for discussion were for main question 2 (the word "phases" refers to the different phases in the decision model used in the product development projects at the case study company):

- Important logistics questions and parameters in the different phases
    - Which logistic questions should have been brought up for discussion (and decision) in the different phases?
    - Which logistics parameters should have been focused on in the different phases?
- Important persons to involve

    - Which representatives from the logistics (posts) should have participated in the different phases?

- Influence on the logistics of the decisions taken in the product development process (which and when taken)
    - In which product development decisions do you think it is especially important to consider the logistics?
- Suggestions for improvement
    - Do you have any suggestion for how the interface between the product development process and the logistics could be improved?
- Influence of collaboration
    - Is collaboration important?
    - If yes, in which phases and with which parties in the different phases (for example external networks, between companies, within the company, or between internal departments)?