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COLLABORATIVE PRODUCT INTRODUCTION WITHIN EXTENDED ENTERPRISES

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To Knut, Emma, Anna and Karl

Abstract

The trend of outsourcing within the electronic industry has contributed to the creation of new types of extended enterprises. These extended enterprises must be able to manage a challenging situation with shorter product life cycles and increased collaboration between companies during the vital product introduction process. For the electronic industry, which is currently acting in an "era of hyper-competition", it is a challenge to implement an efficient and flexible collaboration within an extended enterprise during the product introduction process. In the product introduction process, a product design is prepared for and transferred into production.

During the course of this research, the electronic industry has changed continuously. Empirical data were first collected within an Original Equipment Manufacturer (OEM) that was responsible for its own production. Based on a strategic decision at the OEM, a new extended enterprise was established. In general, these new extended enterprises within the electronic industry consist of: a "product owner" in the form of an OEM that owns the product design and its brand; a "producer" in the form of an Electronic Manufacturing Services (EMS) company that is responsible for the production; and suppliers of services, material, components, equipment etc. However, in the later stages of this research the studied EMS was responsible for the product introduction, production and distribution of the product to the end user. In order to compare and contrast trends and lessons learned in similar industries, case studies within the mechanical engineering and aerospace industries also were performed.

The dissertation primarily describes the process of collaborative product introduction (PI) within the electronic industry, and presents among other things a number of general conditions for efficient collaborative PI within an EE in that industry. First, a clearly communicated definition of what is included in product introduction is needed. A second condition is that early participation from all involved partners in the EE's product introduction process supports efficient collaboration. Third, clear communication and information handling within the extended enterprise – both internally and externally – was found to facilitate collaboration. Fourth, business approaches should be built on trust, reliability and respect for each other's competence. Finally, the importance of cultural awareness, both between different companies and countries, cannot be ignored. This research also presents a framework for supporting collaborative product introduction within an extended enterprise, which serves to both synthesize and summarize much of the research.

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List of publications

Appended Papers

Paper I:
Johansen, K., Winroth, M., Björkman, M., 2001*,* An economic analysis of investment in an assembly line: Case study at Ericsson Mobile Communications AB, Linköping, Sweden, *Proceedings of ICPR-16 International Conference on Production Research,* Prague, Czech

Paper II:
Comstock, M., Johansen, K., 2001, Towards the mass customization of mobile telephones: Current strategy and scenarios for realization at Ericsson, *Proceedings of ICPR-16 International Conference on Production Research*, Prague, Czech

Paper III:
Johansen, K., Björkman, M., 2002, Product introduction within extended enterprises, *Proceedings of ISCE'02 International Symposium on Consumer Electronics,* Ilmenau, Germany

Paper IV:
Comstock, M., Johansen, K., Winroth, M., 2004, From Mass Production to Mass Customization: enabling perspectives from the Swedish mobile telephone industry, *Production Planning & Control*, Vol.15, No 4, June 2004, p.362-372

Paper V:
Johansen, K., Björkman, M., 2003, Conflicting goals in Concurrent Engineering: Case Studies from Product Introduction within Extended Enterprises, *Proceedings of the 10^th^ ISPE International Conference on Concurrent Engineering: Research and Applications,* July 26-30, Madeira, Portugal, ISBN 90-5809-622-X

Paper VI:
Johansen, K., Björklund, S., 2003, Methods for cooperative product development in extended enterprises, *Proceedings of the Euroma/POMS Conference,* June 16-18, Como, Italy, ISBN 88-86281-78-1

Paper VII:
Johansen, K., Björklund, S., 2003, Product realization through concurrent engineering within extended enterprises: A case study, *Proceedings of the 10^th^ ISPE International Conference on Concurrent Engineering: Research and Applications,* July 26-30, Madeira, Portugal, ISBN 90-5809-622-X

Paper VIII:
Johansen, K., Comstock, M., Winroth, M., 2004, Coordination in Collaborative Manufacturing Mega-Networks – Observations from a Case in the Commercial Aerospace Industry, Accepted for publication in Journal of Engineering and Technology Management

Other Publications

Conference paper:
Johansen, K., Winroth, M., 2003, Localization of manufacturing – A systematic framework*, Proceedings of the Euroma/POMS Conference*, June 16-18, Como, Italy, ISBN 88-86281-78-1

Swedish journal:
Johansen, K., 2003, Konstruktion för produktion ger förutsättningar till bättre produktivitet, *Bättre Produktivitet,* No. 7 (In Swedish)

Reports:
Johansen, K., 2000, *Global production – a short review of some papers and the situation in a manufacturing network,* A report in a doctoral course*,* Reference number: LiTH-IKP-I-260, Linköpings Universitet, Linköping, Sweden

Sundin, E., Kihlman, H., Johansen, K., 2001, *Trend & Frontiers at BT Products, Mjölby, Sweden: The Orion Project,* A report in a doctoral course*,* Reference number: LiTH-IKP-I-275, Linköpings Universitet, Linköping, Sweden

Grünberg, T., Johansen, K., Johansson, B., Nordell, P., Tangen, S., 2002, *Productivity Improvement work at ABB Robotics, Västerås,* A report in a PhD-student project within the *PROPER Productivity Project,* Reference number: LiTH-IKP-R-1256, Linköping Universitet, Linköping, Sweden

Comstock, M., Johansen, K., Kihlman, H., Sundin, E., Winroth, M., 2002, *Project Course within Assembly-NET*, A report in a doctoral course*,* Reference number: LiTH-IKP-I-289, Linköpings Universitet, Linköping, Sweden

Tangen, S., Grünberg, T., Johansson, B., Nordell, P., Johansen, K., 2004, *Produktiviteten i fokus,* Reference number: LiTH-IKP-I-312, Linköpings

Definitions

Product design

This means the process of transfer an innovative idea into a product design that can be transferred into production by utilization of the product introduction process.

Product development

This is a definition used by different researchers in slightly different ways but generally it is the process that covers product design, production system design and product introduction processes and start of production. In this thesis this definition is used when citing other researchers.

Product realization

Here, this is defined as the process that transforms a product idea into a designed, produced, and distributed product to the customer, by utilization of the product design and product introduction processes.

Product introduction

This means the process to transfer a product design into production. A common synonym is industrialization.

Extended enterprise

This means a network of companies or partners that collaborate in order to achieve extended competence, resources, etc.

Abbreviations

ASIC	Application Specific Integrated Circuit.
CAD	Computer Aided Design.
CDM	Contracted Design and Manufacturing. This means that a product owning company order a specified design and manufacturing from a service company, such as an EMS company.
CDS	Contracted Design Services. This means that a product owning company can hire engineering expertise in order to increase the competence during different phases in the product realization process.
CE	Concurrent Engineering.
CEM	Contracted Electronic Manufacturer.
CEMS	Contracted Electronic Manufacturing Services.
CEO	Chief Executive Officer.
CM	Contracted Manufacturer.
CMMN	Collaborative Manufacturing Mega-Network.
CT	Collaborative Technology.
DFA	Design For Assembly.
DFM	Design For Manufacturing.
EDI	Electronic Data Interchange.
EE	Extended Enterprise. This means a network of companies or partners that collaborate in order to achieve extended competence, resources, etc.
EMP	Ericsson Mobile Platforms.
EMS	Electronic Manufacturing Services. This is a comprehensive term for all the manufacturing services offered by contracted manufacturers (CMs), contracted electronic manufacturers (CEMs) or contracted electronic manufacturing services (CEMS).
FMEA	Failure Mode Effect Analysis.
GEEM	Generic Extended Enterprise Module.
GIG	Global Industrialization Group.
IT	Information Technology.
krAft	kompetens, reflektion, Affärsutveckling och tillväxt; Swedish project for competence development within SMEs financed by Knowledge Foundation.
NPD	New Product Development.

NPI	New Product Introduction.
NRE	Non-Recurring Engineering
ODM	Original Design and Manufacturing. This means that a company develop and produce a certain product that is branded by another company. The product is owned by the ODM company.
OECD	Organization for Economic Co-operation and Development
OEM	Original Equipment Manufacturing. This means that the company design the product OR design and manufacture the product, but it can also be a company that does no more than add their brand to the product.
PD	Product Development.
PDP	Product Development Process.
PI	Product Introduction. This means the process to transfer a product design into production. A common synonym is industrialization.
PIC	Product Introduction Center.
PLC	Product Life Cycle.
PO	Product Owner. This is a company that owns the branded product.
PR	Product Realization. This is the process covering all steps from a product idea to a complete produced product that is delivered to the customer.
QFD	Quality Function Deployment.
SI	System Integrator. This is a comprehensive term for all suppliers that can support the product owner or OEM with manufacturing and engineering services, such as concept studies, product development, production engineering, production system design and project management.
SME	Small and Medium-sized Enterprise
STF	Swedish Technology Foresight.
VAR	Value Added Reseller.

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1 Introduction

1.1 Background

Today, global competitiveness among manufacturers is increasing rapidly, and companies are acting, according to Brown and Maylor (2005), in an era of hyper-competition. A company strategy that focuses on how it can become world class in its core business may be one way of maintaining global competitiveness. Focusing on core businesses, such as production, product design, and logistics, implies that companies with different competencies need to collaborate during the processes of transferring an idea into a producible and distributed product. With this increased focus on core business during the last decade, a trend of outsourcing activities to companies that are world class in their businesses has evolved. Furthermore, this has contributed to the creation of different types of collaborative company networks – so called Extended Enterprises (EEs) – utilizing each participating company's core business competence.

Within the electronic industry this trend has been obvious, and can be exemplified by Ericsson's outsourcing of its production of consumer products to Flextronics (Ericsson, 2001), a move which created one type of EE. The trend of outsourcing production in other industry segments, such as the mechanical engineering industry, is also ongoing, with EEs suitable for these industries being created. These different types of EEs may be consonant with a single multinational organization, or, as is increasingly the case, take the form of a set of strategically-aligned companies which partner to capture specific market opportunities (Stock et al., 2000).

Clegg et al. (2000) argue that an EE may be regarded as a collection of independent, heterogeneous companies working together in order to produce an integrated product or service in whose commercial success they all share a vested interest. In some of these new EEs, the responsibility for production has been transferred from the Original Equipment Manufacturer (OEM)[1], often called Product Owner, to Electronic Manufacturing Services (EMS)[2] or System Integrators (SI)[3], in this thesis called "Producers". According to Stock et al. (2000), these kinds of extended global enterprises are designed to provide the speed and flexibility necessary to respond rapidly to windows of market opportunity. In the future, products will be jointly developed and produced

[1] An Original Equipment Manufacturer (OEM) is a company that owns a brand, designs a product or designs and manufactures a product; it can also be a company that does no more than add its brand name to a product.

[2] Electronic Manufacturing Services (EMS) is a comprehensive term for all the manufacturing services offered by Contracted Manufacturers (CMs), Contracted Electronic Manufacturers (CEMs) or Contracted Electronic Manufacturing Services (CEMS).

[3] System Integrator (SI) is a comprehensive term for all suppliers that can support the product owner or OEM with manufacturing and engineering services, such as concept studies, product development, production engineering, production system design and project management.

within these new EEs. Therefore, tomorrow's EEs need to be efficient in their product realization processes and understand how collaboration supports product design, introduction of new products into production and their ultimate delivery to customers.

1.2 Product introduction within extended enterprises

The extended enterprise (EE) must be able to manage a challenging situation where the product life cycles in the production system has for the most part decreased dramatically during the last decade. This decreasing life cycle is correlated to more frequent changes in product designs in order to support the sensitive consumer market, a market which pushes the technology development in product designs and increasing product functionality. Electronic products are a good illustration of this decreasing product life cycle period, since their product life cycle has decreased logarithmically from 11 years for a product in 1975 to a predicted 0.5 years in 2000, while the profit relative to the product cost has also decreased sharply, from 600% in 1975 to a prediction of around 2% in 2000 (Hunt and Jones, 1998). Today's mechanical engineering industry is facing this same kind of trend, as companies fight to remain competitive (Papers VI and VII).

The increasing competitiveness in the electronic industry has forced Original Equipment Manufacturers (OEMs) to manufacture their products even better in order to reach a level of world class manufacturing as described by Hayes and Wheelwright (1984). One trend for OEMs within the electronics industry is to collaborate with EMS companies in order to optimize their own business processes (Hadaya et al., 2000; Papers III and V). According to cases in this thesis, this type of collaboration tends to evolve into even closer collaboration between Product Owners[4] and Producers[5] in several industry segments – electronic, mechanical engineering and aerospace (Papers III, VI, VII and VIII; Chapter 5.2). This trend towards increased producer responsibility during the Product Realization (PR) process includes activities within concept studies, product design, product introduction, production and distribution. Product Realization is defined here as the process that transforms a product idea into a designed, produced, and distributed product to the customer, by utilization of the product design and product introduction processes.

Such a change in responsibility between Product Owners and Producers can have important ramifications for the Product Introduction (PI) process (Papers III, V, VI, VII and VIII; Chapter 5.2). Skinner (1969) mentioned that the Product Owners' management must decide on the following points and include them in their manufacturing policy:

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[4] A Product Owner (PO) represents a company that owns the branded product, typically an OEM.
[5] A Producer is a company that is responsible for the production of a product, such as an EMS or SI.

- What is the company going to make and what will it buy?
- How many factories should a company have, how big should they be, and where should they be located?
- What processes should a company implement and what equipment should it purchase?
- What are the key elements that a company must control, and how can these elements be controlled?
- What kind of management organization would be most appropriate for the company?

These questions are relevant even given the current creation of new types of EEs, and can be illustrated by the outsourcing of production from OEMs to EMS within the electronic industry (Papers III and V; Flextronics 2004; Ericsson, 2001; Sanmina-SCI; 2005). According to Hadaya et al. (2000), the OEMs within the telecommunication industry have also started to outsource other activities, such as the distribution of their products to the final customer. In some cases, such as that of Ericsson (2001), the OEM also has outsourced Product Introduction (PI) to the EMS, leading to a high demand for close cooperation between the companies during that phase. The Product Introduction is the iterative process of transferring the product design into volume production during Product Realization; in effect, it “bridges” the gap between product design and production in order to adapt the product and production system to each other.

The need for world-class manufacturing, in combination with the outsourcing of PI, demands a structured iterative collaboration between all partners within an EE. However, this structured way of working needs to be facilitated by supporting tools. Several researchers have identified a gap in the understanding of which factors affect the performance of collaboration during integrated product realization (Gerwin and Barrowman, 2002; Corswant and Tunälv, 2003). Furthermore, O’Sullivan (2003) mentions that there have been very few studies of multi-organizational virtual teams where the members must work together over an extended period, such as is the case when performing collaborative product introduction within extended enterprises.

1.3 Research objective and questions

There is a lack of knowledge concerning how to efficiently perform collaborative product introduction (PI) within the relatively new types of extended enterprises (EEs) which today are evolving in the electronic industry. Therefore:

The main objective for this research is to explore and describe factors and conditions that are of importance for an efficient collaborative Product Introduction (PI) within an Extended Enterprise (EE) in the electronic industry.

In order to fulfill the objective above, it is vital to explore the generic PI process and its relation to a generic Product Realization process, as well as to investigate the main factors and parameters relevant for both PI and PR. The main part of the research has been performed within the electronic industry and most of the findings are based on empirical findings from an extended enterprise within the electronic industry that was established during the last decades outsourcing trend. However, as mentioned earlier in this chapter, there are similar trends to observe, and valuable lessons to learn, from other industries as well. By comparing and contrasting different industries, a broader and more insightful perspective can be gained. Therefore, the decision was made to include observations from the mechanical engineering and aerospace industries as well in order to strengthen the relevance of the conclusions and supporting framework presented in this dissertation.

In order to reach the main objective, the following research questions were used as a guide:

1. How can the generic structure of an Extended Enterprise (EE) be described based on observations in the electronic industry?
   - What similarities exist between different EE structures?
2. How can Product Realization (PR) be performed within an EE in the electronic industry?
   - Which activities need to be performed in a PR process?
   - What difficulties are related to PR within an EE?
3. How can Product Introduction (PI) be performed during PR within an EE in the electronic industry?
   - Which activities need to be performed in a PI process?
   - What difficulties are related to PI in collaborative PR within an EE?

The research questions are addressed through case study research within existing EEs mainly in the electronic industry, but also in the different industries mentioned above, and by a literature review from two different perspectives: Product Realization and Extended Enterprises.

This research focused first on the PI process within the electronic industry, as the author’s experience from this segment and preliminary literature studies showed that this was a critical and vital process. Product design and production can be performed either within an OEM or an EE. However, the PI process was identified to be critically independent of the organization that was responsible for designing and/or producing the product. Collaboration within an EE means new conditions for consideration in regards to the achievement of an efficient PI process for electronic products. This can be related to experiences from the automobile industry, where Clegg et al. (1998) state that there is a need for a different approach for performing PI. Clegg et al. (1998) argue for the need of a new approach in order to achieve radical improvement in decreasing the lead-time for new product introduction, and in creating a new product introduction process for the EE that releases the synergy of all the contributors. During the research, the trend towards collaborative PI within EEs increased, as did the quotations from product owners regarding new and increased services from producers, such as product design activities (Flextronics, 2004). Therefore, cases illustrating how to integrate the PI process with a collaborative PR process within an EE, in order to reach an efficient overall process supporting collaborative design of products suitable for production, have been studied (Papers V, VI, VII and VIII).

The scope of this research is meant to illustrate the combination of two areas: Product Introduction and the Extended Enterprise. Product Introduction is a vital part of the Product Realization process that “bridges” the gap between product design and production. In this dissertation, Product Realization is divided into four main processes: concept phase, product design, production system design and production including distribution. These processes iteratively facilitate the transfer of a product idea into a designed, produced and distributed product by utilization of the product introduction process. Furthermore, the author of this thesis uses the Product Realization concept in order to illustrate the difference between the product design, product system design and product introduction processes and the need for them to collaborate iteratively. The author’s strategy for illustrating Product Realization (see Figure 3.1) also focuses on the need for the management of feedback between processes and the people acting in them.

1.4 Delimitations

The research does not provide a deep analysis of product development in theory, but rather illustrates how product realization/product development is performed in different cases. The case within the electronic industry (Papers I – V) enabled real-time research of the effects connected with the outsourcing trend during the last decade. The production unit observed was transferred into another company and its business culture, and thus underwent a change from a role as a part of an OEM to that of an actor within an EMS company. This change also affected this research, since the industrial supervisors changed several times. However, all aspects of what occurred during this transfer have not been covered in this research; instead, the main focus has been on how to perform collaborative product introduction within the electronic industry, and on which issues to manage as a producer while collaborating with product owners and suppliers in extended enterprises.

Given the time and monetary constraints of this research, the study of additional unique organizational structures has been excluded, and undoubtedly the inclusion of additional structures would have led to even further insight for the author. The focus here, however, was more on an engineering level, and to describe the conditions for collaborative product introduction within extended enterprises in the electronic industry. Locke et al. (1993) mention that there are times when all of the factors in a case study cannot be controlled; nevertheless, they continue, it is still the case study that provides the relevant information.

1.5 Thesis structure

This thesis primarily describes an EE within the electronic industry that performs collaborative product introduction. However, supporting cases have been performed within the mechanical engineering and aerospace industries, in order to relate this research's observations within the electronic industry to those in other industries, as described in Section 1.3.

The thesis is divided into eight chapters. Chapter 1 is an *Introduction* to the research, and presents the research questions. Chapter 2 describes the *Research methods* used in the case studies. Chapter 3 gives a *Theoretical framework* that is referred to in this thesis. The *Extended enterprises* are presented in Chapter 4. The *Product realization within extended enterprises* are explored and described in Chapter 5. In Chapter 6, the conditions for performing *Product introduction in product realization within extended enterprises* are described. Chapter 7 presents a *Framework for collaborative product introduction within extended enterprises* that is based on a combination of the observations in the cases. In *Discussion,* Chapter 8, the results are summarized and the contribution of this research discussed. Finally, the *References* in Chapter 9 are included prior to the appendix and the appended papers.

2 Research method

2.1 Scientific approach

The objective for this research is to explore and describe factors and conditions that are of importance for an efficient collaborative product introduction within an extended enterprise, as mentioned in Section 1.3. The three related research questions defined in the introduction are addressed in Sections 4, 5 and 6. The results are based on a review of theory and empirical findings from case studies performed within the electronic, mechanical engineering and aerospace industries in Sweden. The research has primarily been performed within the electronic industry (Papers I – V), but extended case studies in other industry segments (Papers VI – VIII) were also conducted in order to compare and contrast trends and lessons learned in similar industries and thus provide a broader perspective for the formulation of relevant conclusions in this research (see Section 1.3). Additional cases within the electronic industry have also been conducted, and these are briefly described in Appendix A. Finally, the result is combined into a framework for collaborative product introduction within extended enterprises in Section 7.

Changes in industry, such as the trend of outsourcing and thus an increased focus on core business activities (see Section 1), have established new extended enterprises with a need for effective collaboration during the important product introduction process. This research has focused on the study of a combination of theoretical areas – product introduction, product development and extended enterprises – for the reason that today's changing industry needs to manage this combination efficiently, especially given the current climate of hyper-competition (Brown and Maylor, 2005).

The overall research is based on a systems approach (Arbnor and Bjerke, 1997), since the PI process and the interaction between different companies and/or organizations within an EE depend on how actors are interacting. The systems approach aims at finding the indicator-effect relationship between the actors or components involved in the system. These actors or components not only provide information on themselves, but also how they are combined in the system. Therefore, to obtain knowledge concerning the conditions for performing PI within an EE and how an EE can be designed, the systems approach was chosen in order to view the conditions as objectively as possible. Interviews based on a qualitative approach (Leedy, 1997) were performed in order to determine the indicators and their effects, i.e. the conditions for performing the PI.

According to Arbnor and Bjerke (1997) there exist two other approaches: analytical and action. The analytical approach aims at finding the cause-effect relationship, and is usually based on quantitative data in order to be able to predict the course of events. This is a useful approach in traditional natural science where laws are sought and hypotheses formulated and tested. According to Arbnor and Bjerke, the analytical approach is useful when the reality is concrete and conformable to law from a structure independent of the observer or when the reality is a concrete determining process. In the action approach, however, both the view of reality and the view of knowledge differ from the system approach and the analytical approach. Arbnor and Bjerke (1997) suggest the action approach when the reality is a social construction or a manifestation of human intentional. An action approach is useful when the researcher is active during the case and therefore, the observations and the knowledge is dependent on individuals and thus not objective. However, the approaches above are very briefly described.

The possibility for the researcher to participate in the case study of how to perform collaborative PR within an EE (Papers VI and VII) initiate the use of an action approach, since the goal was to solve a problem for a customer and at the same time map the way it was done, and to develop a framework supporting early collaboration in EEs within the mechanical engineering industry. However, the main research is based on observations from the changing electronic industry and the enterprise that has evolved from its start as a single OEM responsible for its own manufacturing – Ericsson Mobile Communications AB – to an extended enterprise (Papers I – V). This extended enterprise was founded when Flextronics International bought the major numbers of production units for mobile phones from Ericsson Mobile Communications AB in January 2001 (Ericsson, 2001). The author of this dissertation worked as an industrial Ph.D. student throughout the course of these changes, both within Ericsson and Flextronics.

Given the changes in the electronic industry and the opportunity to perform case studies in the Swedish mechanical engineering and aircraft industries, relevant literature within the research area has been reviewed from different perspectives. From the very beginning, the focus of this research was on World Class Manufacturing and the criteria to fulfill in order to reach and improve on such a level within an OEM. During the course of this research, however, Ericsson sold the major part of its mobile phone production to Flextronics International, an EMS. Following this, an extended enterprise (EE) was established with the responsibility for product introduction (PI) and production at the EMS. The research was adapted to these changes and focused towards how to perform collaborative product introduction within an extended enterprise in the electronic industry. The product introduction process is a vital component during product realization (Wheelwright and Clark, 1992; Papers III and V). With a system approach, these changes within the electronic industry can be explained from a holistic point of view, and help to describe how companies can establish and perform collaborative product introduction within extended enterprises.

2.2 Research methodology

Theree are a number of different research strategies, each relevant for different situations (Yin, 1994): experiments, surveys, archival analysis, history study, and case study (see Table 2.1).

Table 2.1: Relevant situations for different research strategies (Yin, 1994)

Strategy	Form of research question	Requires control over behavioral events?	Focuses on contemporary events?
Experiment	How, Why, (What)	Yes	Yes
Survey	Who, What, Where, How many, How much	No	Yes
Archival analysis	Who, What, Where, How many, How much	No	Yes / No
History	How, Why, (What)	No	No
Case study	How, Why, (What)	No	Yes

According to Table 2.1 and the focus of this research's first phase (Papers I – V) – the description of product introduction within extended enterprises – a case study approach was deemed as the most suitable. Here, the case study will be used to answer the following questions:

- *How* can companies work in an extended enterprise?
- *Why* it is necessary to do things in a certain way?
- *What* factors should be considered?

There is no need to require control over behavioral events in order to answer these questions. However, there is a focus on contemporary events in industry and on how other industries work with the same types of questions and problems. In this case, the case study method was chosen based on Yin's research strategies, and due to its value as an exploratory tool (Leedy, 1997). In this research, several case studies have been performed in the Swedish electronic manufacturing industry, both within an OEM and an EE. The case studies are based on interviews with those involved with and responsible for engineering, or those in management positions close to manufacturing.

The mechanical engineering case (Papers VI and VII), however, does have an action science approach, as is seen by the first three bullets in Table 2.2. Further comparison with the characteristics of action science (see Table 2.2) shows that the use of the systems approach was helpful in fostering a holistic view in the case. A holistic view relating to wholes or complete systems instead of analysis of parts and supports the systems approach in this research. The cases and the interviews based on the qualitative approach (Leedy, 1997) supports the hermeneutic paradigm (see Table 2.2) and its focus on understanding and interpretation. The positivist paradigm, mentioned in Table

2.2, is producing knowledge that is based on general laws and is traditionally associated with quantitative methods (Patel and Davidson, 1994).

Table 2.2: The characteristics of action science (Gummesson, 1991)

- Dual goals: Solve a problem for the client and contribute to science
- Those involved – researcher and client personnel – should learn from each other and develop competence
- The understanding developed throughout the project is holistic
- Action science requires co-operation, feedback and continuous adjustment
- Action science applies to the understanding of change in social systems
- There must be a mutually acceptable ethical framework
- Pre-understanding of the corporate environment and the conditions of business is vital
- Action research should be guided by the hermeneutic paradigm, although elements from the positivist paradigm may be included

The action approach (Gummesson, 1991; Arbnor and Bjerke, 1994) will be further discussed here, since the author has been an industrial Ph.D. student within the electronic industry. The observations within the electronic industry can, however, not be seen as typical action research, since there was initial difficulty in defining a task to address during the research project in co-operation with participants from the company (Papers I – V). Rather, this research objective has evolved from a more technical initial focus to a more organizational and business-related one as the research progressed. This, in turn, can be related to the author's different industrial supervisors during the turbulent period in the electronic industry. The industrial supervisors have come from diverse backgrounds: a manager for the engineering department within a production unit (OEM); a project manager responsible for coordinating global manufacturing (OEM); a product introduction center manager (EMS); a vice president of product design (EMS), and a vice president of engineering services (EMS). In addition, the research has been continuously adjusted depending on the changes within the industrial segment of electronics. As an industrial Ph.D. student with prior experience from industry, there was an existing understanding of the corporate environment and the basic conditions of the business from the beginning of the research. However, this close connection to the electronic industry and the opportunity to follow its changes from the inside has contributed to the knowledge of the author. On the other hand, some of this knowledge is sensitive or confidential in nature, and for that reason could not be described in detail in this thesis.

2.3 Case study disposition

The disposition of the case studies will be described and presented in this section. The appended papers represent the two different related areas in the research and their relation is illustrated in Figure 2.1.

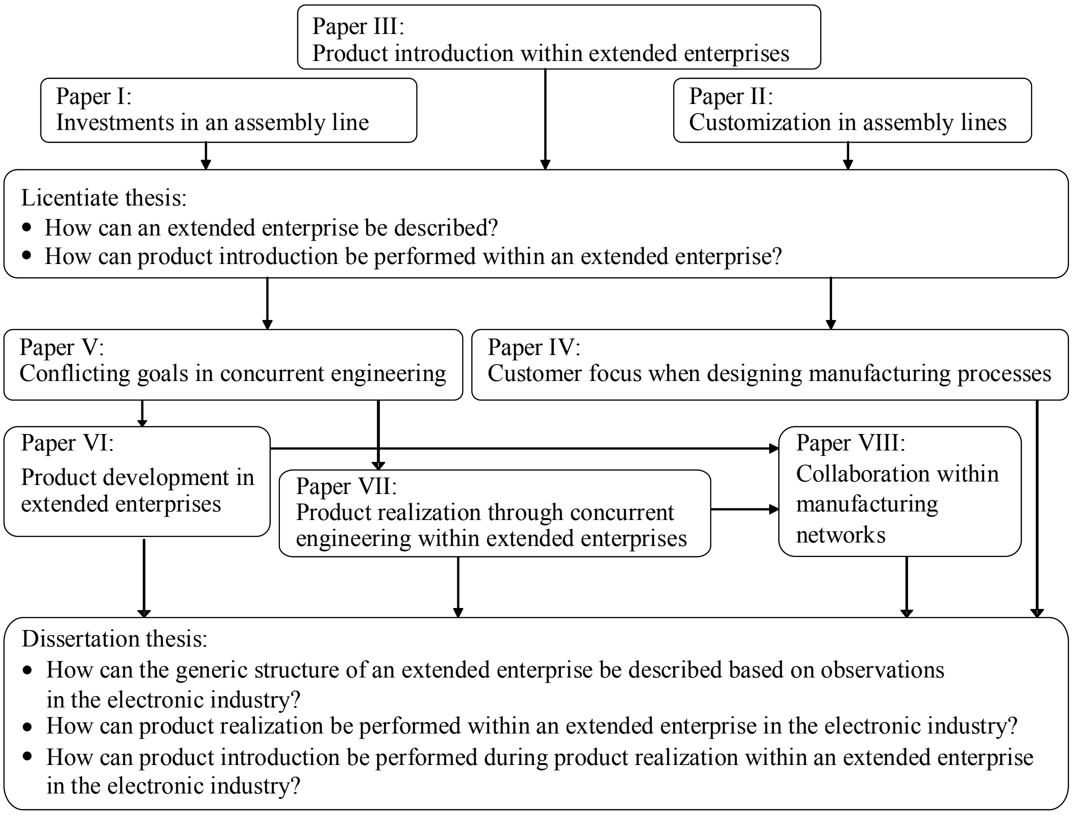

Figure 2.1: Structure for appended papers and performed case studies for supporting the research objective

The first area describes Product Introduction (PI), and is represented in five of the appended papers. The PI is described from three different perspectives: which parameters people working with PI in extended enterprises (EE) think are important and why (Papers III and V), the importance of knowing how to make reliable calculations when investing in assembly lines (Paper I), and the importance of sufficiently considering customer demands when designing a production process (Papers II and IV).

The remaining three appended papers focus on Product Realization (PR) within Extended Enterprises (EEs). The PR is described from two different perspectives: how to use concurrent engineering in order to perform and start-up collaborative PR within an EE (Papers VI and VII), and the need for co-ordination and collaboration within EEs during PR in large, geographically dispersed projects (Paper VIII).

The case studies, interviews and interview series have been performed in both OEM companies and EEs, which primarily represent the electronic and the mechanical engineering industries in Sweden. A minor study has, however, been performed in the Swedish aerospace industry, in order to illustrate an enormous – what the study refers to as a "mega" - EE. Figure 2.1 gives an overview of papers describing the case studies included in this thesis.

2.3.1 Case study –Product introduction within extended enterprises

This case study, referred to in Papers III and V, was performed in an Extended Enterprise (EE) and focused on the process of Product Introduction (PI), where the product owner or supplier of services/consultant is responsible for the product design. Furthermore, the producer is responsible for transforming the design into volume production – the PI process. The study concerning the definition of PI was guided by the following questions:

- How do you define PI?
- What is included in the PI process from your point of view?
- Which criterion is the most important to consider for an efficient PI in an EE?

To obtain the answers of these questions, data was collected through semi-structured interviews within the extended enterprise during the spring of 2002. The group of those interviewed consisted of, in total, 12 people at 4 different units or companies. The interviewed representing the product owner were responsible for signing agreements with partners that could provide Product Introduction competencies and high volume manufacturing. The interviewed representing the Producer were designing products as a supplier of services/consultant for external product owners, selling Product Introduction as a program manager, Product Introduction project management, production and test engineering. The three questions were used as basis for discussion regarding the subject, and those interviewed were selected with the aim of covering as many functions involved in a PI process within an EE as possible. Yin argues that a case study does not represent a "sample", since the investigator's goal is to expand and generalize theories and not to enumerate frequencies (Yin, 1994). As March et al. (1997) put it, "the number of units investigated is less important in field research than in other methods of research because the goal is to expand and generalize theories, not to generalize findings from a sample to a population".

The results of the interviews were coded and analyzed (Miles and Huberman, 1994). As a complement to the interviews, one of the authors has had the possibility to conduct direct observations inside the extended enterprise, as well as participate in different meetings and discussions within the EMS. All information from the case that is relevant for defining PI and what to consider when working with it is presented and analyzed in Paper III. All new information in the case study is from one EE, where Flextronics International is the main contributor, as well as two of their customers, one as a supplier of services/consultant responsible for product design and the other as a product owner responsible for its product design. One limitation is that only two of those interviewed in the case study answered the questions from a "customer point of view", but one of them represented a large, important customer, so the information is of high relevance for the EE.

2.3.2 Interviews – Investments in an assembly line

These interviews, referred to in Paper I, were performed in a large multinational electronic company – an OEM. The aim was to describe and explain a way of working, especially for production engineers performing investment calculations when designing a production process (Paper I). The data was collected through interviews with production engineers working with production process design within the manufacturing unit of Ericsson Mobile Communications AB in Linköping, Sweden. The interviews were not recorded, but minutes were made and approved by the engineers. Some discussions have also been made, without approved minutes, with the factory manager that was responsible for automation of the production process at the time. The authors also had the possibility to make their own observations within the manufacturing unit, both by performing other studies at the unit (Winroth and Björkman, 2000a,b) and through past work experiences at the unit dating back to the mid-1990s. Furthermore, the thesis writer has been working within different areas such as test development, process development, and advanced manufacturing.

2.3.3 Case study – Customization demands on manufacturing

This case study, referred to in Papers II and IV, aimed to investigate the strategic considerations of Mass Customization at Ericsson. The study was conducted over a period of three months during the spring 2001, just after the outsourcing of the company's manufacturing was announced. The study was guided by the following four questions:

- What is the tradition of customized production at the company, and what role does Mass Customization play today?
- What is the current and projected competitive requirement for Mass Customization at Ericsson?
- Should Ericsson decide to become a mass-customizer, how prepared is the company to implement the strategy based on its present processes, infrastructure, initiatives, and market situation?
- What forms could the realization of Mass Customization take at Ericsson?

To obtain answers to these questions, data was collected through a series of semi-structured interviews at the company's factory located in Linköping, Sweden. Five Ericsson managers involved in various areas of production at the company were interviewed. However, the company in focus was not an example of Mass Customization fully realized when performing the interviews.

During the spring of 2001, the manufacturing division of mobile phones was sold to Flextronics International, and the OEM – the product owner – strove to increase customization in an extremely turbulent, high-volume manufacturing environment. In this way, Ericsson can be seen as a representative example of the many companies producing somewhere between the extremes Mass Production and Mass Customization (Paper II). The authors feel that a fruitful discussion of Mass Customization is highly dependent on one's knowledge of, and even attitudes towards, the strategy. Therefore, it is important to consider that while all of those interviewed were familiar with Mass Customization, the concept still represents a great shift from the Ericsson "paradigm" of large order fulfillment enabled by Mass Production. Thus, the authors cannot be sure that those interviewed were equally aware of and receptive to the many issues of Mass Customization.

2.3.4 Case study – Product realization within extended enterprises

This case study, referred to in Papers VI, VII and Section 6.1.1 in this thesis, was performed in an extended enterprise (EE) responsible for product realization of a new variant of an existing product. The case was performed in co-operation with a Product Owner in order to evaluate the performance within a supplier network. The aim for the research was to describe and explain a way of working in an EE that is based on an "old" virtual enterprise. The EE that was studied in this case consisted of a Product Owner, system, second and third-tier suppliers, participants from other specialist companies outside the project, and Linköping University. This particular EE operated within the mechanical engineering industry. The study is based on the author's own observations during the winter of 2002-2003.

The product realization process started with a workshop covering the conceptual re-design phase. The workshop involved participants with different competencies in the extended enterprise described above. The participants were divided into two groups, each of which was given different modules to evaluate. The author participated in one of these groups. The Product Owner chose the modules of interest, and a few limitations, such as connection points to other modules and material, were settled before the groups could begin the re-design. Since the author participated in the workshop and the case had clear goals, this case study has a clear action research approach.

2.3.5 Interviews – Collaboration within manufacturing networks

These interviews, referred to in Paper VIII, were performed during the spring of 2003 at the Saab Aerospace manufacturing facility in Linköping, Sweden. Data was collected through semi-structured interviews of two Saab Aerospace managers. The interviews, which spanned a three-hour period, were recorded, transcribed and subsequently approved by the respondents. Prior to the interviews, the respondents were provided with the following questions to consider for the analysis of an existing collaborative manufacturing network from three different perspectives:

1. What is the design (structure) and organization of the network?
2. How does the network coordinate and plan for resources, material and competence?
3. How do companies in the network relate to external partners such as suppliers, final customers and other units?

Saab Aerospace was chosen as a case study example because of its important role in one of the world's largest consortiums responsible for the product realization of Airbus Industrie's new "mega-jumbo" jet, the A-380 (Airbus, 2003; Saab, 2003). This manufacturing network, in which Saab is a partner, illustrated the parameters or factors that must be managed between different collaborating companies in order to increase efficiency in the product realization process. Furthermore, the manufacturing network was another example of a structure for an EE. Saab's role in the collaboration was that of system integrator (SI) or 1st tier supplier, responsible for the development and manufacturing of the wing structure in collaboration with both its suppliers and the product owner – Airbus. This role of Saab was significant given its strategic shift as product owner of complete aircrafts to that of a SI for structures to other product owners.

2.3.6 Other related studies

In order to find the most relevant areas in which to perform the research, both from an academic and industrial point of view, a number of other interview series have been performed. A workshop within an EMS-company has also been supervised and performed in order to study collaboration between managers. These managers represented different areas and competencies that needs to collaborate efficiently during Product Introduction within an Extended Enterprise. During these studies, the author's own observations and a couple of more informal interviews were performed. The three most relevant studies within the electronic industry for the final research focus were as follows:

- Manufacturing networks
- World class manufacturing
- Collaboration between different competencies

All three studies are further described in Appendix A.

During the research, the author had the opportunity to supervise various project and thesis workers. The results of their reports support some of the findings in the case studies, and are for this reason referenced throughout this dissertation. Two projects were performed to investigate what factors are important to manage when locating manufacturing. These projects focused on factors regarding a strategic perspective and the production engineering perspective (Andersson et al., 2001; Fredriksson and Dahlin, 2001). Furthermore, a master's thesis was supervised within the area of distributed product development and the capability of supporting collaborative tools (Schmidt, 2004).

2.4 Review of the empirical data collection

This research is a combination of a systems approach and an action approach. The system approach has been used in order to understand and explore the product introduction process, while the action approach was more useful for understanding important issues related to the collaboration within extended enterprises. Gummesson (1991) presented the quality criteria to fulfill for case study research, as shown in Table 2.3.

Table 2.3: Quality criteria for case study research (Gummesson, 1991)

- A research project should be conducted in a manner that allows readers to draw their own conclusions
- Researchers should present their paradigm
- Research should possess creditability
- The researcher should have adequate access
- A statement should be made about the validity of the research
- The research should make a contribution
- The research process should be dynamic
- The researcher should have commitment and integrity
- As an individual, the researcher should possess pre-understanding, candor and honesty

Referring to Gummesson's (1991) list of quality criteria for action science (see Table 2.3), an industrial Ph.D. student does not have a problem with adequate access to data within his or her own organization/industry segment. However, as an industrial Ph.D. student, as for all researchers, it is necessary to secure the validity of the research through the recording of data or approved minutes from interviews, etc. Therefore, the data collection for the eight studies performed in industry will be described below.

Five of these eight studies have been published in the eight appended papers. The other three studies are described and included in this thesis in Appendix A, as these illustrate some of the conditions that need to be managed within the EEs observed. Each of the eight studies conducted for this research had a different scope. Four of the studies were case studies based on semi-structured interviews with several people, all answering the same questions, while one study had an action science approach, where the researcher participated in different workshops during a re-designing project and took notes during the study. The five studies reflected in Papers I – VIII are briefly described below:

1. Interviews with production engineers regarding how to work with strategic investments in an assembly line (Paper I)
2. Interviews with engineers and managers at an production unit within an OEM regarding how to work with mass customization when manufacturing mobile phones (Papers II and IV)
3. Interviews with engineers, managers and customers regarding how to work in an EE responsible for electronic products (Papers III and V)
4. Action research, through participation in one part of the concept phase during a PR process within an EE (Papers VI and VII)
5. Interviews with an information manager and a production engineering manager regarding how to work with collaborative manufacturing in a strategic alliance within the aerospace industry (Paper VIII)

The documentation for each of the interviews differs in several ways. The first study is based on an interview with two production engineers at the same time, which was performed by two researchers taking notes. Both researchers wrote minutes that were merged into one document, which was then sent via e-mail to the production engineers for review and approval. The second study is based on interviews performed in the same manner as the first, but with single-person interview sessions. In the third study, two of the interviews were recorded and transcribed. For the remainder of the interviews, minutes were taken and sent to those interviewed by e-mail for review and approval. The fourth study is documented from participation materials, minutes, reports, a reviewed framework on a CD, etc. The fifth study was performed in the same manner as the first.

The remaining three studies are included in Appendix A. One of these studies had a workshop approach regarding collaboration between different competencies, while the other three studies were much more conversational in nature, and related to the interviewees' different competence areas. These studies are called "interviews" or "interview series" in this thesis. All three studies are briefly described below:

1. Interview with one key person working with strategic decisions regarding a manufacturing network within an OEM (Appendix A)
2. Interview with managers at a manufacturing unit within an OEM concerning World Class Manufacturing issues (Appendix A)
3. Workshop performed with managers within an organization regarding collaboration between different competencies (Appendix A)

In the first study, one person was interviewed, with the resulting report reviewed and approved by the interviewed person. The second study is the weakest one from a perspective of validity, as it is based on informal discussions with two managers regarding the subject without any approved minutes. It is included here, however, since the results of the interviews apply to the focus of this research. Finally, the third study had a workshop approach, in which the author had a coordinating role, and thus acted as an action researcher with a clear goal. Throughout the research, the author had access to the internal network (Intranet) within the industrial company supporting the research – first, within the OEM, then within both the OEM and the EMS, and finally within the EMS.

It is also important to note consider that the author's own experience and knowledge within the area can imply that it may have been obvious for such an action researcher, immersed within an organization / industry segment, to see exactly what was happening and solicit the correct information. Finally, it can be seen as a risk to have the possibility to choose colleagues for interviews that support the researcher's own opinions. On the other hand, the own experience from the electronic industry and the opportunity to have full access to information and communication probably reduces the risk that the researcher will not follow the ethical framework.

In order to validate the information collected within the researcher's own organization within the electronic industry (Papers I – V), extended research with cases in the mechanical engineering and aerospace industries (Papers VI – VIII) were performed. In the case study describing product realization in extended enterprises (Papers VI and VII), the author acted as an action researcher during the first steps in the process studied.

3 Theoretical framework

The theoretical framework of this dissertation covers several theoretical areas. The main areas are product realization and extended enterprises. This research focus is on the collaboration during product introduction as a vital part of product realization within extended enterprises.

3.1 Product realization

In this thesis, the term product realization is used instead of the term product development, in order to cover all activities from the conceptual phase to distribution. This means that product realization is defined as the process that transforms a product idea into a designed, produced and distributed product to the end user, by utilization of the product design, production system design and product introduction processes, see illustration in Figure 3.1. However, the term product development is used when referring to authors that use that term instead of product realization. The product realization process aims to manage information and feedback between all involved processes from the concept generation into a distributed product at end users, see arrows in Figure 3.1.

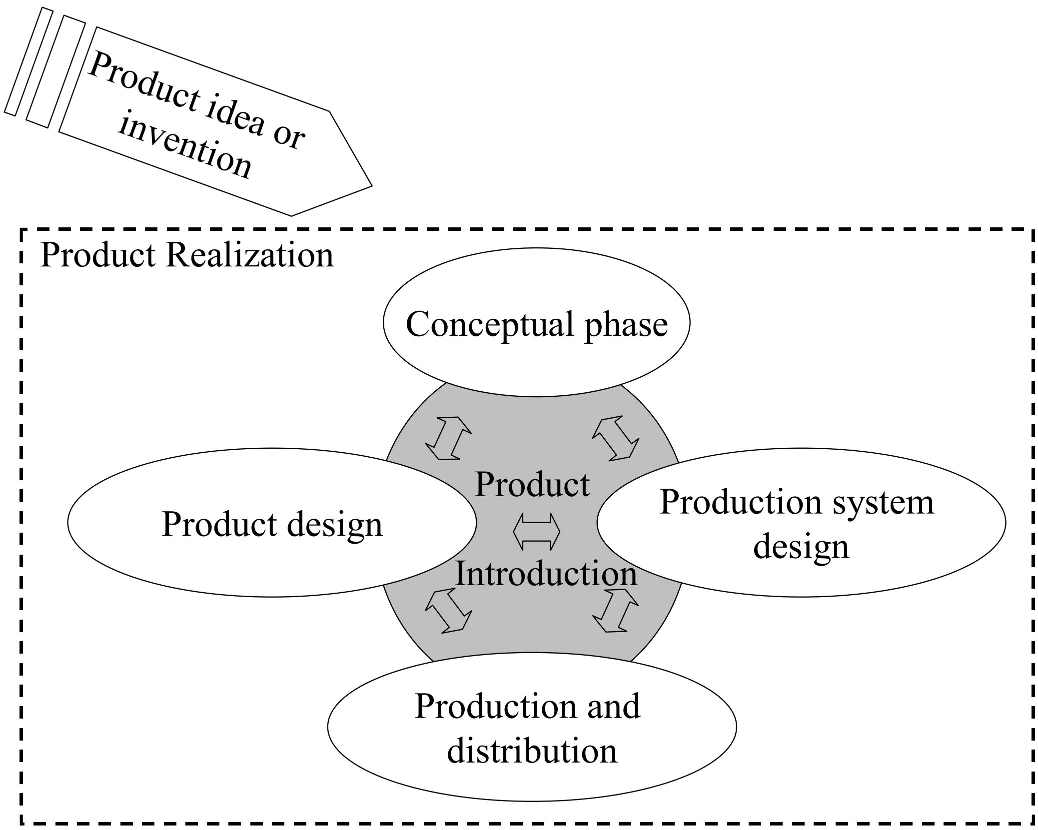

Figure 3.1: The product realization process

Several researchers have indicated that it is important to managing feedback during product development (Ulrich and Eppinger, 1995; Otto and Wood, 2001) which may be supported by multiple design iterations and frequent project milestones (Eisenhardt and Tabrizi, 1995). In the literature, the two terms product development (PD) and new product development (NPD) are used, where NPD is the most common. In this thesis, both NPD and PD are used simultaneously, and both are seen here to represent the same definition presented by Cooper (2003), which states that "*NPD is the process by which an organization uses its resources and capabilities to create a new product or improve an existing one*".

As product development processes become more strategically relevant, companies are being compelled to improve their effectiveness in developing better quality products in a shorter time and with fewer resources (Clark and Fujimoto, 1991; Cusumano and Nobeoka, 1992; Bowen et al., 1994). Product development is an interdisciplinary activity combining at the very least the marketing, design and manufacturing functions, and is increasingly accomplished via cross-functional teams (Adler, 1995; Ulrich and Eppinger, 1995; McDonough, 2000; Otto and Wood, 2001). Furthermore, a product development process can sometimes include development of the distribution channels and the introduction of the new product on the market (Ulrich and Eppinger, 1995; Otto and Wood, 2001). Fast product development is, according to Eisenhardt and Tabrizi (1995), achieved through utilization of multi-functional teams and the experimental strategy of iteration, testing, milestones, and powerful leaders. Applying these references to an extended enterprise within the electronic industry consisting of an OEM, an EMS and suppliers of material, components and equipment, means that a product development project needs to involve at least two companies - the OEM and the EMS, if the EMS is responsible for the material supply, otherwise even the suppliers may be involved. Eisenhardt and Tabrizi (1995) argue that early supplier involvement may be difficult to achieve since the uncertainty in the product design is transferred into an uncertainty about which supplier that will be used. However, there is a need for close collaboration between all actors, during the cross-functional product development process in order to compete successfully, since NPD, according to Cooper (2003), is a people and knowledge-intensive effort whose success is critical to the survival of companies.

Several researchers have evaluated what is important to consider in product development, even if the actual process of product development, according to Brown and Eisenhardt (1995), is largely a "black box". Cooper (2003) summarizes a number of identified factors that influence the NPD process: technology, product characteristics, project structure, team member characteristics and patterns, team processes, organizational context, and external environment. Garvin (1992) argues that new products progress through the following three stages:

Product research:
Basic Research & Development takes place, creating new knowledge and allowing a concept to be developed.

Product development:
Includes market research, prototypes, field-testing and the creation of specifications.

Final design:
The development and approval of design include bills of materials of the final product.

The responsible function or organization for manufacturing needs to be involved in all of the stages above in order to minimize the risks that Garvin (1992) describes below:

- ***Market risks*** – uncertain customer demands before the final product is completed which leads to uncertain volume of purchasing
- ***Competitive risks*** – difficult to predict the competitive response
- ***Technological risk*** – new methods and material can give problems; this can be reduced by involving production / operations early in the process
- ***Organizational risks*** – training and new skills may be needed
- ***Production risk*** – problems of producing a product in high volume might not have been revealed at the prototype stage
- ***Financial risk*** – large amount of debt has been incurred through R&D, marketing and production, and the payoff is uncertain

Eisenhardt and Tabrizis (1995) suggest six phases during product development based on experience from the computer industry: Planning (or Predevelopment), Conceptual design, Product design, Testing, Process development and Production start-up. They argue for that rapidly building intuition and flexible options in order to learn quickly about and shift with uncertain environments is the key to fast product development. Successful product development is, according to Ulrich and Eppinger (1995), characterized by five specific dimensions, all of which ultimately relate to profit, and that are commonly used to assess the performance of a product development effort:

- ***Product quality***: Is it robust and reliable? Product quality reflects the price a customer is willing to pay.
- ***Product cost:*** What is the manufacturing cost of the product? This determines the future profit related to sales volumes and sales price.
- ***Development time:*** Shows how responsive the firm can be to competitive forces and technological developments and how quickly economic returns are received.
- ***Development cost:*** How much was spent on developing the product? This can be used when calculating how required investments affect profit.
- ***Development capability:*** Is the experience from earlier product development projects used to better the team for future product development? This is an asset that can be used to develop products more effectively and economically in the future.

Comparing Cooper's summary (2003) with Garvin's three stages (1992) and Ulrich and Eppinger's five dimensions (1995) shows that Garvin, together with Ulrich and Eppinger, are more technology-focused. Cooper, on the other hand, covers a broader area, which is necessary in order to succeed in the more collaborative extended enterprise environments that have evolved during the last decade. Product development, it appears, is changing towards a more integrated PD process that can adapt to and shift with a dynamic environment (Eisenhardt and Tabrizi, 1995), such as the case when two or more companies collaborate within an extended enterprise.

3.1.1 Product idea

The input to the product realization process is a product idea or an invention, which is transformed into an innovation during the product realization process (see Figure 3.1). However, Garcia and Calantone (2002) reviewed relevant literature covering innovation and identified a lack of conformance in defining 'innovation'. They argue that this may be due to the fact that innovations are researched from many scholastic communities and, therefore, address each community's selected audience. The 1991 Organization for Economic Co-operation and Development (OECD) captures the essence of innovation as an iterative process initiated by the perception of a new market and/or new service opportunity for a technology-based invention, which leads to development, production, and marketing tasks striving for the commercial success of the invention. An invention does not become an innovation until it has been processed through production and marketing tasks and becomes products that reach the market (Freeman, 1991; Smith and Barfield, 1996). An innovation differs from an invention in that it provides economic value (Garcia and Calantone, 2002). Therefore, an innovation is defined here as a technical solution for a specific problem, resulting in a new or modified product, that can be produced in required volumes to the right cost according to the product's marketplace. This implies that innovation is a part of the conceptual phase in the product realization process, and that it needs to be iteratively adopted into both product and production system design (see Figure 3.1).

3.1.2 Product introduction

In the literature, there are two principal terms used to describe the process of transferring a design into production – industrialization and New Product Introduction (NPI). The term Product Introduction (PI) will be used for the most part in this thesis, however, since it is not necessarily a *new* product that is introduced into production – it can also be a variant or an upgraded version of an existing one. In this thesis, the product introduction process is illustrated as a hub within the product realization process supporting the concurrent engineering and information exchange during an iterative collaboration, see Figure 3.1.

During a NPI process in, for example, the automotive industry, extensive communication and collaboration must take place between manufacturers and suppliers at geographically dispersed sites (May and Carter, 2001). May and Carter made an analysis of a case study they performed with data collection within a NPI process, and concluded that within a NPI process there is:

(1) A complexity of the collaborative relationships, both within and across company boundaries.
(2) An ad-hoc and informal nature of much of the communication and collaboration between engineers.
(3) A lack of formal procedures for interactions between different members of the supply chain (e.g. the activities between milestones or gateways in the NPI process are often unscheduled and eclectic).

In the electronic industry, computer servers comprise a very aggressive market with geographically dispersed working teams responsible for the NPI of the products (Classen and López, 1998). In a case study, Classen and López identified the key sub-processes for the engineering activities during a NPI as project management, test strategy, test development, process development, process transfer, design for manufacturability (DFM), engineering responsibility and, finally, printed circuit assembly (PCA) know-how. The collaboration of each party in the sub-processes was supported by three defined roles – owner, co-owner and observer. Finally, Classen and López observed that communication is essential to ensure smooth product introduction, especially when the design site and the manufacturing sites are separated by several time zones. Tennant and Roberts (2001) conclude that to successfully apply quality and reliability tools within the NPI process, it is necessary to consider the predominant and sub-cultural norms that exist within the NPI organization.

New Product Introduction is closely related to the manner of work within new product development, with Brown (1996) arguing that the speed of new product development is becoming increasingly important for successful competition within the telecommunications industry. Firms that get to market faster and more efficiently with products that are well matched to the needs and expectations of target customers create significant competitive leverage (Hayes and Wheelwright, 1992). In other words, there is a need for close collaboration during the product introduction phase in order to successfully compete.

3.1.3 World class manufacturing

In order to increase efficiency in the production system, both from a business and a technological perspective, there is a need for the reuse of existing production solutions. The largest EMS companies in the world manage a portfolio of plants located around the globe using flexible, modular and reconfigurable assembly systems (Hadaya et al., 2000). Therefore, the choice of production strategy and production system is limited within the extended enterprise. The companies involved in the extended enterprise will align themselves with companies that already have a production strategy or production process that fit the product as well as possible from the beginning. Hill (1995) argues that the choice of production process depends mainly on product type, product market, volume and flexibility.

For over a century, the system of mass production has prevailed. Skinner (1985) identifies the characteristics of mass production as a system of long production runs, stabilized designs in engineering, repetitive operations by workers, and many identical machines throughout the factory. The problem with mass production, however, is that it does not address the requirement for quick response in terms of new product introduction or variability (Brown, 1996). Drawing on the work of Skinner, Hayes and Wheelwright (1984) introduced the term “world class manufacturing” in an attempt to describe what was making Japanese and German companies so strong in terms of global competition. Hayes and Wheelwright defined six dimensions connected to practices that a company striving for world class manufacturing should adopt (see Table 3.1).

For an EMS as a partner in an extended enterprise, all working areas defined by Hayes and Wheelwright are of interest, but the three most important areas are competing through quality, rebuilding manufacturing engineering and workforce participation. Quality ensures that the product has the right design and robustness so the customers, both the product owner (the OEM) and the consumer, buy the service or the product and recommend it to others. Rebuilding manufacturing engineering ensures that the EMS makes a profit when reusing equipment and production processes, and thus gets lower refinement cost for the product, giving the product owner (OEM) benefits of higher profit margins. However, some investments within the production system need to be taken in order to secure future competitiveness. The last area of importance – workforce participation – focuses on profit. If the workforce participates to a high degree and feels that it is in business together with the extended enterprise, the management does not need to push every single operation.

Table 3.1: Suitable practices within different working areas (Hayes and Wheelwright, 1984)

Working areas	Practices
Workforce skills and capabilities	• Apprenticeship programs • Co-operative arrangements with vocational technical institutes • Internal training institutes • Extensive advanced training and retraining beyond entry level, focusing on skills, work habits and motivation
Management technical competence	• Ensure that a significant number of managers have engineering or technical degrees • Train potential managers early on in their careers in a variety of technologies important for the firm • Rotate managers through various functions to broaden their experience
Competing through quality	• Seek to align products and processes to meet needs that are important to customers • Long-term commitment to quality • Strong attention to product design • Involvement of all functions in product design and quality improvement
Workforce participation	• Develop a culture of trust between workers in various departments and between workers and management • Close contact between management and workers • Develop participation policies to ensure that "We are all in this together"
Rebuilding manufacturing engineering	• Invest in proprietary equipment • Bolster ability to perform sophisticated maintenance, process upgrades and continuous improvement of existing equipment
Incremental improvement approaches	• Continuous improvement in small increments • Continually adapt to changes in customer needs

According to Schonberger (1996), a company can reach world class status by building up strength through 16 customer-focused principles (see Table 3.2). For an electronic manufacturer, such as an EMS, Schonberger's principles are interesting, especially concerning the areas of capacity, quality and process improvement, operations, design, and the customer connection. It is important to have control over the process so the operator does not need to do anything that is superfluous, as every step in the production process costs money and influences the refinement cost. If the company can find a way to satisfy the customers' needs, meaning both the product owner (OEM) and the consumer, and at the same time stabilize and improve the production process, the company will make a profit.

Table 3.2: Principles of Customer-Focused, Employee-Driven, Data-Based Performance (Schonberger, 1996)

General	• Team-up with customers; organised by customer / product family • Capture / use customer; competitive, best-practice information • Continual, rapid improvement in what all customers want • Frontliners involved in change and strategic planning
Design	• Cut to the few best components, operations and suppliers
Operations	• Cut flow time and distance, start-up / changeover times • Operate close to customers' rate of use or demand
Human Resources	• Continually train everybody for their new roles • Expand variety of rewards, recognition and pay
Quality & Process Improvement	• Continually reduce variation and mishaps • Frontline teams record and own process data at workplace
Information for Operations and Control	• Control root causes to cut internal transactions and reporting • Align performance measures with customers wants
Capacity	• Improve present capacity before new equipment and automation • Seek simple, flexible, movable, low-cost equipment in multiples
Promotion / Marketing	• Promote / market / sell every improvement

Schonberger's principles and Hayes and Wheelwrights' practices define world class in similar ways. Schonberger foregrounds customer focus and close co-operation with suppliers regarding material and design. This improvement of the definition of world-class manufacturing is good, since the impact from the customer has increased during the years, especially within the consumer electronic industry where the customization of products is increasing. Customer demands for customized products with a short time-to-market and flexible volumes have forced world class manufacturers to reconsider their mass production practices and explore new ways of working that enable them to more quickly respond to the changes of the market.

According to Flynn et al. (1999), Hayes and Wheelwrights' thoughts about world class manufacturing in the early 1980s are still strongly supported. A combination of Hayes and Wheelwrights' thoughts about world class manufacturers with Schonberger's principles, JIT and quality management are, in the opinion of the author of this thesis, very useful even today. For a manufacturer of consumer electronic products, such as an EMS within an extended enterprise, it is necessary to cut cost and delivery time and to be flexible to produce according to the product owner's (OEMs) order. Furthermore, there is a need for an efficient way of working with PI within EEs that secures the producability of the product and its future productivity in the production system.

With a world class manufacturing solution, the electronic industry – especially the consumer electronic segment – can support the continuously changing conditions for time-to-market. This can also be applied to the mechanical engineering industry since the decreasing time-to-market and the decreasing life cycle of products, both at the market and/or in the production system, force the PI to be efficient and flexible in order to support the market demands independently of industry segments. The goal for an EE is to develop and introduce products in the production system as quickly (short time), well (right quality) and cheaply (low cost) as possible in order to secure that the product realization process supports the customer demands.

3.1.4 Feedback management

The need for anticipating feedback in order to reduce uncertainty and make better decisions in the early phases of the project is important (Bartezzaghi et al., 1997). Therefore, these authors argue that the overlapping between product design and process design entails an early transfer of preliminary information and feedback about product/process interactions. Furthermore, Bartezzaghi et al. (1997) argue that the most valuable feedback is given by the actual production and consumption of the product. They argue that the actual consequences of a product design choice on manufacturing costs and defectiveness emerge only several months later, during volume production. Bartezzaghi et al. (1997) mention that in this moment, identification of the design choices that yield excessive costs and poor quality is often extremely complex. However, the designers or the traditional participants in the innovation phase, such as entrepreneurs or innovators, do not collect this feedback; rather, it is the production operators and engineers who are most closely related to the production process development, and who can easily collect feedback.

In relation to the theory discussed above, the aim for a product realization process is to deliver a complete product to the end customer, as well as having a structured way of handling feedback from the end customer back to the concept phase for the next product realization process. Figure 3.2 describes the information system view and the conventional material view as Clark and Fujimoto (1991) define them. These two views do not consider the need for an iterative way of working between different actors, but they do point out the necessity of having a feedback loop in the information system. In strategic alliances or other types of networks, this kind of information feedback-loop needs to be developed in a consensual way. Furthermore, today’s industrial trend towards increasing remanufacturing (Swedish Technology Foresight, 2000; Sundin, 2004) indicates a need for a feedback loop even in the material view, which also needs to be developed in a consensual way between involved partners.

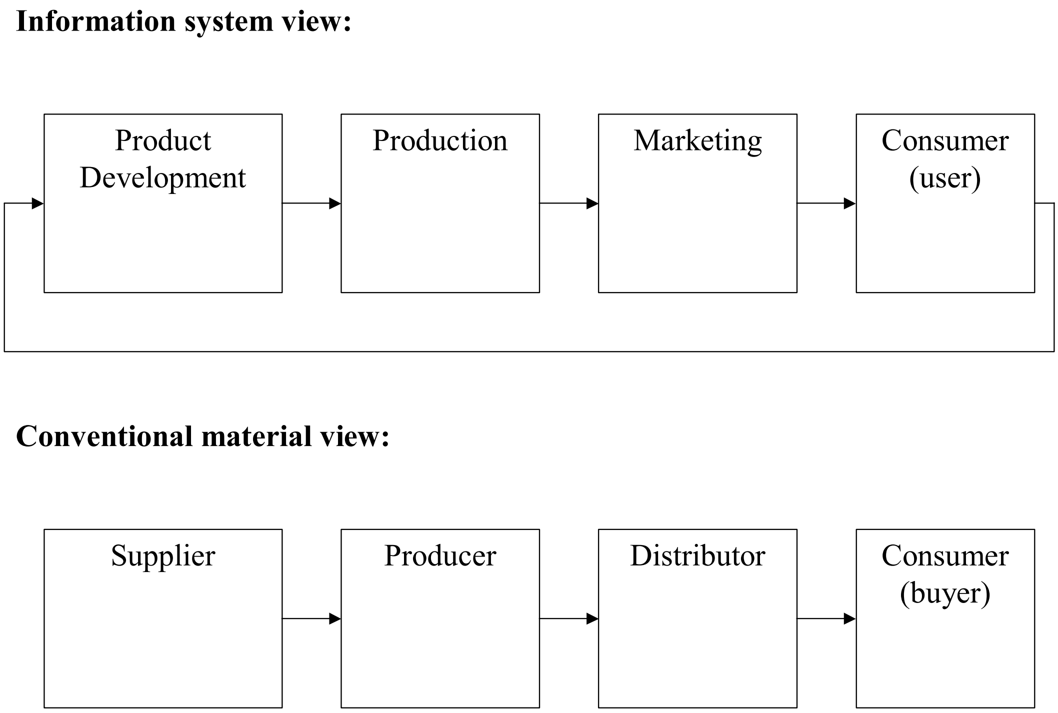

Figure 3.2: Information perspective versus material perspective (Clark and Fujimoto, 1991)

3.1.5 Collaboration during product realization

The speed of new product development is becoming an increasingly important and critical factor for the electronic industry, such as for example in the computing and telecommunications industries (Brown, 1996). In the telecommunications industry, there are three major competitive imperatives have emerged and appear to accelerate the need for collaboration between OEMs and EMSs: advances in technologies, the overriding importance of velocity and cost reduction (Hadaya et al., 2000). Effective product development is difficult, and managers and engineers struggling with new products that are too slow to market have failed to meet cost or performance objectives, are beset by rampant engineering changes or quality problems, or have found no market at all (Clark and Fujimoto, 1991). Nonaka and Takeuchi (1986) have suggested that speed and flexibility in the development process of new products is an important factor contributing to the success of the new product. Gerwin and Susman (1996) found that early integration of the different functional disciplines is of significant importance. Prior research indicates that the integration between product concept studies, design and production is of significant importance to successful new product introduction, and that there is little known about cross-functional integration in the early phases (Ettlie and Stoll, 1990; Brown, 1996; Gerwin and Susman, 1996). According to Nihtilä (1999), integration during product development depends on the planning process. The case study performed by Nihtilä shows that improvement in the planning process can be shown if there is a clearly defined time limit and a use of modern tools and methods (such as Quality Function Deployment – QFD) to structure it.

Concurrent engineering has a major impact on the product development time from concept study to volume production (Dröge et al., 2000). To benefit from the application of known tools and techniques within an organization, these must be applied at an early stage of the new product introduction process – i.e. in the concept phase – in order to take advantage of the relatively low cost of product changes at that stage (Tennant and Roberts, 2001). As Hill (1995) notes, the order-winners for a product can change over time, and to fully support the changes the major thrust will be from manufacturing. Concurrent engineering within EEs demands an efficient method for communication and information handling in order to decrease the waiting time and increase the work efficiency with shorter time between concept study to volume production as a result. Development of products with software tools, such as CAD, has in one case study within the aerospace industry and its US suppliers including three big US automotive industries shown that as much as 25% of the development time was spent on waiting for information (Joglekar and Whitney, 1999). According to Whitney (2000), there is a need for research about co-ordinated methods of product and process designs that are inherently flexible, at least within certain known bounds.

Applying these arguments for integrated, efficient, fast and flexible product development, the need is shown for a structured, iterative and flexible way of working during the whole product realization process. This should involve all participants – from those working with the product concept study to distribution of the final product – which indicate a need for concurrent engineering or collaborative product realization. Concurrent engineering has a major impact on the product development time from concept study to volume production (Dröge et al., 2000). To benefit from the application of known tools and techniques within an organization, these must be applied at an early stage of the new product introduction process – i.e. in the concept phase – in order to take advantage of the relatively low cost of product changes at that stage (Tennant and Roberts, 2001). Applying this on an EE implies that there is a need for an efficient manner of working in order to decrease time-to-market.

Focusing on the Product Introduction (PI) process within product realization shows that PI demands a way of working that strives for an efficient production system and that works with high productivity. This means that the PI process needs to ensure that the product design is adapted to the production system, and vice versa. Furthermore, all functionality within the product and within the production system needs to work without problems. Last, but not least, the material supply needs to be managed, guaranteed and secured. However, Hill (1995) notes that the order-winners for a product can change over time, and to fully support the changes the major thrust will be from manufacturing. However, the trend of collaborative work during product realization, involving several companies into the process from concept to produced product in required volumes, demands a process supportive to extended enterprise solutions.

Summarizing the references cited above, the following parameters are deemed important for efficient product realization:

- Speed for product development and product introduction
- Advances in technologies
- Cost reduction
- Flexibility
- Early integration of the different functional disciplines

3.2 The extended enterprise area

This thesis focuses on collaborative product realization within extended enterprises. Therefore, this section will refer to relevant literature in the area of the extended enterprise and briefly describe the area of collaborative tools.

There is an ongoing shift in the manufacturing industry, that from "self-centered" closed-enterprises to global open-enterprises. One term that is frequently used to describe this new approach is "extended enterprise" (Browne and Zhang, 1999). The concept of the extended enterprise focuses on long-term enterprise relationships across the value chain, based on trust and mutually dependent relationships between partners. Furthermore, Browne and Zhang (1999) conclude that success for the extended enterprise depends on intensive information sharing, with a result of greatly reduced time-to-market through quick response manufacturing with integrated and co-ordinated product design and manufacturing from all the participants.

There are several ways in which to structure a collaborative network. The two traditional ways are either through vertical or horizontal integration (De Wit and Meyer, 2002). The four main categories in these relationships are defined as follows:

- Upstream vertical relations. This is based on that premise that each company has suppliers of some sort.
- Downstream vertical relations. This is the "output side", where the company and/or organization have a relationship with its customers or buyers.
- Direct horizontal relations. This is the relationship between the company and/or organization and other industry incumbents. These actors are competitors producing similar goods and services on the same level.
- Indirect horizontal relations. Here, the company and/or organization have a relationship with a company outside its own industry segment.

Scott (1996) argues that networks may be horizontal (across a domain of complementary technologies), vertical (covering an industrial sector) or diagonal (cross-sectoral, such as focusing on bridging technologies). Many companies, in fact, are moving away from vertical integration, where all operations and logistic issues are handled from the inside. Now, the emphasis is on external and horizontal co-operation, connecting all members of a supply chain, i.e. integration both geographically and functionally (Azevedo and Sousa, 2000). However, some practitioners have other philosophies, with some companies striving to keep between 40% and 50% of the value-adding activities in the company in order to guarantee quality and cost efficiency, as is the case at the Swedish Scania (Hallberg, 2002).

Many companies, however, often cluster together into groups of two or more organizations, as in strategic alliances, joint ventures and value-adding partnerships (De Wit and Meyer 2002, p.10). This implies that new forms of organizations are taking place, such as virtual enterprises, global manufacturing, logistics networks, and different company-to company alliances (D'Amours et al., 1999). Furthermore, D'Amours et al. argue that co-ordination of the supply chain will become increasingly strategically important as these new forms of organizations are formed. For different kinds of strategic alliances between small and medium-sized enterprises, Hoffmann and Schlosser (2001) have identified critical success factors, of which the most significant were:

- Precise definition of rights and duties
- Contribution of specific strengths and looking for complementary resources
- Establishing required resources
- Awareness of time requirements
- Equal contributions from all partners

Furthermore, Brown and Eisenhardt (1995) argue that communication among project team members and with outsiders – such as high-performing individuals not regularly participants in the project – stimulates the performance of development teams. This way of work with outsiders can be combined with the traditional definitions of co-operation between different companies and/or organizations, either vertical or horizontal.

In 1994, O'Neill and Sackett defined the EE to include three levels: a domain level (the facility), a realization level (the operational EE), and a node level (the companies). They argue that the goal for an EE is much more ambitious than automated transaction processing and reduced costs. The challenge is not really a technical one, they say, but far more so a challenge to management. The EE, they continue, needs to support in an integrated fashion the customer lead-time, the just-in-time supply chain and logistics – throughout the product and/or service life. In order to fulfil this challenge, O'Neill and Sackett note that a class-leading competitiveness flourishes in an environment of dependency and interdependency with other providers of components, services and ideas. All this can be achieved in an EE, but it demands a new organizational concept (Browne et al., 1995). To identify the significant aspects of the EE, O'Neill and Sackett (1994) compared the EE model with two classic and well understood forms of manufacturing: mass production and lean manufacturing (see Table 3.3).

Table 3.3 reflects O'Neill's and Sackett's interpretation of the definitions of the traditional system of mass production and the more recent lean production – two different manufacturing strategies that can be readily compared. Working in an EE is not so much a manufacturing strategy, rather, it can be considered more as an organizational structure or business approach. Therefore, it is difficult to compare an EE approach with the manufacturing strategies of mass and lean. Furthermore, most mass producers today operate according to the lean philosophy in order to maintain competitiveness.

The categorization for the EE in Table 3.3 shows O'Neill's and Sackett's need for defining and relating the term EE to something that existed in 1994 and was confirmed in the industry. Comparing "lean" with "extended" in Table 3.3 illustrates the slight differences in phrases describing the same thing of two different perspectives – manufacturing strategy and organizational structure or business approach. According to the "Business strategy" in Table 3.3, lean invests in core business. On the other hand, today's EE usually consists of collaborating companies that focus on their core business, i.e. manufacturing or design. Another example, with regards to "customer values", lean supports high variety and extended supports customized products, which is a kind of business approach that can utilize a manufacturing strategy that handles high variety. Furthermore, for the "production type", in Table 3.3, lean focuses on high variety, and within an EE there is a need for customized unitary lot size, which also can be seen as a kind of high variety demand. Therefore, the aspects relevant for today's EEs in reality are mostly combined with the manufacturing strategy of lean production.

Table 3.3: Manufacturing categorization (O'Neill and Sackett, 1994)

	Mass	Lean	Extended
Customer values	Low price	High variety; high quality; short response time	Customized product, highly flexible, easy to use and adaptable; importance of service
Management philosophy	Scientific management	JIT; TQM	Wide anthropocentrism
Management focus and scope	Technology; efficiency; individualism; control; functional; local optimization	Quality; market; co-ordination; internal value chain; local integration	Effectiveness; flexibility; partnership; facilitation; network; diversity; global integration
Business strategy	Investment in growth areas; large dedicated units; multinational	Investment in core business; medium-size dedicated units; regional (global)	Investment in intra-organizational integration; small flexible units; transnational
Manufacturing strategy	Manufacturing as a cash generator; production totally in –house; economies of scale	In-house core operations; continuous improvement; partnership; subcontracts	Manufacturing as a specialized form of service; co-operative manufacturing; integration of competencies; economies of scope
Production type	Low variety; high volume; long product life-cycle	High variety; short product life-cycle	Unitary lot size; customized; total product life cycle; diversity of unique, evolving product
Product development process	Sequential; expert skill; prototype to prove; waterfall life-cycle	Concurrent; user consultation; model to validate; helical life-cycle	Participatory design; direct engineering; product to use
Production planning and control	Make to stock	Make to order	Engineer to order
Supplier dealing base	Price	Cost; quality	Knowledge-sharing; flexibility; accuracy
Customers' relations with product	Identified with company name; long term	Identified with product brand; short term	Identified with product item; proactive
Trading channel	Independent retailer	Franchise	Interactive catalogue
Organization structure	Formalized hierarchy; division of labor; technical skills; people as a liability	Quality circles; shared decision making; multiskilled; people as an enabler	Systemic; cells and teams; widespread strategic thinking; metaskills; people as knowledge base
Performance metrics	Financial	Cost; quality	Multi-dimensional; individual value

The most relevant points in Table 3.3 that can be seen as unique for an EE are viewed here as the demand of partnership, global integration of competencies, participatory design, knowledge-sharing, flexibility in working with suppliers, widespread strategic thinking and people as a knowledge base. However, Table 3.3 does not explicitly consider the need for collaboration between the product owner (OEM), the producer (EMS or SI) and the suppliers, which in this thesis is seen as one of the main factors for reaching an efficient manner of work within an EE.

3.2.1 Manufacturing networks

Ferdows (1989) defines international manufacturing systems as a network of factories. Manufacturing networks can, according to Ferdows, be designed in at least three different shapes as illustrated in Figure 3.3 below:

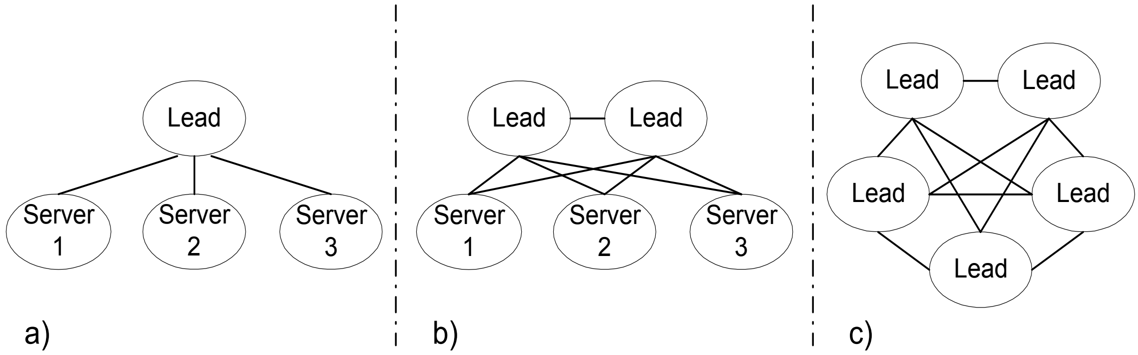

Figure 3.3: Three different kinds of manufacturing networks (Ferdows, 1989)

In Figure 3.3 a lead factory is responsible for developing new manufacturing processes and technologies for all involved factories within the company. The lead factory is also the material supply co-ordinator. A server can be a factory within the OEM, an EMS or a supplier. The server manufactures products for a specific market or region, and is therefore located close to the market or within the region. The server location gives the companies opportunities to minimize total taxes, decrease cost and time for transportation and minimize delivery delays.

Ferdows (1997) defines six strategic roles for factories, as shown in Figure 3.4:

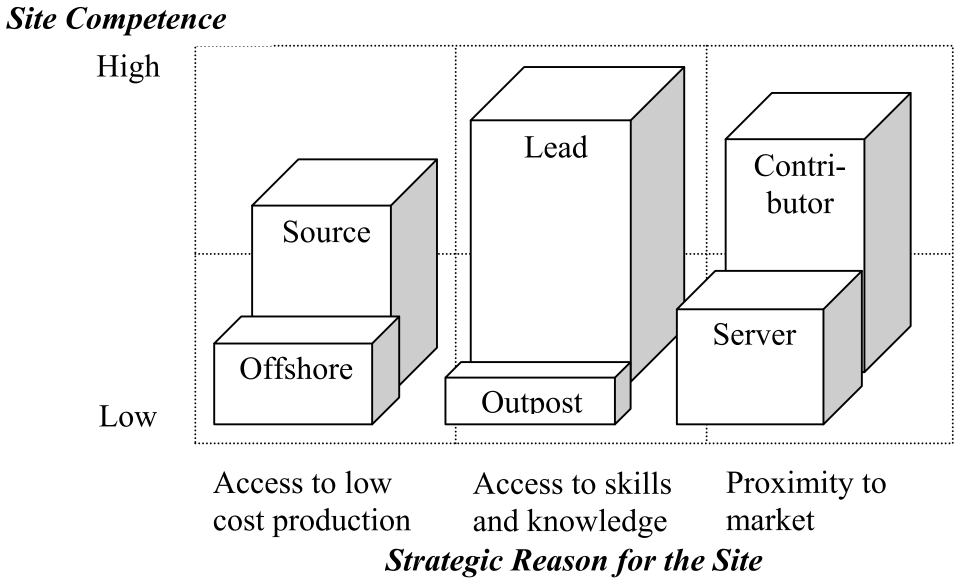

Figure 3.4: The Roles of Foreign Factories: A Strategic Matrix (Ferdows, 1997)

The site in Figure 3.4 is to be seen as a factory, with the different manufacturing roles defined (by Ferdows) as follows:

1. ***Offshore:*** produces specific items at a low cost that are exported for further work or for sale. All investments are kept at a minimum and non-local management makes all decisions.

2. ***Source:*** Low-cost production with a broader strategic role than for an offshore. The local management has greater authority, especially regarding decisions connected to the supply chain. The source factories are located where a skilled workforce is available.

3. ***Server:*** Supplies specific national or regional markets in order to overcome tariff barriers and reduce taxes, logistics costs or exposure to foreign exchange fluctuations. It can do minor modifications in products and production methods to fit local conditions.

4. ***Contributor:*** Serves a national or regional market with extended responsibilities for product and process engineering and development of the supply chain. Participates in the choice of key suppliers and has engineering and production capabilities.

5. ***Outpost:*** Primarily, it collects information through its strategic placement in an area where suppliers, competitors, research laboratories and/or customers are located. Often has a secondary role as a server or an offshore.

6. ***Lead:*** Creates new processes, products and technologies for the entire company. The management has the decisive voice in the choice of key suppliers, and participates in joint development work with them. Frequently initiates innovations.

The first five manufacturing roles (1-5) can be seen as some sort of a server role, but with different strategic aims. In Figure 3.3, Servers 1, 2 and 3 may have any of the manufacturing roles 1-5. The manufacturing network in Figure 3.3a has one lead factory, while the other factories – the servers – are "following the leader". The lead factory is responsible for PI and the transfer of the manufacturing process to the server factories. Figure 3.3b has two or more lead factories with the role of both co-ordinating themselves to each other and co-ordinating shared server supply units so they get the most benefit out of the network. The third network, Figure 3.3c, describes a network consisting of only lead factories and how they need to co-ordinate everything with each other. According to Shi and Gregory (1998), Ferdow's network focuses on the strategic role of each factory, instead of the function each factory plays in the network.

Ferdows (1997) argues that moving a factory (site) upward in the matrix gives it a broader, upgraded strategic role in the company's network of factories (see Figure 3.5).

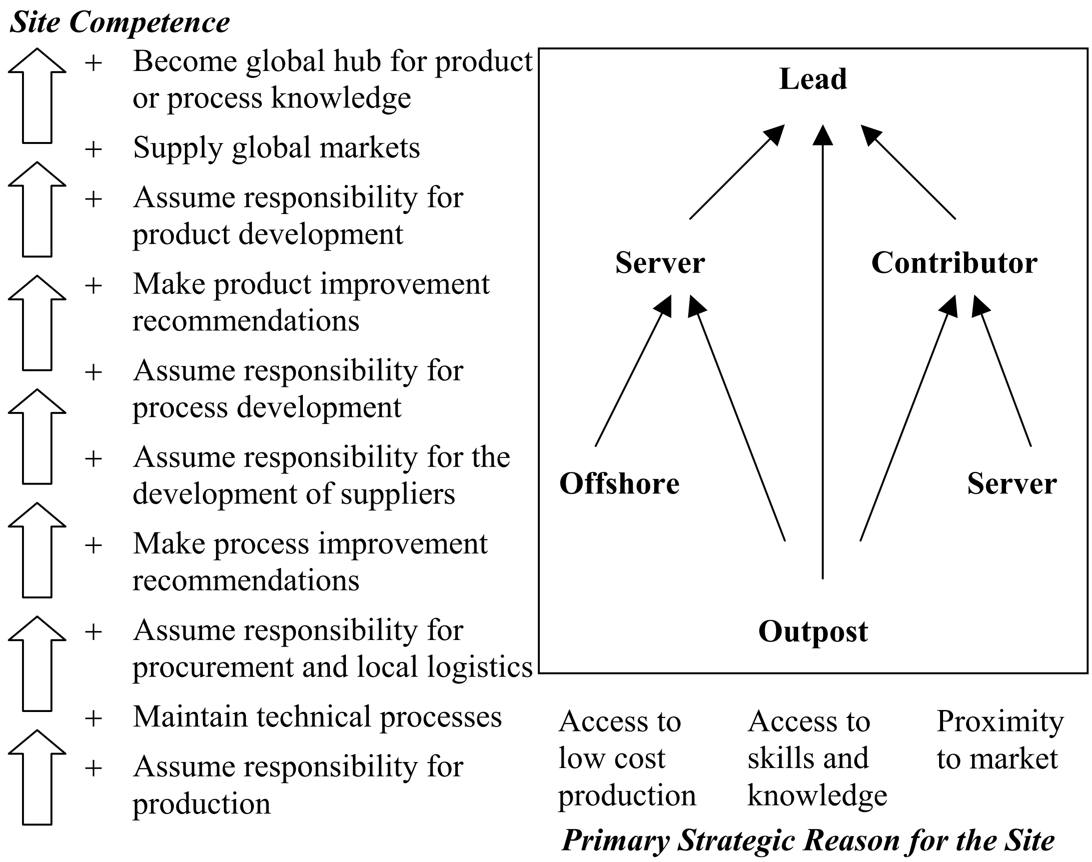

Figure 3.5: Paths to Higher Strategic Roles (Ferdows, 1997)

If all factories in the manufacturing network strive for a position as a lead factory (Figure 3.5), the overall network will consist of only lead factories (Figure 3.3c).

3.2.2 Trust-based relationships

The last decade has seen the rise of the extended enterprise: companies working together in intimate, trust-based relationships to develop, produce and deliver complex products (Dyer, 2000). Dyer argues that a trust-based relationship saves money when compared to an arms-length relationship. Furthermore, he contends that building this kind of collaboration requires time and commitment. The partners must be willing to invest in people and assets that are dedicated to each other, and to share both explicit and implicit knowledge with other companies – companies which may also be their competitors. Open communication between partners increase the degree of trust among team members, which, in turn increases their cooperative behaviour (Susman et al., 2003). Susman et al. (2003) argue that collaborative partners should strive for a mediating relationship because trust development is encouraged by behaviors, such as replying promptly and reliably of messages. Dyer (1996) argues that getting supplier involvement in product and process development requires a partnership with a real two-way flow of ideas, not an adversarial relationship. Greis and Kasarda (1997) argue that external integration, such as joining a strategic alliance, encompasses the entire supply chain. Furthermore, these authors conclude that in order to compete effectively in the market, the set of companies involved need to form a productive enterprise.

When cooperating in an extended enterprise, Loeser (1999) argues that culture-forming management is a necessary base for successful cooperation. He concludes that one of the most important success factors in the field of cooperation is the adoption of an approach that encompasses process management, information and communication technology, integrated logistics solutions, and the management of behaviour and culture. In order to produce co-operative advantages, certain tacit behavioural features are suggested by Corbett and Rastrick (2000), such as open culture, employee empowerment, and executive commitment.

The allied companies need to capture the alliance insights and experiences, codify the alliance management lessons and best practices, communicate person-to-person to obtain the know-how that is more tacit in nature, and create guidelines and training programs to finally coach the organizations within the alliance. This is an example of knowledge networking, which is about openness and collaboration across departmental, organizational and national boundaries (Skyrme, 1999). According to Savage (1996), time to learn is as critical as time-to-market.

3.2.3 Evolution of extended enterprises

Today’s increasingly competitive markets are generally perceived to be demanding higher-quality and higher-performing products, in shorter and more predictable development cycle-times, and at lower cost (Maffin and Braiden, 2001). To reach these demands, there is a need for active involvement of both manufacturing and suppliers on product development project teams (Maffin and Braiden, 2001). New logistics practices and technologies must also link production and logistics processes in different organizations across geographically dispersed locations (Greis and Kasarda, 1997; Quinn, 1997; Brunell, 1999). Goldstein (1999) has described the evolution of EEs within the electronic manufacturing industry regarding the OEM–supplier relationships due to increased outsourcing (see Figure 3.6). The arrows in Figure 3.6 describe how Goldstein identifies transports of material and/or finished goods between different companies.

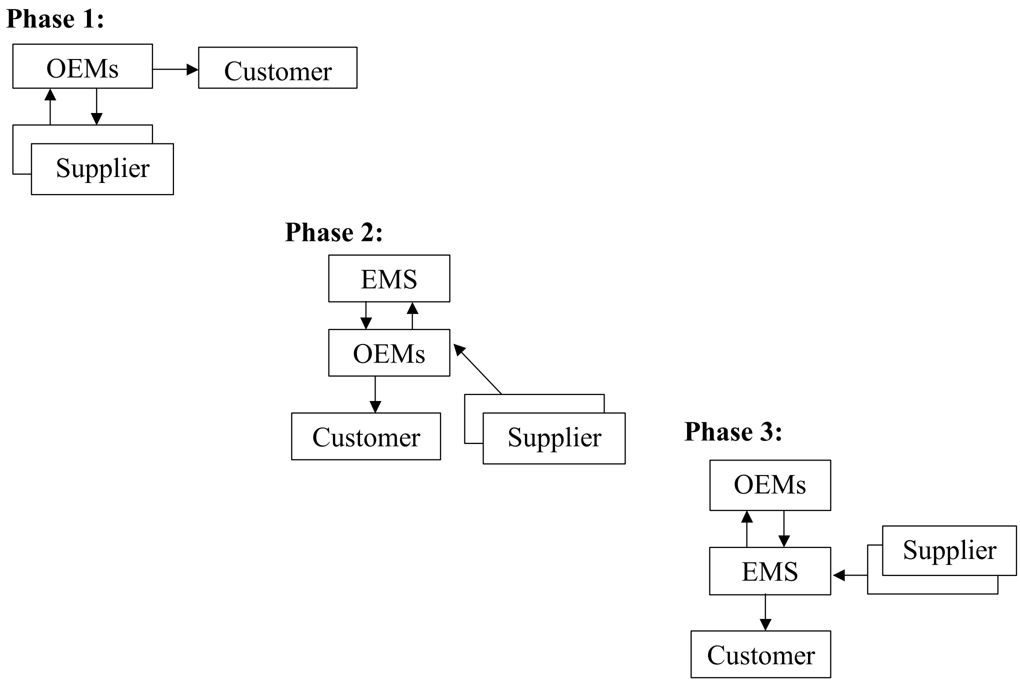

Figure 3.6: Evolution of relations in electronic supply chain (Goldstein, 1999)

Traditionally, the OEM has developed and manufactured its own products (Phase 1, Figure 3.6). In Phase 1 of Figure 3.6, the OEM purchases materials and components from suppliers, as well as manufactures finished goods that are shipped to the customer. The next step in the evolution involves the EMS assigning responsibility for the manufacturing of products to the OEM (Phase 2, Figure 3.6). Here, the OEM purchases material and components from suppliers and provides the EMS with material and components. The EMS fulfills the manufacturing and ships finished goods to the OEM. Finally, the OEM ships the product to the customer. The trend is that the EMS covers more of the supply chain for a product, including PI, material supply, manufacturing and delivery to customer (Phase 3, Figure 3.6). This trend implies that the

OEM designs the product and contracts the EMS for manufacturing, fulfillment of the supply chain and the shipping of finished goods to the OEM or directly to the customer.

A further evolution of Goldstein's extended enterprises could be a situation where a company responsible for future remanufacturing joins the EE (see Figure 3.7). However, Goldstein does not consider the communication that is needed between all three actors participating in a product development project, namely the OEM, the EMS and the suppliers, or possibly four actors if remanufacturing joins the extended enterprise.

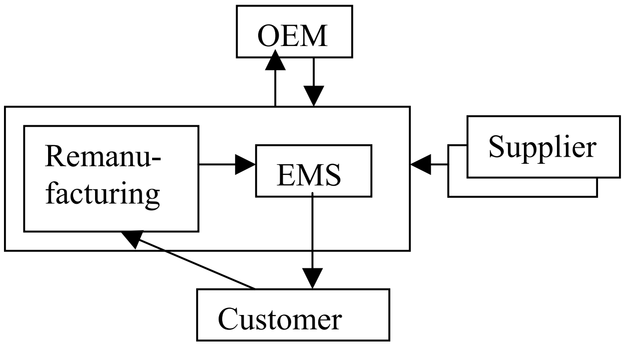

Figure 3.7: A possible evolution of Goldstein's (1999) extended enterprise

Co-operation between OEMs and EMSs is extremely important, especially if the companies expect to survive in today's situation of demanding global competition. This competition demands great innovation skills and a commitment to continuous improvement (Stopford, 1994). The EE needs to find a manner of work that is flexible and changeable in co-operation with the future demands and development of the EE. Savage (1996) says that companies competing in a global economy need shorter product life cycles, concurrent engineering, greater cross-functional co-ordination, and external co-ordination with suppliers and distribution channels.

Hadaya et al. (2000) propose a conceptual model, based on two case studies performed in the telecommunications industry, that reflects the evolving relationship between OEMs and EMSs (see Figure 3.8). According to Figure 3.8, a less complex product has few activities that can be contracted to an EMS or to other companies. Furthermore, the more complex a product is, the more activities can be outsourced to an EMS or other companies and the more the relationship between the OEM and the EMS can evolve.

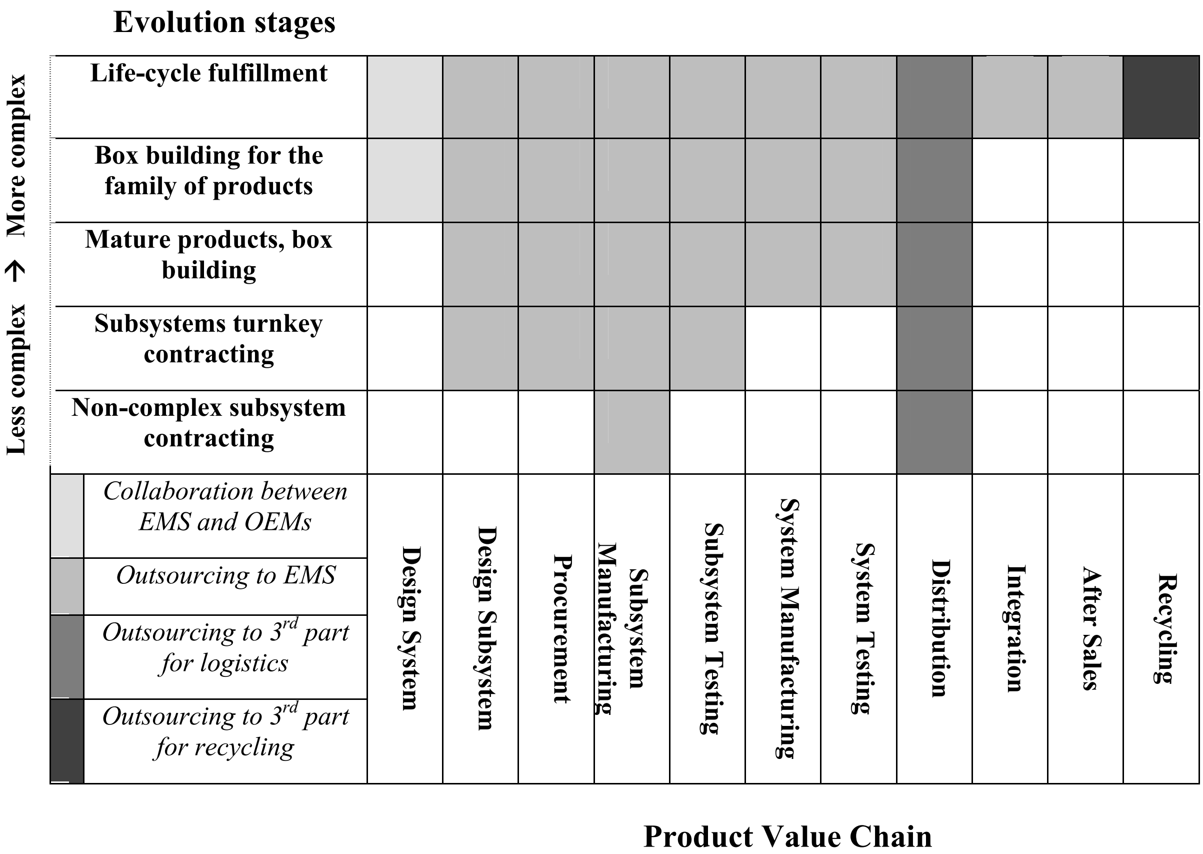

Figure 3.8: Evolutionary stages in the OEM and EMS relationship (Hadaya et al., 2000)

Swink conducted a study of 91 finalized product development projects, and concluded that more research is needed in the area of how to work in the boundary between product development and industrialization, especially in regards to the management of outsourcing after it is implemented (Swink, 1999). Clegg et al. (2000) note that an understanding of the nature of factors that affect the extended enterprise manner of working puts organizations at an advantage in their ability to manage the extended enterprise more effectively. Therefore, they conclude, it is imperative that processes do not only operate successfully *within* each company, but *across* company boundaries as well.

3.2.4 Reasons for establishing extended enterprises

Current research indicates that it is possible to distribute complex manufacturing systems into a virtual process development environment, where personal from different organizations cooperate and the traditional borders between different enterprises decline. This subsection will exemplify this trend with a brief review of the literature.

Fleury and Fleury (2003) assume that there are three different strategies with which companies compete in the market: through operational excellence, product development or a customer-driven approach. Furthermore, they argue, that given today's new competitive requirements, individual efficiency is not enough; rather, it is necessary to be connected to groups of firms that are collectively efficient. To become a participant in an inter-organisational network, firms would have to negotiate resources such as their infrastructures, intangible assets (brand name) and organisational competencies. Loeser (1999) mentions that a very promising approach for expanding into new markets is co-operation with other enterprises.

Companies, of course, can co-operate in many different ways, and there is a wide spectrum of alliance types, ranging from technology transfer agreements to strategic alliances and joint ventures (Fleury and Fleury, 2003). In order for a company to support aims of expanding into new markets without expanding its own resources, co-operation with other enterprises could be an option (Hamel et al., 1989; Lorange and Ross, 1992; Ring and van de Ven, 1994). Co-operation between legally independent enterprises, which bring complementary competencies and resources into the network, is a strategic inter-organizational network with the aim of increasing the value of the network (Loeser, 1999), a kind of strategic alliance. Strategic alliances, that can be virtually organized, are popular when firms want to share risks and exchange resources with a wider range of competencies, access new markets, achieve economies of scale, use a world-wide pool of potential partners, and obtain synergy and competitive advantages (Snow et al., 1996; Dacin et al., 1997). Companies generally recognize that tight interaction and co-ordination among all the participants of their supply-chain is a key requirement for their survival (Azevedo and Sousa, 2000), and also a reason for joining an extended enterprise. To summarize, it will become strategically important to co-ordinate the supply chain as new forms of organizations are formed such as virtual enterprises, global manufacturing, logistic networks and different company-to-company alliances (D'Amours et al., 1999).

Today, product owners such as Original Equipment Manufacturers (OEMs), need more and more skilled suppliers that can handle more complex, technology-advanced parts of a product or module, and even take an active role in product development in different kind of extended enterprises. This is one trend that is obvious in several industry segments, such as the electronic industry (Johansen, 2002; Papers III and V; Flextronics, 2004), the mechanical engineering industry (Papers VI and VII), and the aerospace industry (Paper VIII; Boardman and Clegg, 2001). However, this leads to a need for supportive collaborative ways of exchanging information and knowledge sharing between engineers during the product realization process in order to fulfil the market demands for competitive, functional and reliable products that reach the market in time and at the estimated cost. Here, it is important that management realize the benefits of early collaboration and knowledge sharing between competencies within product development and production process development. As Tennant and Roberts (2003) says, knowledge transfer is a fundamental aspect that facilitates the development of a "learning culture". In order to attain the possible benefits, management must facilitate early collaboration within extended enterprises. However, there may be difficulties in achieving acceptance for early collaboration, both at different management levels and between engineers.

3.2.5 Communication within extended enterprises

An extended enterprise could have several strategies, such as improvement of cost and time efficiency – "Economies of Scale", multiplicative use of existing core competencies of each enterprise – "Economics of Scope", or develop new competitive competencies through a Competitive Building Strategy (Loeser, 1999). Independently of the strategy and the type of integration (horizontal or vertical), there is a need for structured ways to communicate.

According to Fazio (1999), the ability to communicate and co-operate through the entire supply chain will be the crucial criterion for surviving in the global marketplace. This means that the interaction between all actors within an extended enterprise is of crucial importance, along with communication and information exchange, with the aim of getting the product in time-to-market with the right quality, cost and functionality. The new technologies, the rapidly changing markets and the global competitiveness have revolutionized the business relations between companies. When companies attempt to change the traditional boundaries and their way of working with the aim of supporting the new extended enterprises, the tasks and manner of work become unclear and difficult to define (Hirschhorn and Gilmore, 1992). Working in alliance structures with several companies involved demands a learning system centered on the 4 Cs: Capture, Codify, Communicate and create, and Coach (Kale et al., 2001). The companies need to capture the alliance insights and experiences, codify the alliance management lessons and best practices, communicate person-to-person to catch the know-how that is more tacit in nature, and create guidelines and training programs to finally coach the organizations within the alliance. This is an example of knowledge networking, which is about openness and collaboration across departmental, organizational and national boundaries (Skyrme, 1999). Time to learn is as critical as time-to-market (Savage, 1996).

Within the electronic industries' extended enterprises, the OEM usually has the responsibility for product development while the production is performed by the Contracted Electronic Manufacturer (CEM) or Electronic Manufacturing Services (EMS). An EMS can take care of a PI if the OEM outsources the responsibility. Chan and Chung (2002) define a contract manufacturer as "A provider of goods and services working collaboratively with other providers of goods and services as networked business partners to satisfy market niches by exchanging information through an inter-organizational information system". The engineers working with product development need to secure the functionality of the products through the development of new designs and technologies. The goal for production engineers is to secure time schedules and high productivity in the production line with the aim of reaching a stable function for the product (Ginn and Rubenstein, 1986; Susman and Dean, 1992).

The dependency between decisions taken in product and process development does not always get the credit it should. The consequences for modifying the product or the production process are related to when the decisions are made; the later decisions, the greater the consequences (Susman and Dean, 1992). Adjusting a new product for producability is an example of the ability to fit the product specifications together with the capacity of the production process (Adler, 1995). Today, there are an abundance of tools and methods for adjusting a product for producability, i.e. check lists, DFM tools (Design For Manufacturing), reviewing and approving routines, process planning tools, work rotation etc. (Susman and Dean, 1992; Dean and Susman, 1989; Swink et al., 1996). Given this, Adler argues that future research should evaluate these different models of communication in the boundary between product development and industrialization in order to determine under which circumstances they are more or less efficient (Adler, 1995).

Companies generally recognize that tight interaction and co-ordination among all the participants of their supply-chain is a key requirement for their continued survival (Azevedo and Sousa, 2000). Co-ordination of the supply chain is to become increasingly strategically important as new forms of organizations are established; some examples include virtual enterprises, global manufacturing, logistic networks and different company-to-company alliances (D'Amours et al., 1999). In these cases, integration must be from one end of the business chain to the other – from a company's suppliers through to its customers (Somers and Nelson, 2003). Furthermore, Somers and Nelson argue that in order to achieve the benefits of enterprise systems, it is important to develop a proper "fit" between the technology and the organization's strategy and implementation choices.

Integrated firms use IT to create new products and services, to alter linkages with suppliers and customers, to establish new standards of performance in their industries, and to have the ability to deliver consolidated information to customers (Johnson and Carrico, 1988). However, just using IT does not bridge all boundaries, such as those which are cross-functional, cross-team, cross-organizational, cross-geographical, and cross-cultural, since these can raise conflicts resulting from incompatibility between communication norms and practices (Malhotra et al., 2001). Browne and Zhang (1999) conclude that the success of the extended enterprise, such as a strategic alliance, depends on intensive information sharing, with the result of a greatly reduced time-to-market through quick response manufacturing with integrated and co-coordinated product design and manufacturing from all the participants.

3.2.6 Collaborative tools

The introduction of collaborative technology (CT) in the workplace does not necessarily enhance collaboration among employees, even if some companies behave as they believe, or hope that implementation of software and/or communication tools marked as "collaborative" creates collaboration between employees (Susman et al., 2003). Susman et al. (2003) have performed a new product development (NPD) literature review regarding the use of CT within NPD teams, and found only a handful of studies, from 1998-2002, that have examined the introduction of software applications aimed at helping work teams electronically collaborate. However, CT consists of two major parts, a communication medium and a database, where the communication medium serves different purposes. Maznevski and Chudoba (2000) identify these purposes as information gathering, problem-solving, idea construction, decision-making, and obtaining commitment.

The use of CT may democratize the boundary management role in teams, so that the formal team leader no longer will be the sole gatekeeper between the team members and senior managers (Susman et al., 2003). However, this change of information management may fly in the face of the existing hierarchy and threaten the existing leadership structure (Susman et al., 2003). On the other hand, extended use of CT may support an extended enterprise in its effort to reduce costs, such as personnel disruption, travel and other re-location costs, with favorable implications for resource commitments, time-to-market, and PI frequency (O'Sullivan, 2003). Drawing conclusions from O'Sullivan's (2003) literature review implies that early standardization of design information and synchronicity in workflow are important in the context of collaborative product realization within extended enterprises. Furthermore, communication by CTs is easier and less problematic in an established extended enterprise than in a novel one, and even virtual teams require periodic face-to-face interaction in order to support efficient performance.

Cooper (2003) summarizes that the CT encompasses a variety of functions to support group work. Cooper says, they include "product data and document management systems that provide the capability to store, retrieve, share, and maintain configuration and version control over text- or file-based products, such as requirements documents, plans, and specifications, and often provide additional lifecycle management, traceability, or reporting features; and groupware systems that facilitate communication and coordination between team members." Combining CT with a strategy of designing modularized products, in which modules can be developed and produced independently and in parallel before final assembly and distribution, will support collaborative product realization within an extended enterprise. However, as O'Sullivan (2003) mentions, the modules need to be clustered so functions that are more tightly coupled internally than externally are placed in the same module, in order to reduce complications with coordination. The interaction between the modules should be standardized, as well as each module's performance

(O'Sullivan, 2003). The modularization strategy can successfully use CT supporting design, such as Computer Aided Design (CAD), by enabling the user to create, model, visualize, simulate, and analyze their design (Cooper, 2003). Here, the CT can simplify communication and reduce potential misunderstandings between different companies within an EE, since the users can discuss the same model that is viewed in their own computers in real time, independently of physical location. Similarly, Susman et al. (2003) summarize CT as a powerful tool that allows people to collaborate over distance and time.

CT can support collaboration between different partners within an EE, but not replace the need for face-to-face interaction as mentioned above. Methods (or tools) that can support this face-to-face interaction during product realization, and with the aim of for example decreasing product cost and shortening time-to-market, could be Design For Assembly (DFA) or other DFx-tools and value engineering. Value engineering is a systematic, interdisciplinary examination of factors affecting the cost of a product in order to achieve the specified purpose at the required standard of quality and reliability at the target cost. Value engineering is a multidisciplinary, team-based approach, where the teams are drawn from multiple functional areas, including design engineering, applications engineering, manufacturing, purchasing, and even the suppliers and subcontractors (Cooper and Slagmulder, p.51 1997). Furthermore, Cooper and Slagmulder define the differences between value engineering and value analysis (p. 131, 1997). Value engineering includes the phases up to production, such as the conceptual, the product design and the production system design phases. In the production phase including purchasing, the same process continues, but under the name value analysis. Value analysis and value engineering are one in the same, but occur at different points in the product lifecycle. However, some researchers argue that value engineering enters into consideration too late in the traditional manufacturing system, i.e. after the product design has been completed (Kuo et al., 2001).

To summarize the preceding discussion on collaborative product realization within EEs, some of O'Sullivan's (2003) conclusions are cited. O'Sullivan argues that earlier research has over-emphasized the technical aspects of design rules and neglected their non-technical aspects, i.e. that CT can not replace face-to-face interaction but rather facilitates it. Working in a collaborative environment requires a synchronized work rhythm and an acceptance of what needs to be shared among participants, such as an understanding of inter-module dependencies (technical) and collective assimilation of work norms (non-technical).

4 Extended enterprises

During the last decade the trend within the electronic industry has been towards product realization performed as a collaborative project between several participating companies, each of which have different responsibilities, business goals and/or competencies (Paper V). This collaboration between different actors, in turn, has led to the establishment of different types of Extended Enterprises (EEs) (Papers III, V, VI, VII and VIII). These EEs illustrate different organizational structures where the product realization process – including the vital PI process – takes place. Therefore, this paragraph will discuss the generic structure of an Extended Enterprise (EE) based on observations in the electronic industry (Papers III and V), as well as other EE structures observed in this research (Papers VI, VII and VIII).

4.1 Generic structure of extended enterprises

Traditionally, the OEM within the electronic industry has developed and manufactured its own products, but the trend during the last decade is that OEMs are extending their collaboration with companies that manage production, Product Introduction (PI) and even product design for the more complex and technologically advanced parts of a product or module (Papers III, V, VI, VII and VIII; Johansen, 2002; Boardman and Clegg, 2001). For example, Ericsson has been both “product owner” and manufacturer for its own products with responsibility for coordinating the whole supply chain. Today, different EMS companies are assigned increasing responsibility for the PI and production of products for product owners (Flextronics, 2004). This extended responsibility for the EMS partner is pushed even further, since some EMS companies are increasingly facilitating product development services (Flextronics, 2004), called Co-Design and Manufacturing or Contracted Design and Manufacturing (CDM), in this thesis, the latter term is used. Furthermore, it is rare that EMS companies have their own brands to market, since these products probably will compete in the same market as their customers’ (product-owning companies) products. However, some EMS companies develop their own platform products – making them Original Design and Manufacturing (ODM) companies (Flextronics, 2004). These platform products are branded and, if needed, customized by an OEM or Product Owner.

The new company networks, so-called extended enterprises (EEs), consist in general of the following: companies with their own products and brands, i.e. product owners (OEMs) such as Sony, Dell and Ericsson; producers (EMS) such as Flextronics and SCI-Samina; and suppliers of components, services, material and equipment such as Intel, Fuji and Philips. In Papers III and V, a generic description of these actors’ relationship to each other is shown. This description is, in this thesis, defined as the Generic Extended Enterprise Module (GEEM) (see Figure 4.1).

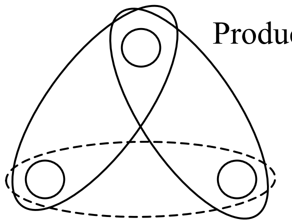

Figure 4.1: The Generic Extended Enterprise Module (Papers III and V)

In a GEEM the producer could take the responsibility for coordinating information, material, knowledge transfer, etc. between the participants in the product realization project, see the ovals in Figure 4.1. The oval between the Product owner and the supplier in Figure 4.1 illustrates the possible early communication between those partners during the conceptual phase or during the product idea generation. The responsible Producer must be aware of this early collaboration since it may affect the future material supply. By giving the producer the coordinating role in the product realization process, it increases the opportunity to utilize the production know-how as early as possible. This is a way to adapt the product to production and increase its producability. In the early phases of the product realization, the product owner, if it has the product development responsibility, normally has the initial contacts with different suppliers of components, material, and others, including potential producers needed for the project. It might be so that the product owner wants to choose the producer after the concept is decided; in that case, the coordinating role is at the product owner level, at least in the beginning. Relating to this discussion the roles in a GEEM, they can be seen as a function of time, they can change over time or they can differ depending on when the collaboration is started. Generally speaking, an extended enterprise structure is a dynamic organizational structure based on collaboration between flexible actors.

The trend within the electronic industry is that EMS companies, like Flextronics or Sanmina-SCI, offer increasingly more activities connected to the supply chain for a product, including product design, material supply, manufacturing and delivery to customer (Flextronics, 2004; Sanmina-SCI, 2005). The collaboration between OEMs and EMS is, therefore, extremely important and must start as early as in the conceptual phase, especially if the companies are to survive in today's demanding global marketplace. As Flextronics states in its May 2004 Investment Profile:

"*Increased competitive pressures are shortening product life cycles, forcing Original Equipment Manufacturers (OEMs) to continuously release new products in order to maintain their market share and margins. Flextronics' business philosophy has produced a strong service culture at the Company in providing technology companies with highly efficient and flexible operations that are necessary to maintain a competitive advantage and react to market changes quickly*." (Flextronics, 2004)

Global competition demands great skill in the areas of innovation and a commitment for continuous improvement (Stopford, 1994), which supports the need for the early collaboration mentioned above as well as for flexible solutions. However, it can be difficult to involve several companies in the innovation phase, especially if the partners are not yet selected, since the innovation phase is critical and creative. The challenge for the EE is to find a way of working that is flexible and adapted to future demands.

The GEEM described in Figure 4.1 could also be used describe the relations in an organization having different departments responsible for different areas during a product realization project. As an example, the project management could be the product owner, the “producer” could be represented by the production, i.e. engineering, test and manufacturing, and finally the “supplier” represented by other competences in the organization, such as product design, material supply and IT. Therefore, management of an EE is applicable both between companies and within companies, since its all about coordination, responsibility and result. In other words, management of an EE should efficiently support efficiently collaboration between competencies in order to achieve products that support the market’s demands.

In an EE, several Product Owners (OEMs) could use the same Producer in order to better utilize standard production processes; surface mount assembly lines in the electronic industry are but one example. In the same way, an EE usually has several suppliers of components or equipment. Therefore, an EE is generally more complex than a GEEM, and it follows that the relation between an extended enterprise (EE) and a GEEM can be illustrated as:

$$1 \text{ EE} \geq 1 \text{ GEEM}$$

EEs are becoming even more complicated, as the producers and suppliers usually have several different product owners to support. These product owners can often be competitors in the same market. A product owner can also co-operate with different producers and suppliers who can be competitors to each other. As an example, one company can be the product owner in one project and the supplier in another (see Figure 4.2), depending on experience, competence and type of products produced. This more complex EE can take the form of the illustration in Figure 4.2, where several GEEMs are combined. However, one supplier can participate in several GEEMs or, alternatively, several suppliers can participate in a single GEEM. This gives an overall EE that needs to have a structured process for managing information and secure that confidential information not pass between partners (Paper V). Furthermore, it can become even more complicated when a product owner is the supplier of components used in both a company’s own products and its competitors’ products. These products, which can compete in the same market, can then be produced at the same producer. This situation, for example, is a reality for companies that develop technology platforms for mobile telephones that are open to acquire on the market. An example of a technology platform or component could be an ASIC[6] design specifically developed for a certain type of radio communication. The different product owners that acquire and use the ASIC can use the same producer for manufacturing the products in order to get benefits from the same investments in the production lines and reuse of general test solutions.

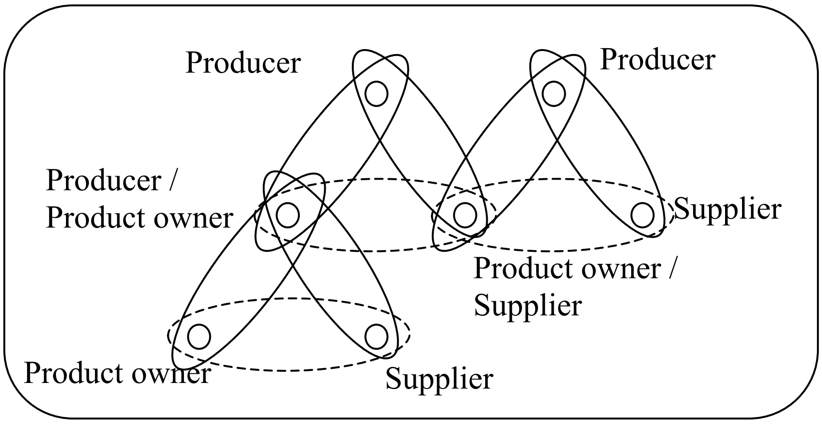

Figure 4.2: A complex extended enterprise (Papers III and V)

Product realization within the electronic industry will in the future most likely consist of a higher degree of joint projects within EEs (Flextronics, 2004; Sanmina-SCI, 2005; Papers III, V, VI, VII and VIII). Here, the product owner owns the product concept while the product design is performed either by the product owner itself, by suppliers of services/consultants, producers or by collaboration between different actors/companies. Therefore, the activities performed during a product realization project within the electronic industry need to include product design as well as product introduction and ramp-up production, including all activities and processes needed to get the product distributed in time to market. The transfer of a design into production, the PI process, needs to be adapted to the collaboration within EEs with the aim of shortening the time from concept to volume production and distribution to customer (Paper V; Eisenhardt and Tabrizi, 1995). Collaborative product introduction demands knowledge of the participants' competence, experience and goals (Paper V) so the work can be divided between the actors in an efficient way without too much cost for project management and general overhead. This also implies that different product realization projects will have different actors and companies involved, depending on the need of competence and knowledge. According to Hadaya (2000), a relationship within an EE can be based on a life-cycle fulfillment for more complex products, which implies that the conditions in the EE are flexible and depend on the complexity of the

[6] An Application Specific Integrated Circuit (ASIC) is developed on the initiative of a company for its specific applications, and therefore cannot be found as a standardised circuit. The company owns the circuit design and pays for the development cost.

product. Furthermore, the manner of working in product realization projects needs to be flexible and adaptive within EEs.

4.2 Structure of studied extended enterprises

Three different extended enterprises have been studied during the research, one in the Swedish electronics industry, one in the Swedish mechanical engineering industry and one in the aircraft industry. Different aspects of these EEs have been studied; therefore, they have also been studied in different depths.

4.2.1 The Swedish electronics industry

It is difficult to apply general conclusions valid for the overall electronic industry regarding the benefits of outsourcing since this industry operates under so many different circumstances, i.e. high vs. low volume, industrial vs. consumer products, etc. This thesis aims to explore and describe factors of importance to consider when working in PI processes within an EE in the electronic industry. In addition to its application within an EE, the result can be more or less applicable within a company that is responsible for the product concept study all the way to production and delivery to the customer, as the structure and organization within a company has strong similarities to that of an EE. The main difference observed concerns financial and legal issues such as how to share profit or losses and how to handle immaterial rights (Papers III, VI, VII and VIII).

An interesting EE within the Swedish electronics industry was introduced in January 2001, when the outsourcing of Ericsson's mobile telephone production was completed and the new partner – Flextronics International – was selected (Ericsson, 2001). The EE consists of Ericsson, a traditional OEM, in the fast-growing communications, networking and consumer markets, and Flextronics International, a leading provider in EMS, and all of the suppliers to both (see Figure 4.3). The established extended enterprise consisted of several product design center that collaborated with one product introduction center within Flextronics. This product introduction center was responsible for production related activities in the product introduction process including transferring the product into dedicated manufacturing unit, mainly within the same EMS company but also to a manufacturing unit within the OEM.

This EE expanded even further in October 2001 when Ericsson formed a new 50:50 joint venture with Sony, which came to be known as Sony Ericsson Mobile Communications, with the aim to combine their respective mobile telephone operations in order to produce highly specified and fashionable phones (Buckley, 2002). The part of Ericsson responsible for new technology platforms for handsets was kept within the company, and was called Ericsson Mobile Platforms (EMP). EMP has the focus on acting as a center of innovation, and according to Sigurdson (2004) is a very precarious venture. However, as of 2004 Sigurdson noted that EMP had four customers – Sony Ericsson, LG, Samsung and Siemens. This can be seen as an example that verifies Figure 4.3, i.e. of an EMP, which is a supplier to several product owners, which utilize the same EMS. The OEMs Sony Ericsson (Ericsson, 2001) and Siemens (Siemens, 2000) both used Flextronics as an EMS partner. In the case of Sony Ericsson, the company outsourced both product introduction and production (Ericsson, 2001; Sigurdson, 2004), while Siemens mainly outsourced production (Siemens, 2000). However, even EMP used Flextronics' product introduction competence (Ericsson, 2001). This illustrates the complexity of the EE that was mentioned earlier in Figure 4.2.

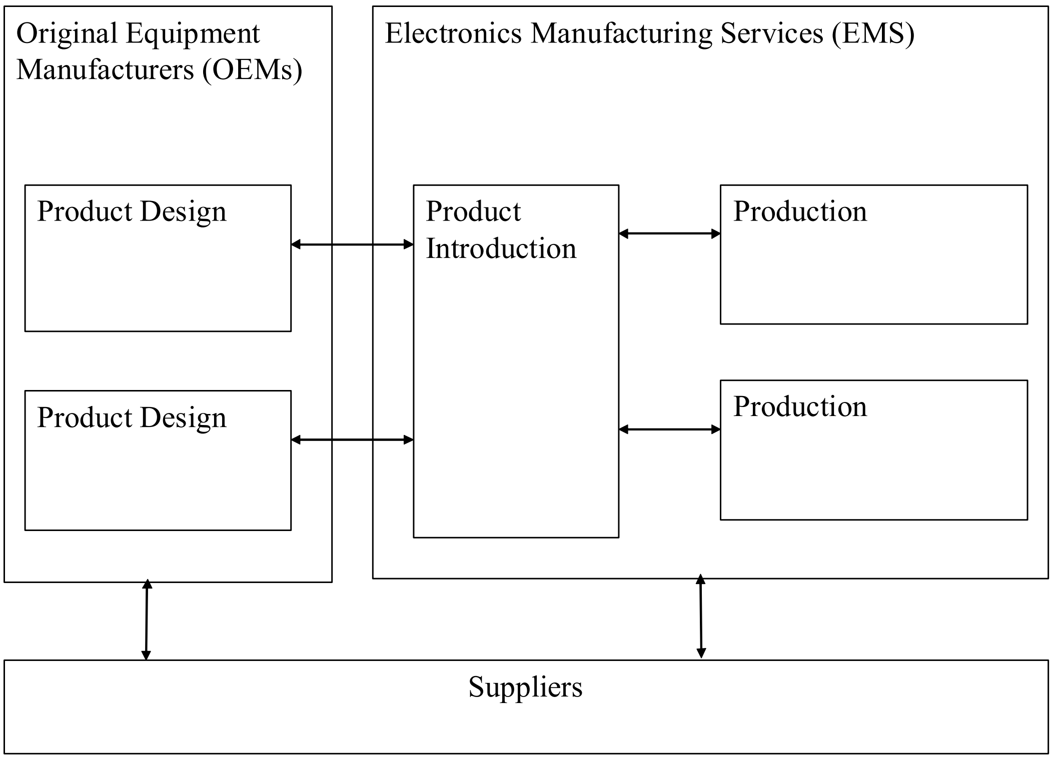

Figure 4.3: The extended enterprise consisting of OEM – EMS – suppliers (Adapted from Johansen, 2002)

The complexity in communicating the right information to the right people within a product realization project, including the PI and the production system design, is observed in the cases (Papers III, V, VI, VII and VIII). As shown in Figure 4.3, it is obvious that there is a need to share information, knowledge and technology between the collaborating companies during the PR and PI processes. One way to handle this exchange without passing confidential information between different product owners that utilize the same EMS, is to use locked areas dedicated to each project (Paper V). Furthermore, producers can manage this by using different production teams working with different product owners (Paper V), but the production teams' are still working in the same company and exchange knowledge in order to develop their way of work. Sharing information, knowledge and technology is also necessary within the EMS during the transfer of the production process between the PI center and the high volume-manufacturing factories. The high-volume manufacturing can be placed anywhere in the world, and so can the OEM and the PI center, which gives the network a global touch with a need for cultural awareness.

In the future, Ericsson will strategically focus on its core businesses – developing new products mainly within the area of mobile infrastructure and mobile platforms (Sigurdson, 2004), finding new applications and quickly getting the products and/or applications in the market. This is the reason why the company sold its consumer production to Flextronics and created a joint venture with Sony for mobile handsets – Sony Ericsson (Ericsson, 2001; Sigurdson, 2004). For Flextronics, this outsourcing enabled it to sell its core business – production competence and capacity – to Ericsson (EMP) and Sony Ericsson. This included the PI, global supply chain management, customization, box-packing and delivery to customer. The EMS has the benefit of buying a large volume of components, and therefore creating the possibility to decrease the material cost for the produced product. Furthermore, the EMS is vertically integrated (Flextronics, 2004) with its suppliers in industrial parks in order to decrease cost, i.e. lead times and storage. The EMS will also get the opportunity to make general investments in the production lines and generalize the test solutions so that the production system can be reused for many products – even products that compete in the same market. However, Flextronics has increased its offering to include services in product design and concept studies in order to be a partner to OEMs that can "transform ideas into reality" (Flextronics, 2004).

During the course of this research, the studied electronic industry here has continued to change, and in 2004 a new organizational map was drawn (see Figure 4.4) which has similarities to the one illustrated in Figure 4.3. However, Figure 4.4 illustrates how Flextronics divides industrialization (or product introduction) into two main categories. The first category is closely connected to the design (or the Product Owner), and covers areas such as DFM and test. The second category is closely connected to the production, with areas such as logistics and process control. However, the company strives for facilitate the customer's need for total solutions by offering Contracted Design and Manufacturing (CDM) or Original Design and Manufacturing (ODM), which means that Flextronics take the role as a product owner within its own organization. This means that the EMS company has product design competencies (this could be compared with the Product Owner in Figure 4.4), industrialization (or Product Introduction) facilities and high volume production. This is a variant of the OEM structure within Ericsson that outsourced its production in 2001, with the difference that Flextronics do not brand its products. On the other hand, the suggested split between different categories in Figure 4.4, and how they are closer related to either product design or production indicates that a possible insourcing trend may occur. Product owners may take the responsibility for activities close connected to the product function, such as DFM and test, while the producers take the responsibility for activities close connected to the production, such as logistic, process control.

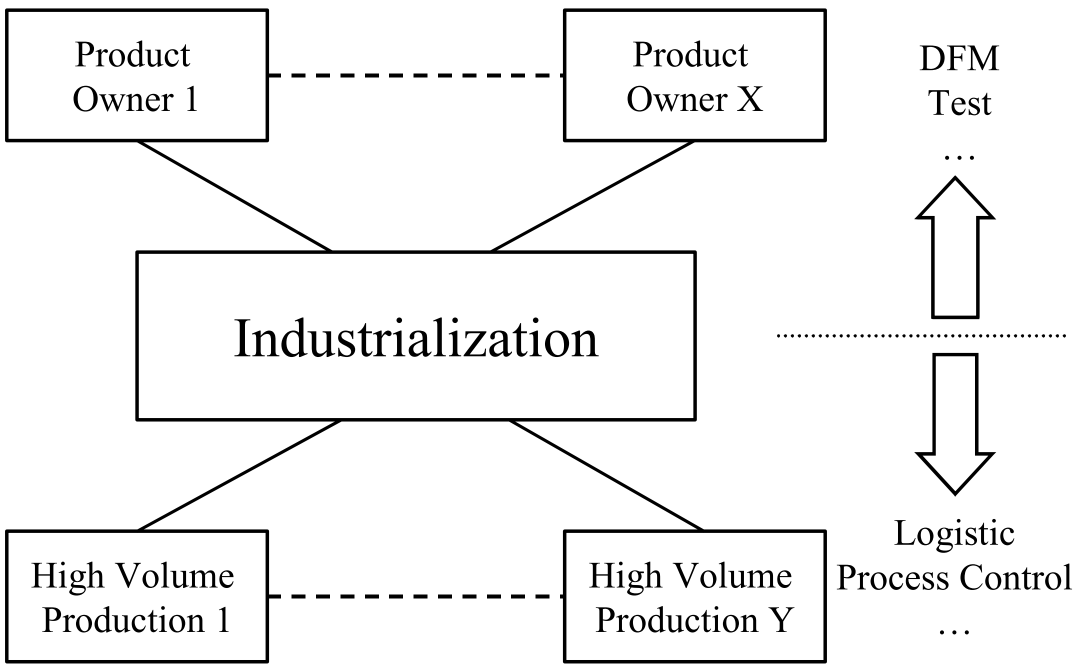

Figure 4.4: The extended enterprise consisting of Product Owners (OEM or internal design at EMS) – Industrialization (Product Introduction) – Production

Hill (1995) argues that manufacturing is not an engineering or technology-related function, but rather a business-related function, which can be related to the discussion about insourcing above. Furthermore, he argues that whereas products need to be made according to their technical specifications, they also have to be supplied in ways that win orders in the marketplace. Within an EE the boundaries and the responsibilities will change over time, and the companies involved will most likely change their core businesses over time. Something unique for the EE studied in the electronic industry for this research is the producer's responsibility for the delivery of final products to the retailers, which can be seen as a change in responsibility within the EE. This is not the usual case within the automobile industry, where the OEM performs the final assembly including delivery. These boundaries and responsibilities need to be managed within the EE in order to support the current need for manufacturing to reach the goal of a quick time to market.

4.2.2 The Swedish mechanical engineering industry

The extended enterprise studied in the Swedish mechanical engineering industry is described in Papers VI and VII. As for the electronics industry, it is difficult to apply general conclusions valid for the entire mechanical engineering industry. The EE observed for this research should be seen as but one example of how companies can efficiently collaborate. In this case, the study focused on how an existing EE that was established by companies in the same region of Sweden, changed its strategy into a new collaborative EE (Paper VII). The new EE (see Figure 4.5) was established in order to increase the level of critical competence, and therefore increase opportunities in the offers from the collaborating companies to potential Product Owners.

The EE studied for this research (see Figure 4.5) can be seen as an extended variant of a vertically-organized extended enterprise (Paper VII). The project observed within the extended enterprise had the purpose of re-designing an existing product with the major aim of reducing cost. The observed extended enterprise involved more companies and organizations during the product analysis, than the network of companies with operative functions during the re-design implementation (see Figure 4.5). This type of collaboration provided the project with extended critical competences, and is defined here as "extended enterprise networking" (Paper VII).

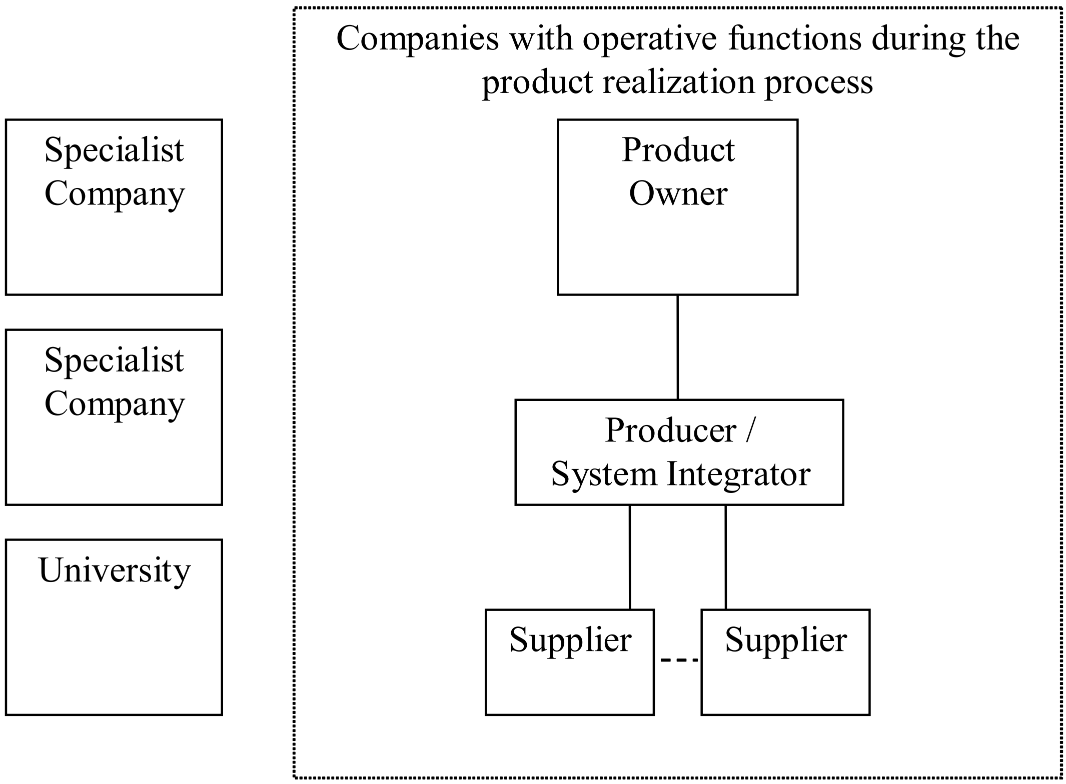

Figure 4.5: The collaborative extended enterprise in the mechanical engineering industry observed in this research (Papers VI and VII)

One of the driving forces for the Product Owner (PO) to join the collaboration in the EE in Figure 4.5 was to decrease the number of suppliers that directly communicate to them (Paper VI). By using such a collaborative EE, the PO's long-term strategic goal to focus on their core businesses was supported by building strong relationships with few strategic supply trading partners. The driving force within the supplier network, the "old" virtual enterprise, was their interest in working with more qualified products than plain contract component manufacturing. The "old" virtual enterprise consisted of companies within the mechanical engineering industry acting in the same region of Sweden.

One of the suppliers in the case was the PO's system integrator (SI), which supplied a module for one of its main products. By collaborating with a few key suppliers, this PO can include the SI as early as in the conceptual phase in order to achieve and utilize extended competence from production. This extended competence helps the PO to design a product that is as adapted for manufacturing. However, this demands SIs and POs that are flexible in their mindset, even if they loose manufacturing or development activities in their own company or organization. In this case, the extended enterprise suggested several revolutionary re-designs, all of which were realistic both from a manufacturing and design point of view. The results surprised the responsible project manager from the PO, who realized that he was responsible for marketing all the improvements to the engineers in his own organization. Instead of trying to explain all suggestions for improvements by himself, he invited all participants to the PO for a day. During that day, the suppliers presented their suggestions to the PO engineers in different groups, and an implementation plan was developed in a consensual way.

Further observations in the case (Papers VI and VII) indicated that managers at the suppliers (SME companies) realized that they needed to change communication channels when discussing new businesses. As suppliers, they usually discussed engineering problems and business with the responsible engineers at the PO (see "Old marketing focus" in Figure 4.6).

The new extended businesses including product development responsibility frightened the engineers at the POs since they felt that their work might move away to the suppliers. One top manager at a SME in the case, the owner of the company, realized this when he was suggesting that his company, in collaboration with the new extended enterprise in Figure 4.5, could re-design and produce one of its customers products. First he suggested this through his old communication channels – the engineers at the PO – and received "no" for an answer. He then prepared a new marketing suggestion, and turned to the higher management at the PO and got the project. All suppliers in the extended enterprise learned that this new type of business, i.e. selling product development service including production, had to be marketed at a higher management level within the product-owning companies (See Figure 4.6). This illustrates a goal conflict between the engineers and the management within the product owning organization, which can be compared to the results in Section 6.1.1.

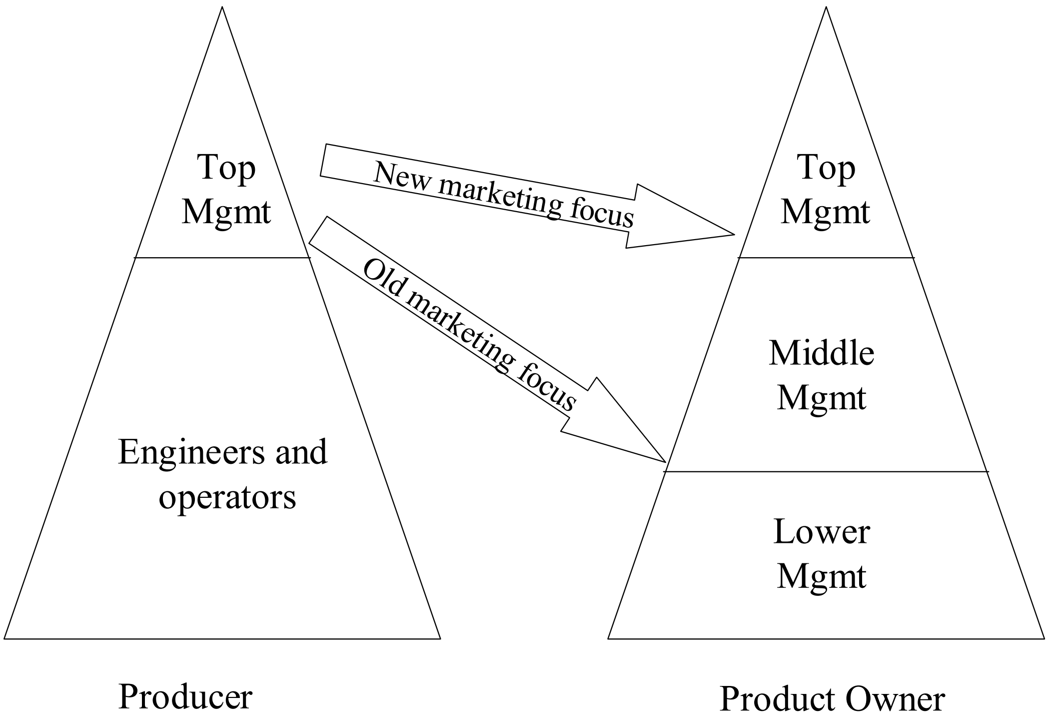

Figure 4.6: Marketing goal conflicts shown in the collaborative extended enterprise observed in the mechanical engineering industry

Another important observation from the mechanical engineering case is related to economy. By participating in an extended enterprise participants from one company might present ideas that lead to patent for another company. This raises the question about how to handle intellectual property within an extended enterprise. Furthermore, in this case all non-operative companies in the product realization process, those mainly were active during the concept analysis, got externally financial support. This actualises the question of how to finance resources that contributes with ideas and knowledge in early phases. Comparing this with observations in the electronic industry it is important to find ways to share the profit after implementation of ideas, especially if the partners that are collaborating either are several companies or parts in an organization that is individually measured with key performance indicators, as is the case in the observed electronic industry.

4.2.3 The Swedish aerospace industry

Paper VIII describes the structure of the Swedish aerospace industry's Collaborative Manufacturing Mega-Network (CMMN). The Swedish aerospace industry acts in a multinational EE that shares risk and exchanges resources, similar to the process that occurs in a strategic alliance. This collaboration gives access to new markets, as well as possibilities to achieve economies of scale through increasing production volumes (Paper VIII). This could be compared with the Sony Ericsson joint venture mentioned in Section 4.2.1, were Ericsson wanted to cut its losses and Sony wanted to re-enter the global mobile handset market (Sigurdson, 2004).

In the EE observed within the Swedish aerospace industry, the companies have broken down the work into structure of parts or sub-systems (see Figure 4.7). This demands a detailed specification of the product and a structure of all sub-systems so they support the management of final assembly and maintenance. Furthermore, a formal information and decision network supports this way of working with a clear structure for decision paths (Paper VIII).

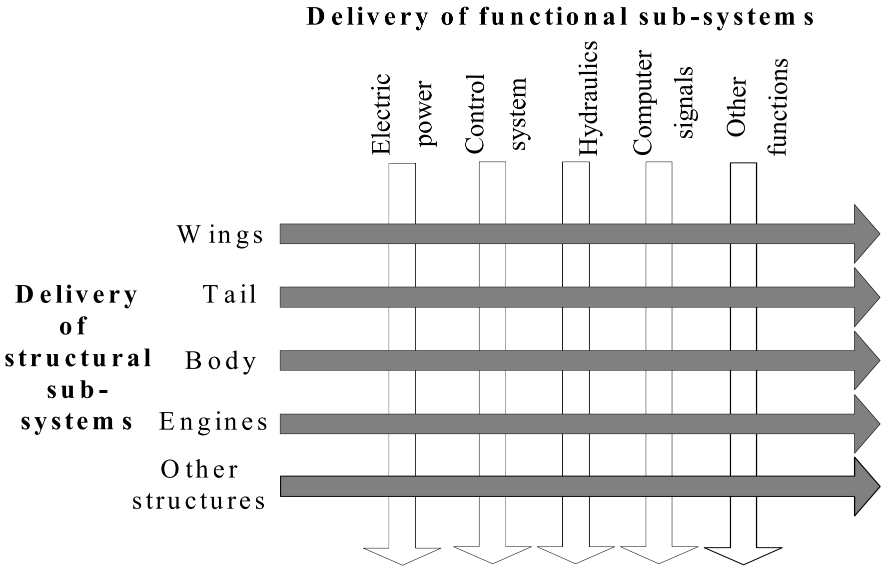

Figure 4.7: Structural / functional sub-system matrix from the Swedish aircraft industry (Paper VIII)

In reference to Figure 4.7 above manufacture of one structural sub-system – the wing, must be coordinated with a number of functional sub-systems. Furthermore, this coordination must be combined with the manufacturing supplier network strategy and structure (Paper VIII).

4.2.4 Important parameters to handle in an extended enterprise

A collaborative network or EE must rely on the people within it, since the results depend on the corporation's ability to communicate and co-operate. This dependency was illustrated in a workshop within the electronic industry in 2004 (See Appendix A). A network or a group characterized by people that continuously change, i.e. when someone can not participate or when new members are invited, will have difficulties to achieve mutual confidence within the group. This may require that the network or group will more or less need to start the working process all over again each time there are changes of participants. Furthermore, if people connected to the network have so much to do that they send a stand-in to some meetings, the network loses its strength in decision-making. As an example related to PI, a stand-in does not have the history, such as knowledge concerning why a certain design solution is preferred, and can therefore have difficulties in joining in on the discussions at the right level. Observations in the electronic industry during a presentation of a concept showed that a production engineer that was not prepared for a concept discussion, asked to detailed questions. The product designer became confused and lost some of his confidence for the project participants. The trustful relationship was rescued by a senior engineer. The network can work and be very powerful if people in it prioritize the meetings, prepare for them, make decisions and are prepared to accept other participant's solutions. This way of working can give a fast and efficient PI process without too much overhead cost for project and process management.

Furthermore, in a global, multinational EE there is also a need for handling differences in culture, time zones, language, etc. In order to minimize double work and rework, there is a need for a flexible solution in transferring knowledge, information and solutions without increasing the overhead. The following important factors for successful collaboration are identified (Paper VIII; Sigurdson, 2004):

- Companies should be prepared for, and open-minded to, different types of inter-organizational collaboration.
- Strategic choices made by collaborative partners are influenced by early participation in the concept phase, unique technology competence, and the level of shared risk.
- Companies should see the trustful, win-win relationship that can arise with participation in an EE through the strategic utilization of each partner's competencies.
- A communication system should support the desired way of working and decision paths, with people trained for using it in the most suitable way.

- EE participants should receive cultural awareness training from the start in order to effectively manage cultural gaps and to avoid potential problems during latter stages of the collaboration.
- The ability of planning for future products and stating goals in order to increase the efficiency and utilization of invested resources, such as time, competence and equipment should be stressed.
- The EE partners should take considerable time to identify mutual shortcomings and hidden agenda.

5 Product realization within extended enterprises

5.1 Product realization

Intense competition in today's industry is driving the companies to improve their overall production, including innovation, product development and production (Dekkers, 2003). Here, this is extended to include even the distribution of products, and is defined as "product realization". Product realization includes all activities and feedback management at a company or within an extended enterprise, from an innovative idea being turned into an innovation (i.e. from the conceptual phase), to a designed, produced and distributed product (see Figure 5.1). Here, an innovation is defined as a technical solution for a specific problem that results in a new or modified product that provides economic value during product realization. The product realization (PR) process in Figure 5.1 is further developed from the processes described in Papers III and V, the two views that Clark and Fujimoto (1991) described (see Figure 2.2), and the importance of cross-functional teams and iterations for product development project success (Eisenhardt and Tabrizi, 1995; McDonough, 2000). Figure 5.1 illustrates the need for iterative collaboration and information sharing between competences and responsibilities by using the product introduction (PI) process during the PR.

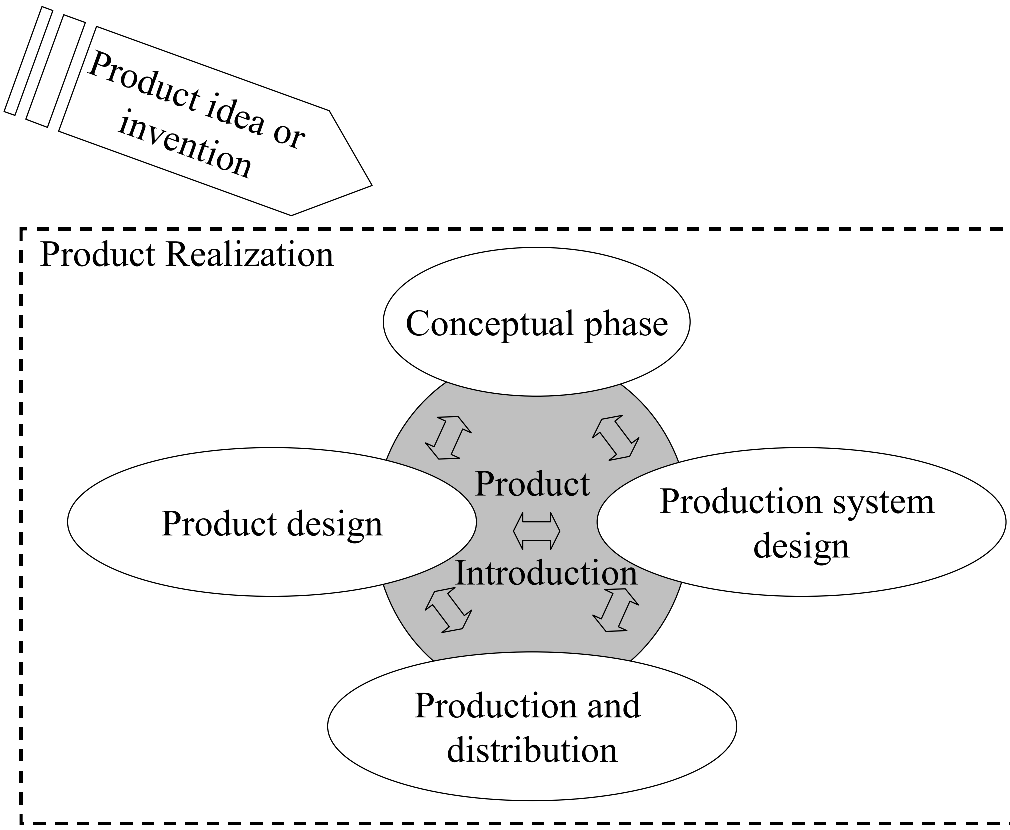

Figure 5.1: The product realization process including product introduction

The PI can be seen as the hub that all activities are iteratively collaborating through or around in order to attain efficient product realization. This linkage between the concept of design and production is limited illustrated in the literature, and the interaction of product design and manufacturing strategy is under-researched (Riedel and Pawar, 1997; Spring and Dalrymple, 2000). However, Dekkers' (2003) case study demonstrated the importance of this link between product development, engineering and early involvement from production.

Brown and Maylor (2005) argue that "innovation is the result of leveraging network-based knowledge and capability, involving customers, suppliers, as well as various types of strategic alliances". Furthermore, innovation is not a firm-specific activity (Teece et al., 1997), the manufacturing function is critically important for the innovation process (Youssef, 1995) and most research indicates that close coordination with suppliers is an important facet of innovation (Handfield and Ragatz, 1999). This implies that collaboration between different companies and/or organizations during the conceptual phase, as well as during product design (including product introduction with production system design), are important as illustrated in Paper III. The collaborative work aims to prepare the product for efficient production, and the results in Papers VI and VII illustrate the benefits that can be achieved through early collaboration. Eisenhardt and Tabrizi (1995) mentioned that early collaboration within product segments that is difficult to predict, such as the electronic industry, can be difficult to achieve since the suppliers are not selected. However, by continuously collaboration between selected partners within an EE this difficulty can be overcome, and as in today's electronic industry the EMS partner can participate with its competencies during early phases if the product owner ask for it. Furthermore, in Section 4.3 and Paper III, the trend of remanufacturing is mentioned and how it still evolving. This is an example of activity together with other environmental issues, such as unleaded soldering, that the EMS partner can facilitate during product realization.

Collaborating partners need to identify how to efficiently perform collaborative product realization, and much criteria need to be fulfilled in a number of areas: economics, marketing, technology, manufacturability, organization, culture, and communication (Papers III and VIII; Evans et al., 1996). The earlier these criteria are decided, the better. The need for anticipating feedback in order to reduce uncertainty and make better decisions in the early phases of the project is also important (Bartezzaghi et al. 1997). However, during a creative phase, such as in the beginning of the conceptual phase, limitations, criticism of ideas and suggested solutions can risk the quality of the outcome from the phase, and in the long run, even the PR. Cooper et al. (1998) state that too much structure can kill such creativity. According to Gause and Weinberg (1989), it is cheaper to fix a fault in the early stages of the product development; in fact, it can cost between 30 to 70 times more to correct a fault assumption in the acceptance test phase than in the conceptual phase.

The PI in the PR process within the electronic industry manages factors such as number of variants, volume flexibility, life cycle aspects, manufacturability, logistics, profitability, quality and productivity (Paper III). This competence needs to be used in the PR process, since it can decrease the development time and simplify production. Furthermore, the PI process contributes with information regarding manufacturing resources, such as the skill of the personal and the accessibility of equipment such as machines and tools (Paper III). However, the production competence in the conceptual phase could be used with two different approaches, based on observation sin the electronic industry. If the concept for a new product is based on i.e. new technologies, new materials, and new joining methods, production must carefully listen and participate with their experience in the conceptual phase without having the present manufacturing resources in mind as a limitation. It is in the evaluation phase of the concept that the existing resources are mapped towards the concept, and specifications for changes in the production system are developed. On the other hand, if the concept is meant to reuse as much of the existing production systems as possible, production must take an active role during the concept phase in order to secure efficient utilization of already existing resources. Given the current focus on shorter development times, it is crucial to be aware of early indications of the necessity of new skills or new technology for production, because of the lead-time to receive it.

5.1.1 Product development process in industry

The PR process illustrated in Figure 5.1 is based on iterative collaboration between competencies. Clear milestones, high-level description of the process and understandable goals (Kamath, 1994) facilitate this way of work. This differs from the approach where the process is defined into major phases, which are checked according to audit principles (Tennant and Roberts, 2003). Today’s product development processes (PDPs) used in industry can be exemplified by Flextronics’ PDP, as shown in Figure 5.2.

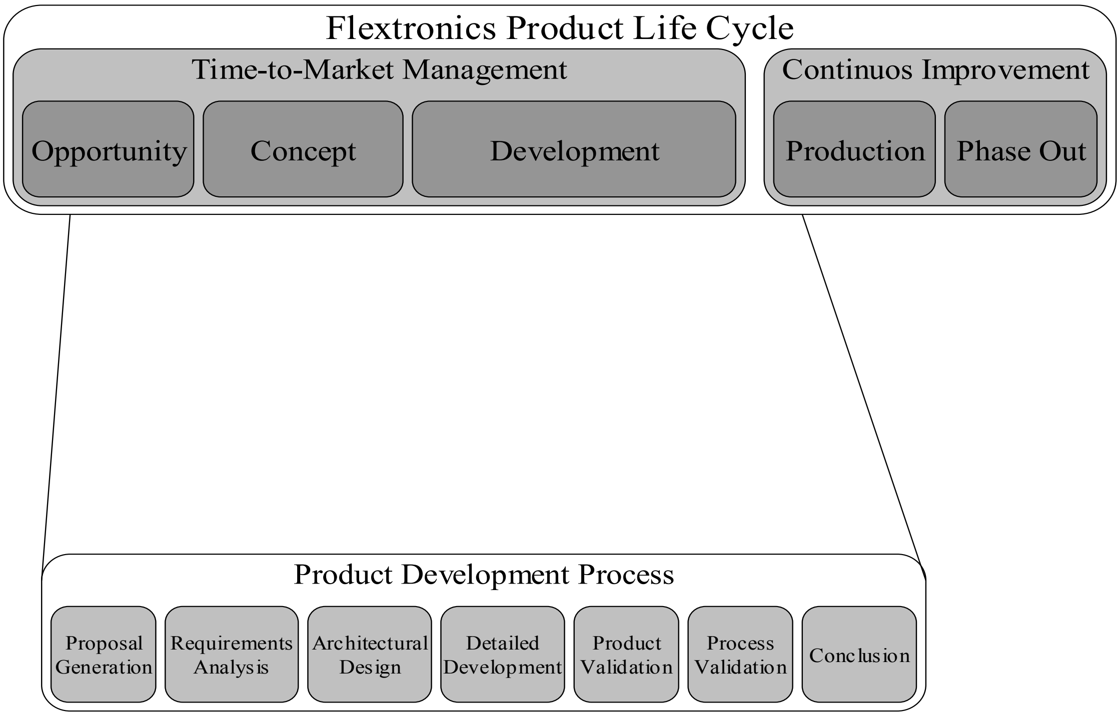

Figure 5.2: Flextronics' Product Life Cycle and Product Development Process (Flextronics, 2004)

The work within the processes in Figure 5.2 is based on iterative collaboration between competencies and/or organizations were the process is described on a high-level (Flextronics, 2004). The product development process (PDP) at Flextronics is part of a defined product life cycle (PLC) process, and their relation is shown in Figure 5.2. Flextronics' PDP runs concurrently with product introduction, from the proposal generation until volume production release. The product introduction is the linkage between different design organizations and the volume production.

The opportunity process in the PLC in Figure 5.2 is where Garvin's (1992) risks (market, competitive, technological, organizational, producability and financial) can be evaluated, and subsequently summarized, in the proposal generated in the PDP. Flextronics' PDP in Figure 5.2 consists of seven main processes, where each process ends on a gate checkpoint, which checks the criteria for the process, such as the milestones. Furthermore, the checkpoints are used to manage risk associated with cost and project schedule, which is an example of an iterative way of working with the risk analysis that started in the opportunity process. Garvin's (1992) more technology-focused stages are supported by the PDP high-level description in Figure 5.2. However, Coopers (2003) summary of identified factors that influence the New Product Devleopment process supports the industry environment were the PDP in Figure 5.2 is used. The PDP in Figure 5.2 must work in different ways i.e. project structure, team member characteristics and patterns, organizational contexts and external environments (Cooper, 2003), such as is the case when Flextronics acts as a partner to different OEMs in EEs. Therefore, as mentioned in Paper V, the participants within an EE must consider the possible conflicting goals between the participating companies as well as between competencies.

Flextronics' PDP is designed to support any of the business models used within the company, such as Original Design and Manufacturing[7] (ODM), Contracted Design and Manufacturing[8] (CDM) and Contracted Design Services[9] (CDS). If a situation occurs at Flextronics that requires special requirements, a document called the Internal Customer Specification will be created and used throughout the development process (Flextronics, 2004). Flextronics' PDP in Figure 5.2 aims to be flexible and support different kinds of development, defined by Flextronics as common and non-common development (Flextronics, 2004). Common development supports products that are designed by using existing modules or reference designs in order to satisfy the features defined by the product requirements. Here, the product and the project risk are reduced, as well as the product development cycle, while existing production system solutions also can be re-used. Non-common development is used when the requirements have a greater demand on higher speed and/or smaller size, or when the product design explores new areas of combining technologies or pushing the edge of existing ones. In these cases, additional investigations are needed in the concept phase since such a project is connected to higher risks, both technological and financial. Common development can be seen as a development using "off-the-shelf" modules, while non-common development concerns the development of new modules, including research in new technologies and solutions.

The term product realization, as it is defined in this thesis (see Figure 5.3), can be exemplified with Flextronics' PDP plus product introduction, production and distribution. The way Product Realization is illustrated in Figure 5.3 highlights the importance of working iteratively and sharing information. By managing the experience earned in each phase in a structured feedback loop (the arrows in Figure 5.3), future projects can efficiently utilize knowledge from previous projects and products. Figure 5.3 is an attempt to visualize the iterative thinking that facilitates a concurrent and collaborative product introduction process between all participating partners.

[7] ODM – Original Design and Manufacturing means that a company develops and produces a certain product that is branded by an OEM company.

[8] CDM – Contracted Design and Manufacturing means that a product-owning company orders a specified design and production process from a company, such as an EMS company.

[9] CDS – Contracted Design Services means that a product-owning company can hire engineering expertise in order to increase its level of competence during different phases in the product realization process.

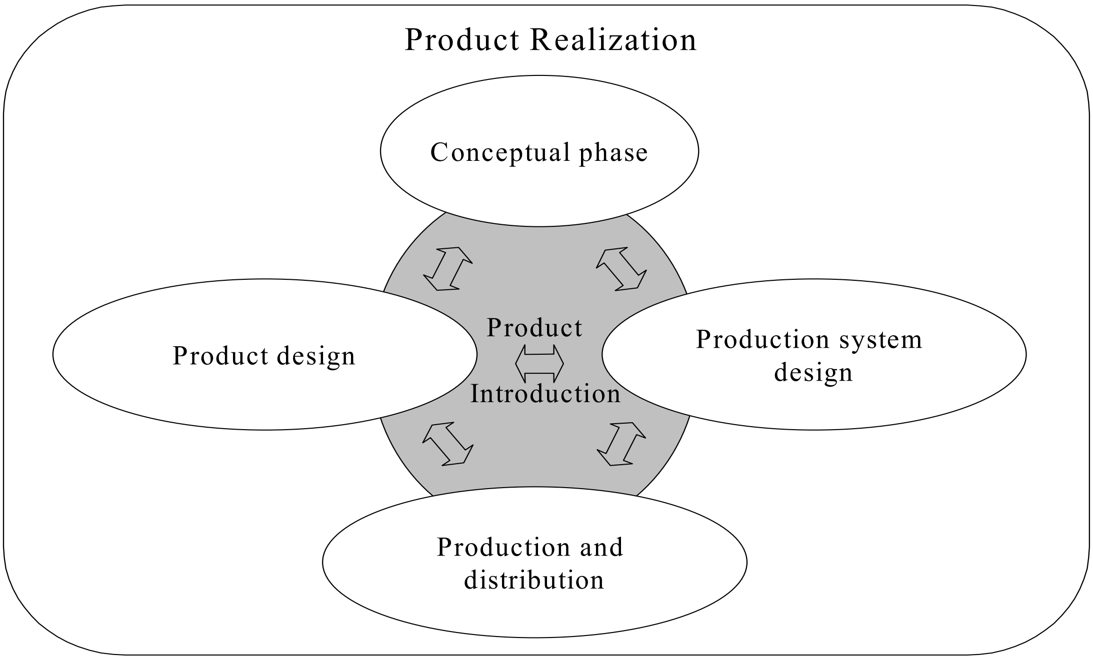

Figure 5.3: The product realization process including product introduction

5.2 Contract Design and Manufacturing

In the electronic industry, the outsourcing trend has expanded to involve concept studies and product development performed by EMS for different product owners (Flextronics, 2004; Samina-SCI, 2005). This concept is sometimes referred to as "Co-Design and Manufacturing" or "Contract Design and Manufacturing" (CDM); in this thesis, the latter term is used. This research's study in the mechanical engineering industry indicates the same trend, i.e. the system integrator increasing its product development responsibility (Papers VI and VII). A similar trend is shown in the Swedish aerospace industry, but here the collaborating companies are responsible for a specific function, sub-system or system (Paper VIII).

CDM in the electronic industry can include everything from some level of design services coupled with manufacturing to a full turnkey product development including manufacturing and distribution (Flextronics, 2004). However, the CDM concept must be coupled to a business model in order to finance all the work included in the CDM project. Different types of business models can be used to cover the nonrecurring engineering (NRE) and manufacturing expenses. NRE costs are one-time engineering costs associated with a specific project, such as project management and specific test and production system design adapted for a certain product or module during the PI process. One way of handling the NRE costs in a project is that the project costs can either be NRE-based, plus manufacturing costs, or NRE amortized over manufacturing. However, in both cases it is important to define what activities that are NRE, and then calculate how much time and resources each activity will need. Furthermore, it is important to analyze the market for the product, since this affects whether it is preferable to amortize the NRE over manufacturing or not. This could be connected to the case described in Paper I, where the conclusion was that it is important to conduct a sensitivity analysis of used data, such as predicted production volume and frequency of new products that can reuse the production system. This means that it is important to have suitable calculation models that facilitate the analysis of which business model is best for all partners.

When a CDM project results in a full turnkey product development, it becomes possible to build a design infrastructure which more effectively captures additional manufacturing opportunities and better utilizes an EMS company's global design, logistic and manufacturing resources. However, an EMS company that offers CDM as a business solution for its customers must be as efficient as the product owner itself, or even better, in the product realization process including the product introduction. This efficiency is one key criterion for the product owner (OEM) in choosing a CDM; other important criteria are increased critical competence and flexibility in resources.

5.3 Customer focus in product realization

As the customer increasingly demands individualized products (Papers II and IV; Swedish Technology Foresight, 2000) designed for remanufacturing (Swedish Technology Foresight, 2000), it becomes evident that product realization must have the possibility to efficiently generate such products. The trend of collaborative PR within EEs (Papers III, V, VI, VII and VIII) further drives the need for information and knowledge sharing that supports customer demands. Collaborative IT tools, as mentioned in Section 3.2.6 and in Papers VII and VIII, could efficiently support this.

The individual customization of each product demands a production process that is flexible enough to handle individual product structures for all product variants and models in an efficient way (Paper IV). This means that the PR process must take the customer demands into account as early as possible in order to design a product and a production system that can efficiently manage the modules and/or product variants. This could be facilitated by a product realization road map, which is defined as a product family plan (or product road map) in combination with a production system plan including test strategies. This PR road map can consist of a shared database with traceability of all changes made for each product, such as new software and new hardware, even after delivery to customer and assembly technologies. Furthermore, existing technology and product road maps are inputs to a PR road map. As technology road maps are high-level planning tools for supporting technology management and planning, these can be utilized to support and identify areas where different POs (OEMs) can use the same production system technology and/or test strategies. Furthermore, the product road maps are usually based on market research, and thus provide input to the PR road map from the customers. A PR road map can be a vital strategic tool that supports the PI process. However, if these kinds of road maps consider too detailed information they become obsolete, more or less, immediately for companies acting in a marketplace for products with short product life-cycles. If these road maps are on a high-level instead, they can be used as a strategic tool in order to increase the efficiency and utilization of existing resources in the PI process and in production.

5.4 Conditions for product realization within extended enterprises

Product realization in a collaborative extended enterprise can utilize different types of supportive processes, such as the mentioned product development process at Flextronics in Section 5.1.1. If the extended enterprise is complex (see Section 4.1), i.e. with several POs using the same Producer or different Producers, then there is a need for flexible and adaptive product realization process at the different partners. This could be supported by collaborative IT-tools that facilitate information sharing and communication (see Section 3.2.6; Papers VII and VIII). If there is one large company with several small suppliers, the large company will probably drive the product realization according to its own processes (Papers VI and VII); this demands, however, that the small producers are careful so they do not loose their identity regarding other customers (POs or OEMs).

The trend of increasing remanufacturing, as described in Section 3.2.3, also needs to be integrated into the product realization process. The product realization process used within an extended enterprise need to effectively adapt, evaluate and manage new trends, such as the issues of remanufacturing, preferably in the conceptual phase. The earlier remanufacturing issues are managed, the more efficient and beneficial the remanufacturing will be (Paper III). It might be a suitable solution to involve a remanufacturing company into the extended enterprise, as previously discussed and illustrated in Figure 2.6.

The following issues for successful product realization within extended enterprises are identified, and are illustrated in Figure 5.4:

- Clear definitions of what is included in the specifications
- Shared risks and a trustful win-win relationship
- Efficient utilization of resources and increased shared competence
- Early collaboration in the conceptual phase
- Management of potential goal conflicts
- Iterative work and open-minded for collaboration
- Collaboration tools facilitating communication
- Cultural awareness

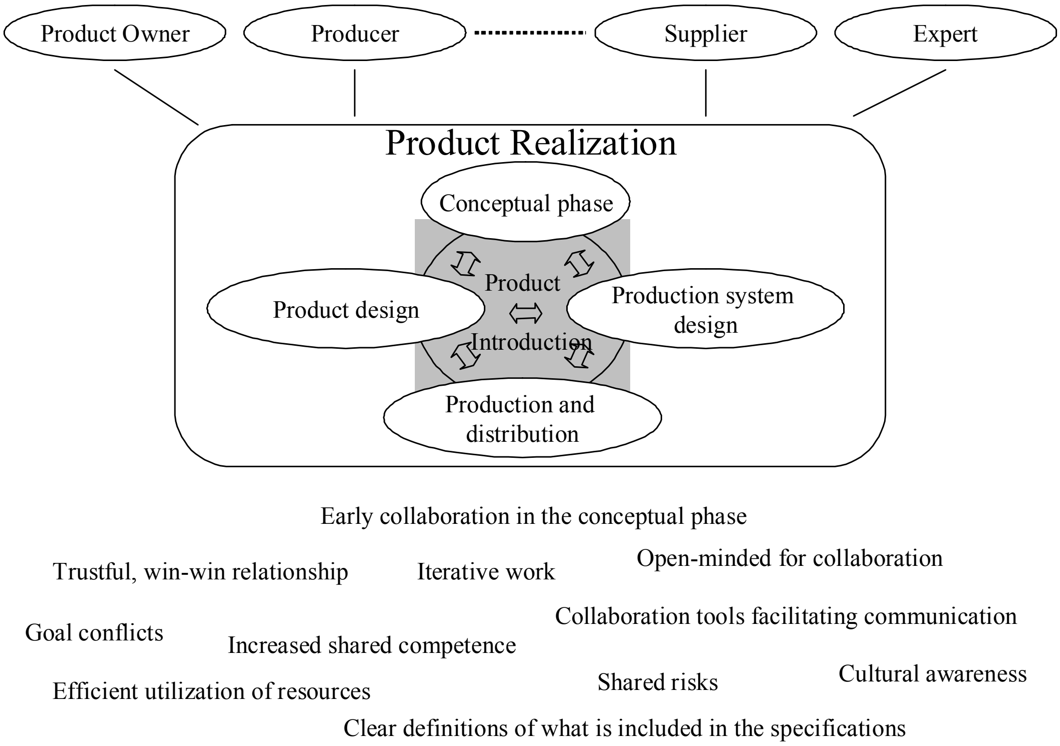

Figure 5.4: The collaborative product realization process with its participants and the important parameters to consider during the vital Product Introduction process

6 Product introduction in product realization within extended enterprises

6.1 Product introduction in product realization

Product introduction (PI) is a vital and iterative part of the product realization process. This process is arguably the most significant key business process, which if executed effectively and with passion can capture the commitment, innovation and creativity of the whole organization (Wheelwright and Clark, 1992). The PI activities, as they are defined here, are performed from the conceptual phase to a developed, manufactured and distributed product. As an example, today's electronic industry has developed into an outsourcing of product introduction, production and distribution (Paper III). The PI process is responsible for production system design, production start-up, the production ramp-up and the distribution of the products connected to these activities. This definition is a little broader, since it includes the start of distribution, rather than the phases of activities throughout the cycle from concept to start of production as Ellison et al. (1995) say characterise the NPI process based on studies in the automobile industry. A main difference between the electronic industry and the automobile industry is that the EMS in the electronic industry often take the responsibility for production and distribution of the final product to retailer or end customer.

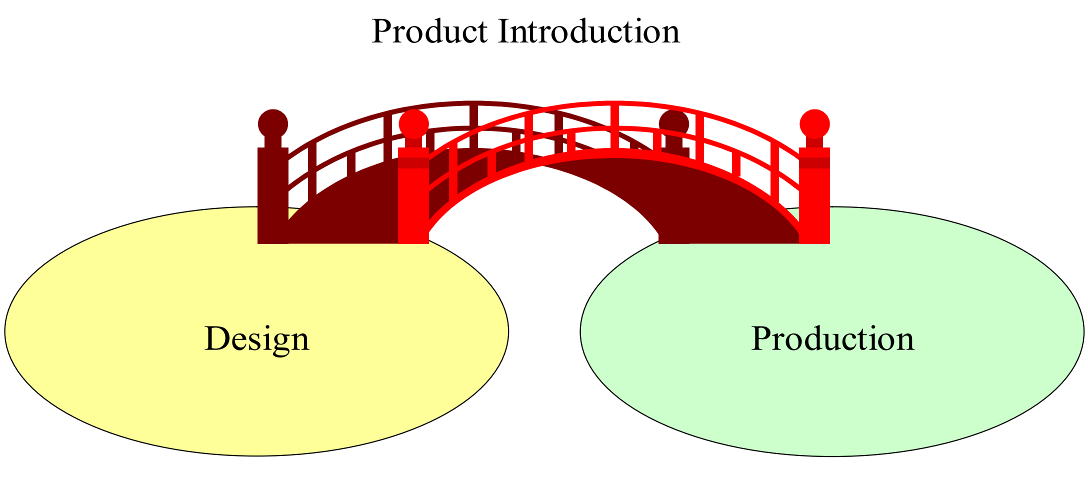

Figure 6.1: Product Introduction – the link between product design and production (Paper III)

Product Introduction is the process of transferring the product design to production, or as described in Paper III, the “bridging” of the gap between product design and production (see Figure 6.1). PI is defined here as the iterative process for adjusting the product and the production processes with each other during the production system design, to include supportive test processes, in order to efficiently transfer a product design into volume production.

The PI (see Figure 6.2), which is a part of the product realization process, starts in the conceptual phase for the product and proceeds until the delivery of finished products to the customer is working according to defined project goals (Paper III).

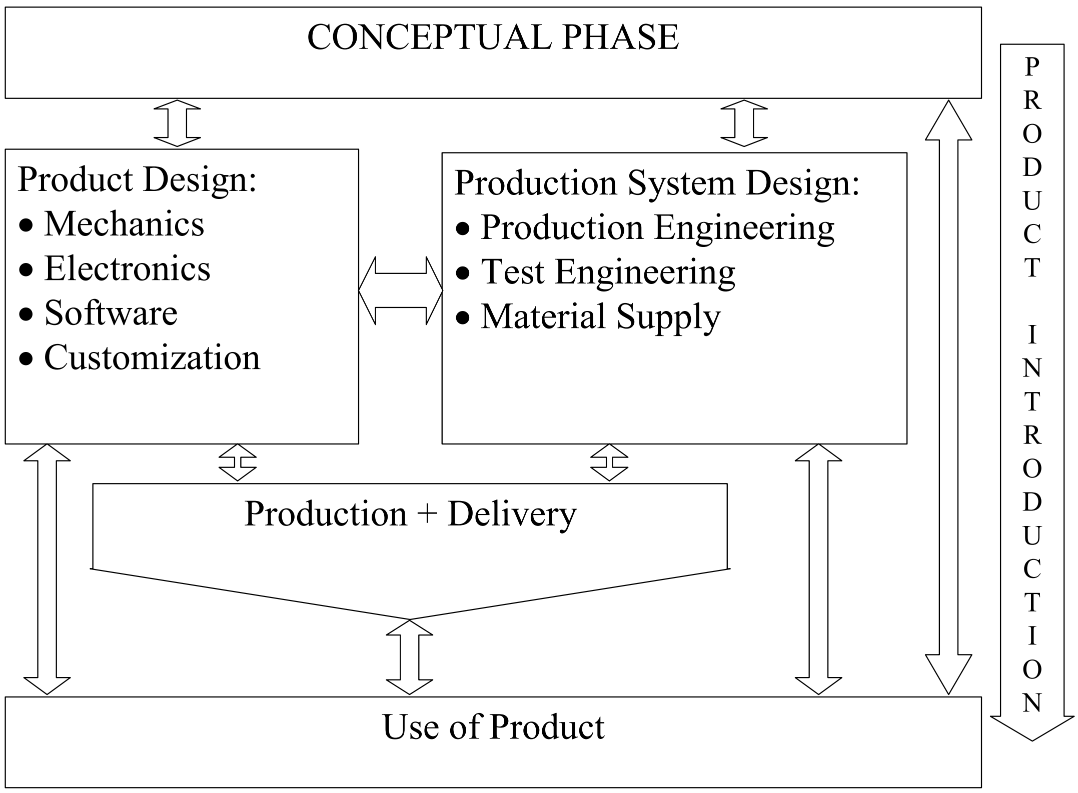

Figure 6.2: The PR process including the PI process (Paper V)

During the product conceptual phase shown in Figure 6.2, a completely new product concept is developed or an existing product model is modified. In both cases, considerations regarding production aspects, remanufacturing and feedback from the customers need to be taken into account in order to secure the producability and the functionality of the product. The production system design and the product design (see Figure 6.2) are two parallel and iterative development processes, where the production process is developed or redesigned for suitable and efficient assembly adapted for the product. (Compare with the PI circle in Figure 5.3). An evaluation of different test philosophies is also performed before the final production system design is decided. The tests can either be process-focused, functionally-focused and / or product-specific. However, a producer can efficiently use a PI process in order to reduce the product's final cost, as mentioned in Papers III and V. Here, it is important to start the PI collaboration as early as possible in order to efficiently utilize the manufacturing knowledge in the conceptual phase, since the cost for changes is relatively low at that stage. Furthermore, iterative sharing of information during the product and production system design supports the efficient utilization of manufacturing knowledge. According to Tennant and Roberts (2003), knowledge transfer is a fundamental aspect of the process that facilitates the development of a "learning culture" to embrace new practices in real time.

The case studied in Paper III indicates that a successfully running PI also includes a secured material supply and product structures that are designed and possible to order in the IT-system. Therefore, PI within an EE demands collaborative IT-systems that can efficiently communicate over company borders or within global organizations (Papers III, VII and VIII; In: Supervised thesis work by Smith, 2004). The production structures may need to be adjusted for different factories if there are several factories producing the same product with different equipment. Finally, the PI project transfers the production process into volume production by using a ramp-up production plan.

6.1.1 Possible goal conflicts during product introduction within an extended enterprise

Throughout an entire PI process involving several companies in its early phases (such as the conceptual phase), there must be a reliable and trustful relationship between the companies involved in the work (Papers III and VIII). All participants in an EE must strive for a business approach that is built on trust, reliability and respect for each other's competence at all levels in the organizations (Papers III, VI, VII and VIII). Usually there is a cross-functional project group responsible for product introduction, with participants that are working iteratively and concurrently with product design and production system design. Observations in the cases (Papers III, V, VI, VII and VIII) indicate that different participants may focus on different goals (Figure 6.3) during the product realization. For an EE, it becomes even more important to have a shared joint goal (Papers VI, VII and VIII) and which is communicated within the EE. If this not is achieved, there is a risk that the goal of each discipline or company will dominate the process, and that the differences will make it harder to reach efficient PI within an EE.

Designer:	Production engineer:
Functionality Robustness Specification protocols Low component cost	Reuse of production processes High producability Short production cycle time Few components Low refinement cost
Project management:	Marketing:
Low project budget Efficiency in work Efficiency in process Short time schedules Guaranteed deliverables	Short time to market Low price Volume flexibility Customer satisfaction Attractive product design

Figure 6.3: Examples of different goals that need to be considered when performing product introduction (Paper V)

Furthermore, the challenge for PI within an EE in the electronic industry is to manage the following (Paper II):

- High-volume production
- Use of advanced manufacturing technologies
- Increasing product complexity and features
- Extremely short product lifecycles
- Trends towards miniaturization
- Increasing requirement for variation and customization

However, the mechanical engineering and aerospace industries are also changing (Papers VI, VII and VIII) in a similar way, but with other starting values. The challenge for each industry segment is similar, however, with regards to their particular situations.

Interviews within the electronic industry (Paper V) showed that its designers focused on developing a robust, high-technology product with advanced functionality. Furthermore, specification protocols for different electronic standards and legal regulations were very much in focus. Designers strived to use components with high functionality relating to cost.

The production engineers within the electronic industry (Paper V), in contrast, argued for the possibility of reusing existing production processes and equipment, especially when designers intended to use a great deal of new and advanced technology in the products. New and advanced technology in a product's design can demand investments in new and advanced production technology. Such technology needs to be considered as early as possible, i.e. in the beginning of the production system design, since such investments usually have long lead and configuration times.

Notable was that the production engineers felt that in order to achieve high producability with few components and low assembly and refinement costs, it was important that the product designers and the production engineers had sufficient communication before the final design was determined. Observations in the electronic industry (Papers III and V) confirm that efficient production demands a product design that is adapted for manufacturing. In another case study performed in the mechanical engineering industry (Papers VI and VII), there were several suppliers of material and components involved in product introduction of the redesigned product. Here, the redesign process was, in fact, the most important part of the product introduction. Both case studies indicate that managing the product realization – i.e. supporting the communication between product designers and production engineers – requires a defined, supported, communicated and accepted process. This is particularly important when one company is responsible for a product's design and another company is responsible for the product introduction and production for that particular product, which can be the case in EEs.

In addition, project management (Paper V) sometimes seemed to focus more on the project's process than on its result. Instead, quantifiable goals such as short time schedules, reaching milestones on schedule, and low investments became the focus. This is another example of the importance that the overall goal of the project is communicated and accepted by all the participants. Finally, the marketing personnel (Paper V) evaluate the result of the product introduction project according to the criteria of volume flexibility, time-to-market and competitive price.

Applying collaborative PI in EE demands a more business-focused way of working which supports the profitability goals for all companies involved. The electronic industry lives with the demands of a shortened time-to-market or, as Brown and Maylor (2005) express it, the current era of hyper-competition. If the time-to-market is delayed, there is a huge risk for missing the market window of opportunity, and thus future market shares for the products. Therefore, it is necessary for the actors working with product realization, such as for example designers, production engineers, and project managers, to understand what is included in a PI process and how they can act to increase process efficiency. Having the knowledge of the most important factors, parameters and conditions to take into account, working with PI can help the product realization projects to find good solutions for future demands, such as decreased costs, shorter time-to-market, customization, maintenance and remanufacturing, and as early as in the conceptual phase. Collaborative PI within EEs demands a trustful and reliable concurrent engineering mindset within each participating company.

The experience during the period of this research is that the parameters to handle within a PI process are, more or less, the same both within a company and within an EE. One benefit of performing the PI within an EE is that costs become more visible. Within a company, there is a risk that costs are hidden or included in the overhead. Collaboration within an EE demands that all actors account their costs for such things as time, material, etc. This in turn means that all actors need to have knowledge and experience of how much time each activity takes, the price of material and equipment, etc. Furthermore, this demands a common way of performing calculations for time, investments etc. in order to get comparable results where the actors have the knowledge of how the data in the calculations is selected and why (Paper I).

6.1.2 Prototypes in product introduction

The activities performed during a product realization project within the electronic industry include the product conceptual design and product design, as well as the product introduction (PI) and ramp-up of production, including all activities and processes needed to get the product in time to market. Based on observations in the electronic industry, the PI process aims at adapting the product and the production system to each other (Paper III). This is comparable with the result in the re-design project described in Paper VII, which increased the number of product modules and enabled a more parallel assembly process. Furthermore, observations in the electronic industry indicated that the PI demands engineers with production and product competence working together with operators skilled in evaluating the producability for a product, including providing relevant feedback to the engineers. In practice, this iterative, collaborative way of working is performed to a large degree through the design of prototypes (Paper III). Broughton (1998) argues that the key elements in the PI process are the activities of developing products to identify weaknesses in the initial design, and developing manufacturing processes to improve performance capability. This supports the important role of prototypes during the PI process as they push the design towards volume production, as illustrated in Figure 6.4.

In Figure 6.4 the volume production is positioned separately, as it is the receiver of the result from the PI process. However, the volume production is a vital part of the product introduction since it is here problems, which should have been prevented in earlier processes, can occur and increase the final product cost. Such problems can be related to the product’s adaptability to the production system, material supply, maintenance and changes. During the PI process, the product and the production system are improved throughout the process of designing, building, and analysing prototypes. In addition, feedback from earlier prototypes is used to push the product design and the design of the production system forward to a suitable final solution for volume production.

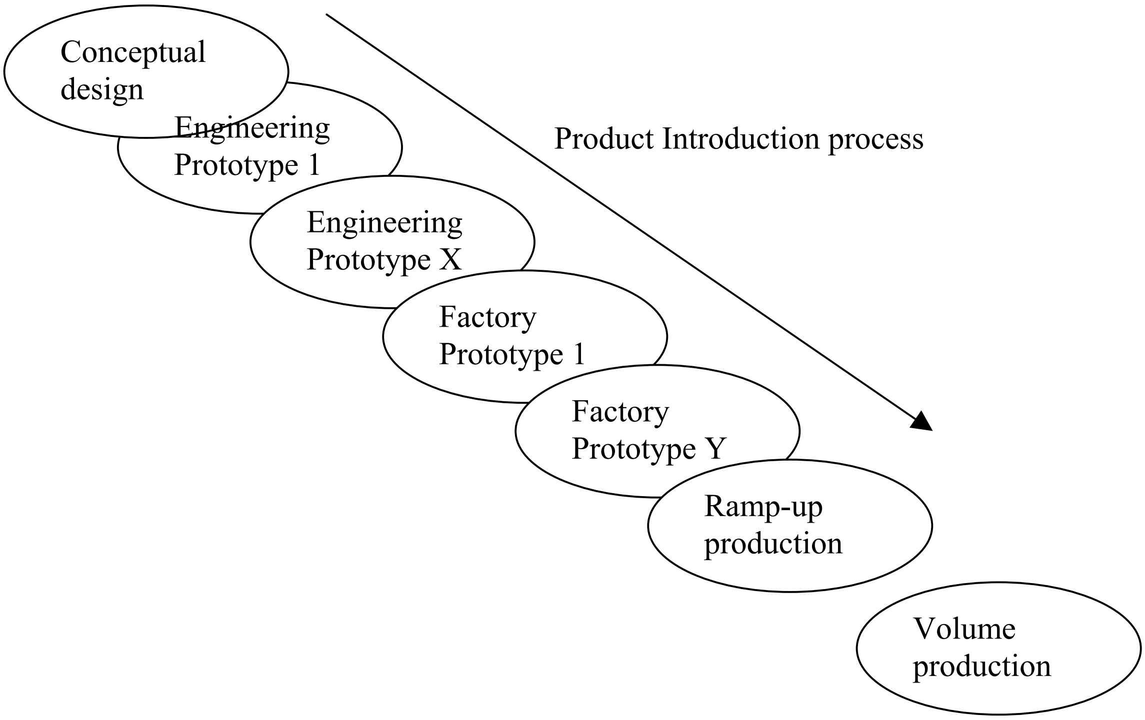

Figure 6.4: The important role of prototypes in the Product Introduction process based on observations from the electronic industry

Prototypes can be either physical or virtual (Paper III). Both types can be used in order to validate the design of a product, a production process or how they are adapted to each other. A prototype is not a final product design, but rather an important source for improvement of the design, which is used within the electronic industry as described in Paper III. Prototypes can be used for increasing the robustness and reliability of the product as well as the production process. Furthermore, observations in the electronic industry showed that prototype series were analyzed with the aim of improving the product and/or the production process, so the production will work as smoothly when starting the volume production (Paper III).

Engineering prototypes are mostly used for validating different technological and/or functional solutions in the product design. In the electronic industry (Paper V), these are usually printed board assemblies (PBAs) without any covers or shells. This PBA is usually mounted in the ordinary surface mount assembly (SMA) line and evaluated in a laboratory environment, both at the design department and within the PI organization. Furthermore, engineering prototypes are used for evaluating the products' characteristics and functions according to producability and usability (Paper V).

The factory prototypes are used for validating the final product designs adaptability together with the final production process, and with regards to cycle times, yield, and logistics as material supply and variant handling (Paper V). Here, the electronic product has all of its components – PBAs, covers, shells etc. – and the whole production process is working as it is planned to do in volume production. Generally, for the prototype series, the product is analyzed according to its producability, tolerance chains, functionality, assembly cycle time, material, etc.

The observations in the electronic industry (Papers III and V) can be compared with the mechanical engineering industry case (Papers VI and VII). Here, an engineering prototype was exemplified with a new conceptual design for a certain function, which was first validated in a bench test. The next step was to validate its functionality in a field test, with the module assembled in the ordinary complete machine. For the mechanical product studied, this step could be defined as an extended engineering prototype, which is assembled in the ordinary production line, as a kind of factory prototype.

The main purpose for all prototype series is to improve the total solution and eliminate misunderstandings (Paper V). Engineering prototypes can be used for evaluating a product's functionality and factory prototypes can be used for evaluation of how the product and its production system are working together. This can be viewed as a manifestation of concurrent engineering – pushing the design to be more reliable and suitable for volume production (Papers III, V, VI and VII). All results, analysis and suggestions for improvements from the prototype series can be summarized in a report after each prototype series is build and validated, as was observed in the electronic industry. These reports are aimed at the project management, the product designers and the production engineers, and are to help them push the final product design and the production system forward in the development in order to get the most efficient solution before starting up the volume production. The reports can also be seen as a structured way to give continuous feedback in the PI process, and as a support tool for an iterative way of working. The responsibility for PI can rest either with the producer or the product owner; however, both need to participate during the entire PI process in order to facilitate information sharing and knowledge exchange during the prototype series.

The use of prototypes and the planning of prototypes must support the product design with a focus on product introduction, and therefore work iteratively within the PI process in a concurrent engineering mindset. This iterative way of working within the electronic industry is symbolized with the repetitive prototypes for engineering, and by the factory evaluations where the product is finished to a higher degree in the factory prototypes, with the aim of validating the production process together with the product. The prototypes should support Garvin's (1992) three stages for a product consisting of *product research*, *product development* and *final design*. Based on observations within the electronic industry, prototypes should create new knowledge, allow development of concepts, create specifications, approve the design and deliver a bill of material.

6.1.3 Collaborative tools within product introduction

Production engineers evaluating product concepts or product designs must decide if the products are suitable for production in general and a certain production system in specific, and/or if there is a potential for improvements in order to increase producability. The opinion of the production engineers within the electronic industry is that the earlier they are involved in the product development/realization process, the better the product will be adapted to production (Paper III). This can be problematic if different companies are involved, since the production engineers from a Producer get early information about a Product Owner's new products in the conceptual phase. This Producer may also be a Producer for other Product Owners, which in turn can be competitors to the first Product Owner. The Product Owner must trust the Producer not to pass on confidential information to other Product Owners, see Paper V. Legal agreements must, of course, also regulate this, but trust is fundamental. Producers can manage this dilemma by using different production engineering teams working with different customers/Product Owners.

In the electronic industry case described in Paper III, the production engineers used tools, such as Design For Assembly (DFA), Design For Manufacturing (DFM), and Failure Mode Effect Analysis (FMEA) in order to improve the Concurrent Engineering (CE) aspects during the product introduction project. These tools are used for analyzing the product design (or the production system design) in order to find areas of improvement so the producability can increase. By using these tools and techniques, it was possible to reduce many of the problems that can occur in production, according to the engineers within the observed electronic industry. This way of working has saved time and eliminated misunderstandings during product introduction in the case study (Papers III and V). However, it is not uncommon that factors identified in FMEAs are ranked in another priority order during the project rather than identified in the beginning as one manager within the electronic industry explained to the author. An experience in the electronic industry is that DFM gave the opportunity and possibility to estimate the need for testing and to calculate investments, value-added time, station time and the number of stations needed for a specific volume in each production line. A conclusion from observations in the electronic case is that it is important to use these kinds of tools early in the conceptual phase in order to achieve a product design adapted to production (Paper III). Since the product life cycle is short for products within the electronic industry it is important to identify areas of improvement as early as possible, preferable within the conceptual phase.

Otherwise, it may be difficult to implement improvements for the analyzed product if it is not related to a functional problem. The author has been informed about a case within the electronic industry, where an analysis of a product showed potential production related savings. However, these improvements were not implemented since a re-design project would demand both resources and time. The resources were already working with the next product model and therefore, the earn knowledge was transferred into the next product instead.

Observations from the mechanical case described in Papers VI and VII also show that collaboration between different participants was extremely powerful during a value analysis (see Section 3.2.6) performed in order to improve the producability of the product. The value analysis focused on the re-design of an existing product in order to increase its level of modularization and thus achieve cost reductions, both for components and assembly. The different participants studied drawings as well as the physical product. The result for one of the product modules was the reduction of component cost by about 40%. However, this value analysis could and should have been performed when the product was designed for the first time, which could be compared with the observations in the electronic industry described above. The suggested improvements, which have also been implemented, focus on the main structure of the product, not on its details. The module studied was completely re-structured. The opinion of the product designers and production engineers involved was that it would have been possible to achieve the decreased cost in this case without having existing complete drawings or physical products to study. This example shows the strength and the benefit of involving production engineers in the conceptual phase.

Working in an extended enterprise demands control over which production solutions are the most beneficial. When calculating investments for production lines, observations in the electronic industry showed that its becomes important to perform a sensitivity analysis regarding volume changes, frequency of new product introductions, technology flexibility and production parts connected to the new technology, as mentioned in Paper I. An efficient PI process within the electronic industry demands products and production systems that can reuse equipment in order to minimize the product-specific investments and therefore decrease the production cost for the product. Notable is that the future production of electronic products, for example, will probably also demand the increased use of general test equipment in order to generalize and reuse test functions and test solutions.

6.2 Conditions for product introduction within extended enterprises

Summarizing the cases described in Papers I – VIII, the general conditions that must be fulfilled in order to achieve an efficient PI within an EE can be formulated as:

1. *A clearly communicated definition of what is included in product introduction.*
2. *Early participation from all EE partners in the product realization process, such as those involved in product and production system design, and temporary expert competencies.*
3. *Clear communication and information handling within the extended enterprise – both internally and externally.*
4. *Business approaches built on trust, reliability and respect for each other's competence.*
5. *Cultural awareness, both between different companies and countries.*

The five conditions above can be related to the empirically-based PI process in Figure 6.5. Each of these five conditions can be fulfilled through efficient use of different factors and parameters of importance for PI within EE, many of which are presented in text below as well as in Figure 6.5.

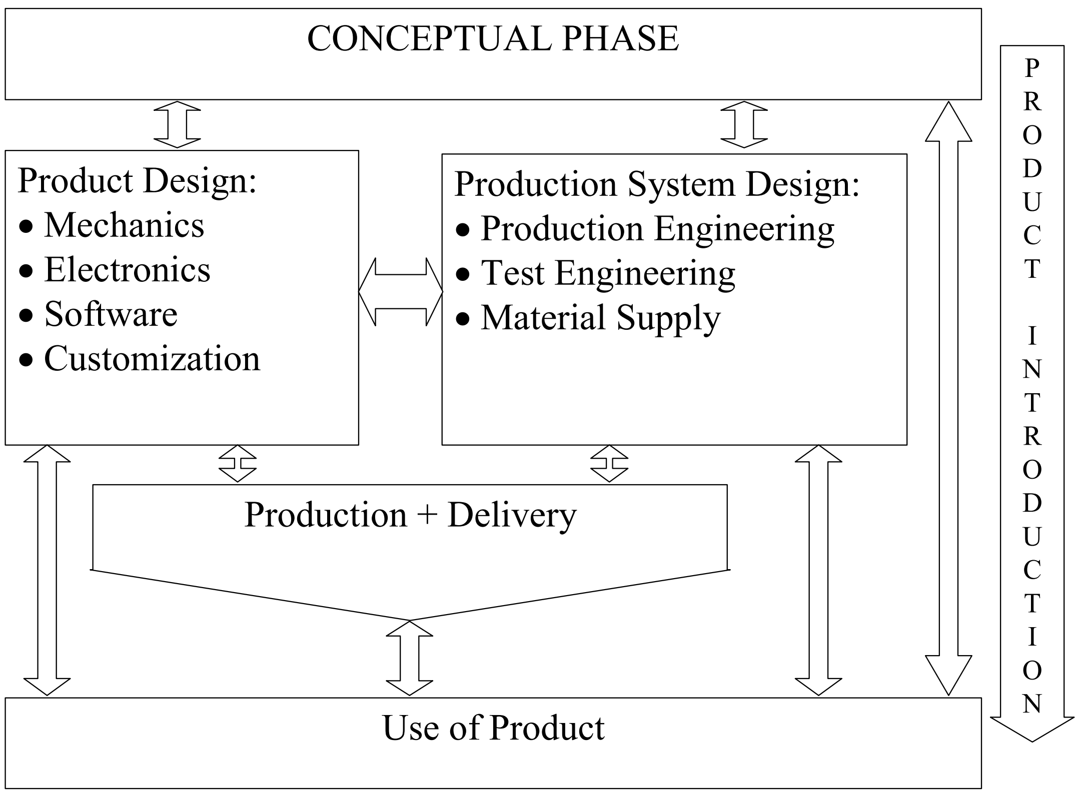

Figure 6.5: The PR process including the PI process based on observations from the electronic industry (Paper V)

1. *A clearly communicated definition of what is included in product introduction.*

There must be a clear definition that is firmly established, both within the EE as well as in the internal organizations within each company. All participants in the PI need to have the knowledge of what activities are included in the PI, how much time each activity takes and when the resources are needed. Furthermore, if the defined goals and milestones support a concurrent engineering approach, then the EE can efficiently and iteratively control the progress of the PI.

2. *Early participation from all EE partners in the product realization process, such as those involved in product and production system design, and temporary expert competencies.*

Participation representing a combination of competence areas, such as “new technologies”, “product design”, “product introduction”, “volume production” and, “external experts”, and as early as in the product conceptual phase, can improve the producability of the product. An improved producability in the early stages of the product design can decrease the need for late and therefore expensive changes in the product design and the design of the production system. Such important work in the conceptual phase can result in a product design adapted for manufacturing and a shorter production cycle time, which in turn can result in a lower refinement cost for production. It is necessary to find efficient solutions for performing this early co-operation when the needed competencies are within different companies and most likely geographically dispersed.

3. *Clear communication and information handling within the extended enterprise – both internally and externally.*

Identification of how to communicate what to whom within a project team, both within a company as well as within an EE, can increase the efficiency of the information handling. Using the right competencies and decision levels for different questions decreases the time needed from question to solution and minimizes the risk for misunderstandings. Furthermore, it is of high importance to have knowledge of the cost for each activity and why. In order to obtain comparable data, at least within each company, it is necessary to define how to calculate costs connected to projects, investments, and production – both regarding the refinement cost and the rework, material and maintenance. An early sensitivity analysis regarding volume changes, frequencies of PIs, technology flexibility and new technologies can be valuable during decision-making in the PI process.

Communication and information handling within an EE can be efficiently facilitated by different suitable collaborative IT-tools; examples include shared databases, shared CAD drawings and internet meeting places.

4. *Business approaches built on trust, reliability and respect for each other's competence.*

This is a basic requirement for all three conditions above. An efficient collaboration within an EE does not only consider technical and organizational aspects. An EE is also dependent on the people within it.

5. *Cultural awareness, both between different companies and countries.*

Many misunderstandings can be avoided if the collaborating organizations have a high degree of cultural awareness. Differences in culture can be seen on various levels, such as business, organizational, management, geographical, communicative, and technological. During collaborative product introduction within extended enterprises, all of these levels are involved, making it crucial that cultural differences are managed in a sufficient way.

7 Framework for collaborative product introduction within extended enterprises

This section will discuss the results from observations in the cases as well as how they are related to the theoretical framework, and present a general framework for collaborative product introduction within extended enterprises. The aim with the framework is to help actors to prepare for and perform an efficient collaborative product introduction. The framework is based on a combination of observations from the electronic industry and a framework developed in the mechanical engineering case, as discussed in Section 7.1.

7.1 Start-up framework from mechanical engineering case

The goal for the project studied within the Swedish mechanical engineering industry (Papers VI and VII) was to develop a framework for supporting how to collaborate successfully within an extended enterprise. The development of the framework was documented during the ongoing collaboration between different competencies and included participants from the Product Owner, Producer, Supplier, Specialist and Researcher categories.

The participants in this project were selected with regards to their different competencies and experiences in order to develop a framework for efficient collaboration. The framework is based on experiences from a re-design process for a new variant of an existing product performed in an EE. Experiences from the performed workshop indicated that the new extended competence that critically evaluated the design could after a short time (approximately one day) suggest large re-design solutions for the selected product modules. In this case, the mixed competencies and the “new eyes” from external participants were shown to give rise to new ideas and solutions, something which is defined in this thesis as “extended enterprise networking” (Papers VI and VII).

Early collaboration between different companies, organizations and competencies in the conceptual phase for re-designing a product is obviously beneficial (Table 7.1). Notable is that this type of collaboration – extended enterprise networking – could have been performed for an earlier version of the product, even as early as in the first conceptual phase, since some of the performed improvements were realized simply from looking at drawings (Paper VII).

Table 7.1: Result of the improvement work (Papers VI and VII)

Area of improvement	Expected	Reached
Lead time	-40%	-85%
Manufacturing cost	-17%	-40%

The extended enterprise networking increased the competence level at the small and medium-sized companies investigated, i.e. how to collaborate, work with project models, and identify and define the working processes that were used (Paper VII). To facilitate the extended enterprise networking, the companies in the EE have started to use a joint IT platform that facilitates communication, both in order to achieve faster and cheaper communication, and to increase the opportunity to collaborate strategically when making future quotations to potential customers.

All activities performed during the project in the mechanical engineering industry have been collaboratively documented during the process and summarized in a framework by the researcher and her co-author in Papers VI and VII. This framework describes how to start collaborative product realization within an extended enterprise, and is based on the case study described in Papers VI and VII. The aim is to reach a short and efficient time to market or a product developed iteratively together with production. The framework illustrated in Figure 7.1 is a result from this action research, were the researcher had an active role and participated primarily in the execution process, supporting processes and the documentation.

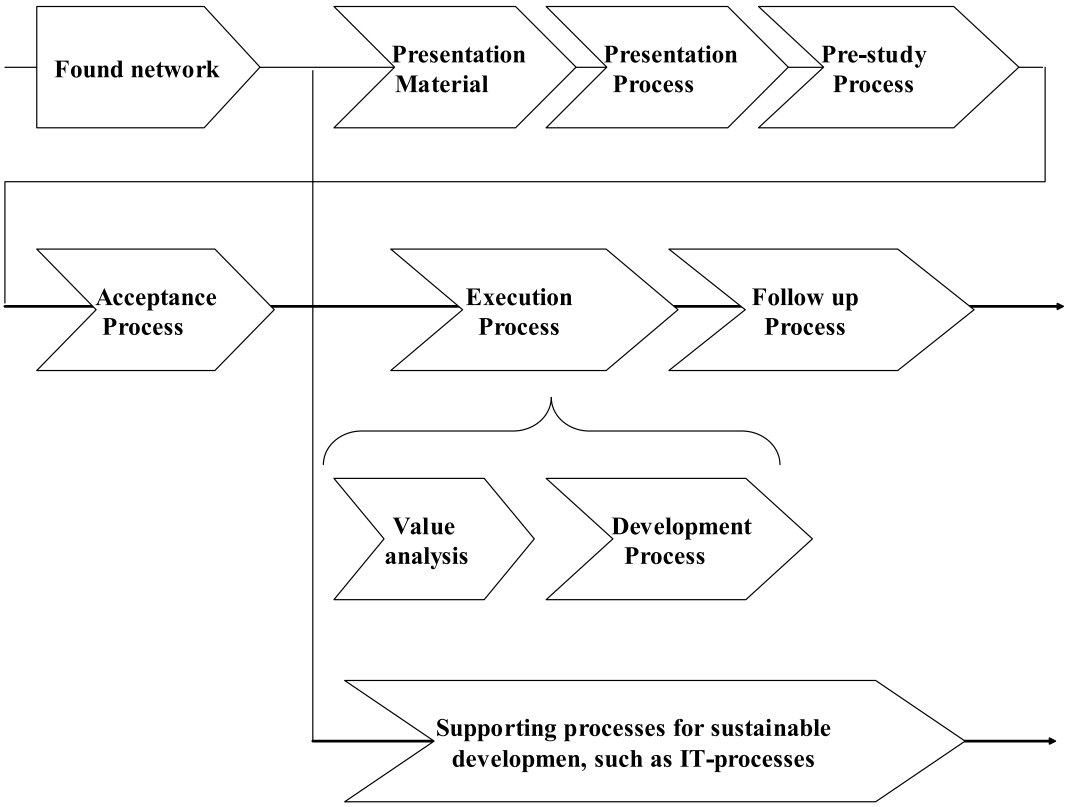

Figure 7.1: The framework for start-up of collaborative product development (Industrigruppen, 2004)

The framework consists of ten identified processes, which together can facilitate the establishment of a competitive collaborative extended enterprise. Each process has its own aim, consists of several activities and has its own goal. Furthermore, each process has its own input and output. Different krAft projects in the Swedish SME industry, which focus on competence development within SMEs and financed by the Knowledge Foundation, have been informed of this framework by the co-author of Papers VI and VII. A few follow-on projects have just been initiated, and the aim is to follow this framework. Furthermore, the Swedish industrial group “Industrigruppen” plans a marketing campaign during 2005, with the purpose of spreading knowledge and facilitating the participation of other companies that are interested in collaborative product development with their partners.

7.2 Framework for collaborative product introduction within extended enterprises

The results from the research are collected in an extended framework for collaborative product introduction within extended enterprises, as seen in Figure 7.2. This extended framework is based on the framework from the mechanical engineering industry in combination with observations from the electronic industry.

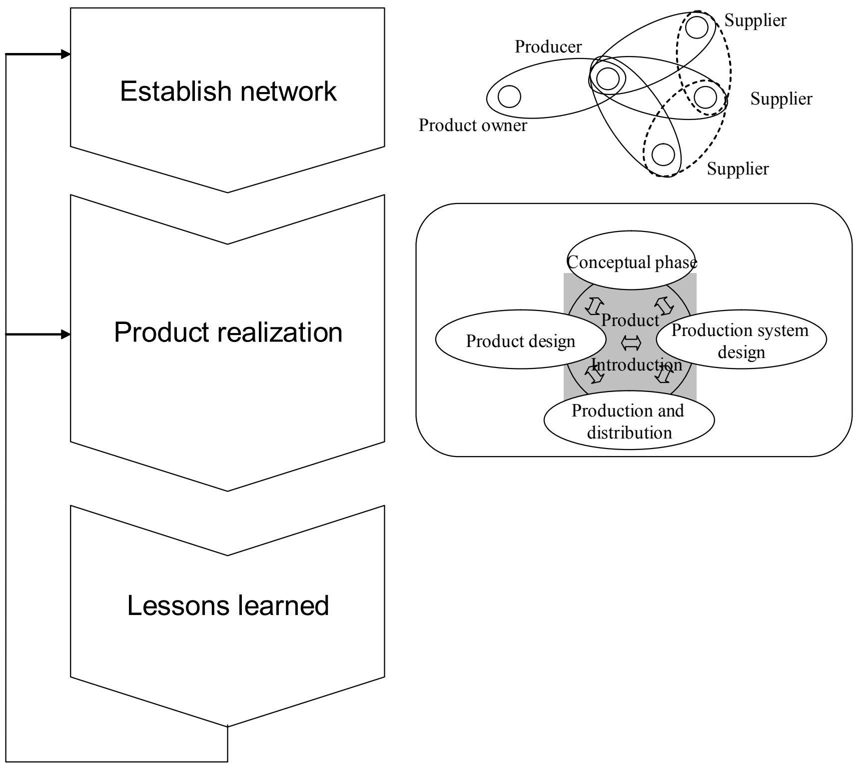

Figure 7.2: Framework for collaborative product introduction within extended enterprises

First of all, when collaborating, the producing partners or companies that wish to collaborate need to identify their common target group and how they want to be organized, for example horizontally or vertically, and determine how the partners will be linked to each other (see Section 4 and Paper VIII). This establishing process is important for all partners involved, since each partner presents its core competence and also lack of competence in order to identify how the collaboration could increase the overall critical competence. Another issue of importance during this process is that the participants should be aware of each other's different goals that depend on each company's strategy and competencies (See Paper V). Establishing a network demands that the partners involved discuss and agree upon a common strategy for the network. In theory, there exists several examples of different company-to-company alliances (see Section 3.2), and the strategy selected can be seen as a complement to each partner's own strategy, while at the same time providing all participants a broader virtual competence. Establishing a collaborative network can provide the partners a combination of, for example, the cost effectiveness and flexibility of producing companies with the competencies and resources of product-owning companies, as was shown in the mechanical engineering case. The people representing each partner in this establishing process should be on the top management level, since it is a strategic decision to join a network, and one activity in the process is to market this new strategy within the participating organizations. The marketing and acceptance of the collaboration that the organization will take part in is easier and faster if it is clearly supported by the top management.

The first step in the establishing process is the organization of the main production company and its suppliers (Compare this with the network in Figure 7.2, which shows the producing network including the product owner.) During the next sub-process, marketing (see Figure 7.3), the established production network develops common marketing material that explains the network's strategy and how the partners aim to combine their competencies in order to offer their customers an increased level of critical competence. One key issue to market is how the network will combine the small company's cost effectiveness and flexibility with the larger company's competence and resources, if that is the case.

Other aspects to highlight from the follow-up process are experiences and results from earlier collaboration in product realization projects, and how the increased virtual competence has been utilized. In short, the marketing material should include arguments for the network's competitiveness compared to traditional competitors or companies. In order to increase the flexibility, the marketing material should be developed so that all partners can use it and easily rewrite it to fit different potential customers. Furthermore, the marketing process demands travel to, presentations for, and discussions with the identified customer's management, with the aim of obtaining acceptance for performing a pre-study.

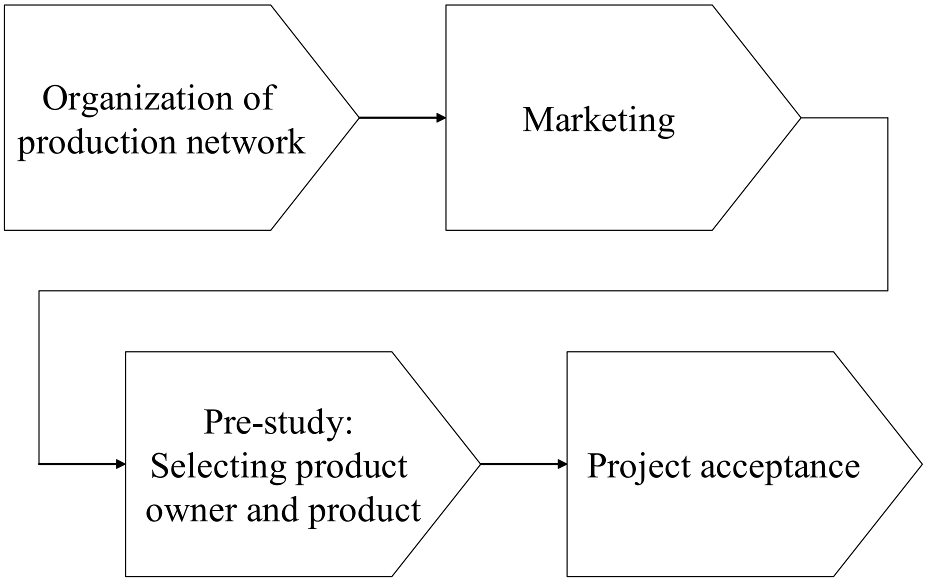

Figure 7.3: Processes during the establishment of a network

A pre-study process (see Figure 7.3) can be performed according to the agreed pre-study specification and start after contract signing. The aim is mainly to identify a possible project at the customer where the collaborating competencies can be efficiently utilized. A pre-study can either be based on a new concept, or concern a re-design project based on an existing product. A re-design project can have different goals, such as reducing cost, introducing a new product variant or increasing producability. The outcome from this process is a project specification which includes time and resource plans. Furthermore, a competence map specific for the project is developed, and a contract is prepared facilitating all participants' responsibilities and involvement, and how to share risks and profit. This process should deliver all material needed for the acceptance process supporting the project start decision.

In an ordinary product development processes (Ulrich and Eppinger, 1995; Otto and Wood, 2001), the acceptance process can be compared to a tollgate, checkpoint or milestone. The acceptance process is highlighted here (see Figure 7.3), as it is important that all partners agree and sign contracts before the work is started. This may require several meetings and trips, depending on how many partners are involved and how the network is organized. Performing this process successfully can decrease future problems regarding such things as the owning of results, responsibilities, and profit sharing. In order to support a smooth acceptance process, all material should be carefully developed, such as the project specification, cost analysis, competence mapping, and time plan.

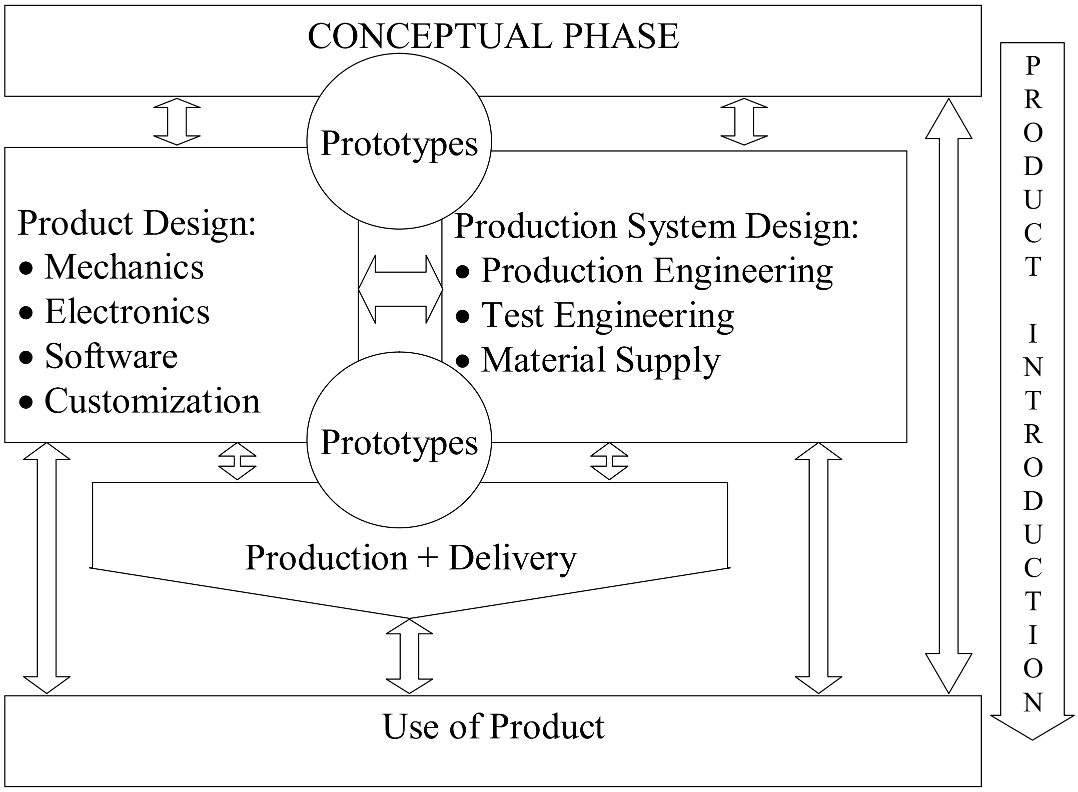

Figure 7.4: Processes during product realization based on observations in the electronic industry

The product realization process in Figure 7.4 is based on observations from the electronic industry and is divided into several sub-processes covering analysis and design processes, all which are linked together with different prototype series, engineering prototypes in the early phases (the upper circle in Figure 7.4) and factory prototypes in collaboration with production (the lower circle in Figure 7.4). The overall aim for the total product realization process is to create and develop value through product design, product system design and production integration through product introduction (see Section 6) facilitated by cross-functional and cross-organizational resources and competencies that work concurrently and iteratively (see Section 3).

The concurrent and iterative work between product design and production system design (see Figure 7.4) analyze the product and its producability in order to adopt the product and the production system to each other. The analysis can utilize several types of supporting tools, such as DFM, DFA, FMEA and value analysis (see Sections 3.2 and 6.1.3) that facilitates a product design suitable for production. However, the earlier processes are important, since acceptance in those facilitate an efficient execution and implementation of the results. Analysis of a product can be performed either on an existing product or be based solely on drawings for a new product and its planned production process. If the analysis is performed on an existing product, this should be documented as much as possible, such as through the use of drawings, specifications, production process specifications, work instructions, material supply specifications, supplier specifications, and restrictions in re-design possibilities. The analysis is performed with competencies from the entire network, including participants from the customer (product owner). It is preferable if the analysis can be performed close to the production line for the product. Ideally, the analysis should be conducted as a product is being produced in this line, as was the case in Papers VI and VII. This increases understanding, and is a resource added to the analysis that affects the outcome from the process, which consists of suggestions for improvement for the product and its production process based on cost calculations.

The next step is to implement the improvements suggested in the analysis process into the product design. This implementation process includes both the design of the product and the production process, and utilizes different prototype series in order to evaluate the product and its adaptation towards the production process (see Figure 7.4 and Section 6). Here, it is important to work iteratively between product and production process design according to the product introduction process discussed in Section 6. Furthermore, the product realization process needs to manage feedback from earlier projects in order to utilize experiences and further develop the manner of collaboration.

In order to evaluate the result of the collaborative work in the network, the follow-up process is performed. Here, the outcome is measured in cost, production-related key factors and technology, but also in increased experience, closer and deeper relationships within the network and its customers that can result in further collaboration, and in increased competence within the participating companies. However, follow-up calculations are not always performed in industry (Paper I), yet this process is important since knowledge gained here can increase future competitiveness for the entire network.

Finally, all the processes mentioned above need to be facilitated by supportive processes for sustainable development, such as IT-processes. Today's IT technologies open many opportunities for companies to reduce cost for things such as, for example, travel and lead time for regular mail (See Section 3.2.6). However, using IT technology demands that participants have a structured and coordinated way for communicating and labeling all documents. One example could be that all mail related to a certain project always begins with the project name, which gives the opportunity to automatically sort this mail into a project map in the mailbox.

8 Discussion

This section will summarize the research. Furthermore, the contribution of this research will be discussed, and possible future research areas will be suggested.

8.1 Understanding the conditions for product introduction in product realization within extended enterprises

The main objective of this dissertation was *to explore and describe factors and conditions that are of importance for an efficient collaborative Product Introduction (PI) within an Extended Enterprise (EE) in the electronic industry.* The objective addresses three research questions:

1. How can the generic structure of an Extended Enterprise be described based on observations in the electronic industry?
2. How can Product Realization be performed within an Extended Enterprise in the electronic industry?
3. How can Product Introduction be performed during Product Realization within an Extended Enterprise in the electronic industry?

Based on the results described in Sections 4, 5, 6 and 7, these three questions are further discussed below.

Research question 1:
How can the generic structure of an Extended Enterprise be described based on observations in the electronic industry?

An Extended Enterprise (EE) is a dynamic collaboration between companies or organizations, where the partner with the most suitable competence for an activity will most likely be responsible for performing it. A Generic Extended Enterprise Module, or GEEM, is defined here, based on this research's observations in the electronic industry, as containing a Product Owner, a Producer and a Supplier as shown in Figure 8.1.

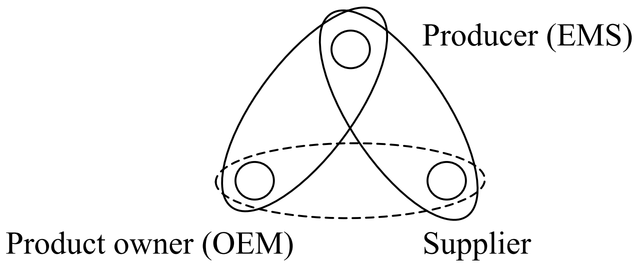

Figure 8.1: The Generic Extended Enterprise Module (GEEM) (Paper III)

However, in general an extended enterprise is more complex than a GEEM, although a product design primarily requires material and components from several suppliers. An EE, such as one based on observations from within the electronic industry, can, of course, consist of several combinations of the GEEM structure, such as one Producer collaborating with several Product Owners and Suppliers. A Producer (EMS or SI) often has several Product Owners (OEMs) as its customers, and a Product Owner can use several Producers in order to decrease its dependency and increase its flexibility, as seen in Figure 8.2. Here, it is very important to maintain a close and trustful collaboration with the Product Owners as early as possible within the Product Realization process (Papers III, V, VI, VII and VIII).

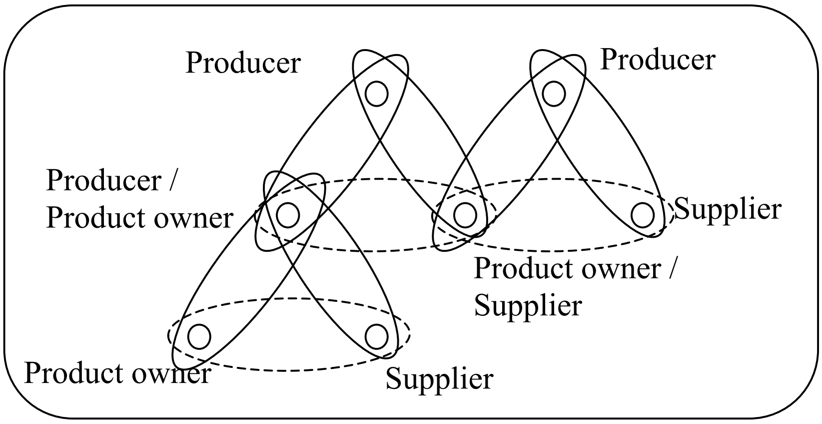

Figure 8.2: A complex Extended Enterprise (Paper III)

The extended enterprises observed in the cases (Papers III, V, VI, VII and VIII) comprised several different types, as described throughout this dissertation. In the electronic industry (Papers III and V), a structure such as that shown in Figure 8.2 was described, i.e. several Producers involved in the production of products owned by several Product Owners, and utilizing the same suppliers of components and material. In the mechanical engineering industry (Papers VI and VII), the extended enterprise under study involved companies that were co-operating with, or were suppliers to, the Producer and the university in order to extend the critical competence during the re-design process. Finally, in the aerospace industry (Paper VIII) the focus was on one System Integrator (Product Owner) in close collaboration with a number of sub-system suppliers who were responsible for the development and production of different functions or product modules. These system suppliers, in turn, were responsible for the collaboration with the next level of suppliers.

In summarizing the observations from the extended enterprises investigated for this research, it is clear that they all contained a Product Owner that owned the branded product and marketed it. The extended enterprises consisted of one or several Producers competing with each other. The Producer's responsibilities differed from: (1) production at a Contracted Manufacturer (CM) (Johansen, 2002; Siemens, 2005); to (2) responsibility for product introduction including volume production and distribution to the end user, in this case within the electronic industry, (Papers III and V); to (3) design responsibility for products or modules including product introduction and volume production (Papers III, V, VI, VII and VIII).

Observations in the mechanical engineering case indicate the importance of the establishment process for a collaborative extended enterprise. The use of extended critical competence seems to be a very beneficial strategy for the Product Owner (Papers VI and VII). Applying this in the generic model described in Figure 8.1 implies that a supplier could be an expert within a specific competence area. However, it is important to solve issues regarding risk sharing, profit sharing and resource management before the collaborative work starts, such as the case in Paper VIII illustrates.

Research question 2:
How can Product Realization be performed within an Extended Enterprise in the electronic industry?

Product Realization (PR), as it is illustrated in Figure 8.3, covers all activities involved in transforming an innovative idea into an innovation, i.e. from the conceptual phase to a designed, produced and distributed product including managing feedback between all actors. Performing PR within an extended enterprise means that several actors are collaborating in order to reach its joint goals. For a product, these actors usually consist of the Product Owner, the Producer(s) and all suppliers of components, material, equipment and services, such as experts that increase the critical competence (see Figure 8.3).

Performing collaborative PR within EEs entails a number of difficulties, such as goal conflicts (Paper V), economical issues such as how to share risks and profits (Papers VI, VII and VIII), how to calculate (Paper I), cultural misunderstandings (Paper VIII) or how to divide the product into modules and design a supporting production system for it (Papers II, IV, VI and VII). However, based on this research's observations within the electronic industry in combination with the literature review, increased flexibility, more efficiently utilized resources, and increased critical competence are factors that efficiently support collaboration within EEs, since the difficulties can be solved by training, clear specifications, communication, joint calculation methods and collaborative IT-tools for information sharing. All this is based on a trustful relationship, as mentioned in Section 2.2.3.

As observed in the cases, it is important to have a structured way to manage the product realization process including its utilization of the collaborative product introduction process. In Section 7.2 of this dissertation, a framework is suggested for managing the collaborative product realization process where several activities must be performed. Summarizing the case studies and the literature review performed in this research gives the following important issues to manage during PR:

- Identifying a joint and shared goal for the PR within the EE that supports a trustful win-win relationship between the partners (Papers V, VI and VII; Section 3.2.2)
- Efficient iterative collaboration and information sharing between competences and responsibilities, preferable facilitated by collaboration tools (Papers III, V, VI, VII and VIII; Sections 3.1.4, 3.2.5 and 3.2.6)
- Early open-minded collaboration during the initial work (Papers VI and VII; Section 3.1.5)
- Identifying remanufacturing aspects that affect the product and production process design (Section 3.2.3)
- Identifying customization aspects that affect the product and production process design including distribution (Papers II and IV)
- Identifying how to fulfill important criteria for an efficient PR, addressing issues such as economics, marketing, technology, manufacturability, organizational, culture, and communication (Paper VIII; Section 3)
- Efficient utilization of the product introduction process that manages factors such as: number of variants, volume flexibility, life cycle aspects, profitability, logistics, manufacturability, quality, and productivity (Papers I and III)
- Agreeing upon clear definitions of what is included in the specifications (Paper III)

Research question 3:
How can Product Introduction be performed during Product Realization within an Extended Enterprise in the electronic industry?

Product Introduction (PI) is a vital and iterative part of Product Realization (PR) which, according to Wheelwright and Clark (1992), is a significant and key business process. The PI activities, as they are defined here based on this research's observations within the electronic industry, are performed from the conceptual phase to a designed, produced and distributed product. In the electronic industry, the trend of outsourcing has developed even further into an outsourcing of distribution of the produced product to the end user (Paper III).

The PI is the process of transferring the product design to production, or as described in Paper III, the PI "bridges" the gap between product design and production in order to adapt the product and production system to each other. A

PI is defined here as an iterative process for adjusting the product and the production process to each other during the production system design, and includes a supportive test process. This should, in reference to this research's observations within the electronic industry, support an efficient transfer of a product design into volume production and distribution with secured material supply. Experiences from the electronic industry indicate that PI within EE demands collaborative IT-systems that can efficiently communicate over company borders, which also have been observed within the cases in the mechanical engineering and aerospace industries (Papers III, VII and VIII; In: Supervised thesis work by Smith, 2004). Furthermore, this research's observations within the electronic industry indicate that PI demands engineers with production and product design competence working together with operators skilled in evaluating the producability of a product, including providing relevant feedback to the engineers. In practice within the electronic industry, this iterative and collaborative way of working is performed to a large degree through the design of prototypes (Papers III).

Summarizing the cases described in Papers I – VIII, the general conditions that must be fulfilled in order to achieve an efficient collaborative PI within an EE in the electronic industry can be formulated as follows:

1. A clearly communicated definition of what is included in product introduction.
2. Early participation from all involved partners in the EE's product introduction process, such as product design and production system design and including temporary expert competencies.
3. Clear communication and information handling within the extended enterprise – both internally and externally.
4. Business approaches built on trust, reliability and respect for each other's competence.
5. Cultural awareness both between different companies and countries.

One factor of high importance for these EEs is that all participants in them have a joint responsibility for continuously improving the product and the production process during the PI process. This can be facilitated by collaboration between shared competencies and specific competence according to Miltenburg's (1995) levers within an EE, as exemplified in Appendix A. This is further supported by Tennant and Roberts (2003), who argue that knowledge transfer is a fundamental aspect of the PI process that facilitates the development of a "learning culture" to embrace new practices in real time. An important tool for efficient PI is the different prototype series where the product design and the production process are iteratively evaluated and improved. The PI process needs participants that treat one another with respect and trust. Furthermore, these EEs need to find the right competencies, keep track of the planning schedule, and communicate and inform in a structured way.

Based on this research's observations within the electronic industry, production engineers that perform PI within EEs need to be skilled in business thinking, and at the same time have relevant product development competence. On the other hand, the product designer needs to be skilled in the production issues as well in order to support the adjustment between the product and the production system. One factor of high importance for an efficient PI is early participation from the production department/production system design in the product's conceptual phase in order to increase its producability and decrease its refinement cost (Paper III). Here, it is important to have iterative PI and PR processes that facilitate collaborative work which can be facilitated by collaborative IT tools (Paper VII; Chapter 3.2.6; In: Supervised thesis work by Smith, 2004). Another parameter of importance, also observed in this research within the electronic industry, is the possibility of goal conflicts that can occur within a cross-functional project group (Paper V).

8.2 Critical review

This research was initiated just before the start of a turbulent period in the Swedish electronic industry, a period which has continued throughout much of the research. During this time, the Swedish electronic company Ericsson restructured its organization in several ways; two of the most significant were the outsourcing of its mobile phone production and its joint venture with SONY, which became responsible for the mobile phone design. The researcher has been an industrial Ph.D. student during these changes, both within Ericsson and Flextronics, and thus has had a unique opportunity to observe these changes, first hand. However, it has been difficult to cover all aspects related to the electronic industry; therefore, the results should be seen as illustrative examples from an industry segment that has yet to be thoroughly researched.

Due to the turbulence within the observed electronic industry, the industrial supervisors for this research have changed several times. Therefore, the results described in the papers that are related to the electronic industry (Papers I – V) cover different aspects, all of which were important and relevant for the industry to manage during the time of the observations. This research within the electronic industry are therefore closely related to an action approach, but given the turbulent situation described above, there initially was difficult to defining a task to address. Therefore, there is a lack of focus in the questions to answer, and the results cover several different areas in different depth, (see Section 2.2).

This research's observations in the electronic industry were combined with knowledge and experience with its observations from other industries in a framework for collaborative product introduction in an extended enterprise (see Section 7.2). This framework was, however, not validated in the electronic industry.

8.3 Contributions of this research

This research has contributed knowledge in several areas. First of all, prior research within the electronic industry regarding how to perform collaborative product introduction within extended enterprises is limited. This gap has been observed and explored, and subsequently related to the traditional mechanical engineering industry. The area of how to establish extended enterprises and how to collaborate within them during product introduction is important for the competitiveness of industry, and it is hoped that this research will contribute to an extended exchange of experience and knowledge between different industry segments. During the research, similarities and differences between the electronic and the mechanical engineering industries have been observed. The electronic industry has large similarities with the mechanical engineering industry, but in the electronic industry the product life cycle and the production cycle times are shorter, and the electronic industry often outsources the distribution of the products it produces to the end user.

This research has combined two areas – product introduction as a vital part of product realization and extended enterprises – which have been brought together during the last decade through the trend of outsourcing. During these circumstances, it is important to have early collaboration between all partners within the extended enterprise during the vital product introduction process. In order to facilitate this early collaboration, a practical framework has been developed, as presented in Section 7.2. This framework is primarily based on this research's observations in the electronic industry, with observations in the mechanical engineering and the aerospace industries used in order to compare and identify similarities and differences between the industry segments. This has contributed to an experience and knowledge transfer between the different industries.

8.4 Future research

This research has explored the area of collaborative product introduction within extended enterprises by observing the electronic industry, and subsequently comparing these observations with those from the mechanical engineering and aerospace industries. The experiences within these industry segments regarding how to collaborate during product and production system design and how to establish a fruitful collaborative extended enterprise would be interesting to transfer into other industry segments. The biotech industry, with its instruments for medical or chemical applications, would be interesting to observe. By transferring knowledge from other industry segments, the biotech industry could utilize experiences as well as identify possible collaborative partners. The biotech industry can be seen as a combination of several industry segments, such as the electronic, the mechanical engineering and the process industry, indicating the potential for the establishment of extended enterprises that could manage the product design, product introduction and production and thus an interesting area for future research.

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Appendix A
Other studies performed within the electronic industry

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Manufacturing network

These interviews were performed within one division of an OEM, and focused on a group called the Global Industrialization Group (GIG) that worked with following up PI projects and sponsoring new technology projects with a focus on the production process. The function of the GIG was to coordinate production volumes at sites all over the world. The GIG consisted of five people with extensive experience from different factories within the company, and specifically in the areas of test development and production technology. Most of those interviewed had been managers and/or project leaders, providing each with a large personal network, both internal and external. One of the key leaders in the GIG was interviewed, using a semi-structured format, regarding the best way to work in the manufacturing network (Johansen, 2000). The final report was also reviewed and approved by this key person. Furthermore, the author had the opportunity to follow work within the GIG through her participation in internal meetings, placement on a mailing list, and presence during coffee breaks, all of which were facilitated by her placement within the GIG.

The production sites co-ordinated by the GIG had different responsibilities; this can be compared with Ferdow's (1997) strategic roles in Section 2.2.2. The production sites within the company all strove to become lead factories that utilized CMs for increasing their volume flexibility. Generally, the term lead factory describes a factory within a manufacturing network that has an overall responsibility for co-ordinating production. The lead factory observed for this research within the OEM had six main responsibility areas:

- *Product introduction,* including ramp-up of production, secured training, refinement cost, on-time delivery, verified product and process. Also includes transferring the product and the production process to the production unit at the OEM and / or the EMS.
- *Material supply* responsibility for securing volume and prototype material at right quality and cost to the production process, including supplier audits and approval of second source material.
- *Production process* ownership with the responsibility for the technological roadmap and the preferred equipment list. Secure the use of this information for specifying the assembly process, establish contacts with equipment suppliers, develop the performance measurements, ensure that the production units re-use proven technology and secure the information flow.
- *Global management* of production capacity securing efficient transfer of production to both EMS and OEM factories, if needed after the finalized PI.
- *Global support,* responsible for handling all variants, models or releases for the product and the process during their life cycles, and for coordinating quality issues. Also responsible for co-ordinating activities related to second sources, releases of test programs, exemptions and management of yield improvements.

- *Quality* responsibility for satisfying customer demands, continuous improvements, so that new material is suitable in used processes, and finally, the reporting of yield and quality data.

The lead supply unit observed for this research was subsequently transferred into a PI center within an EMS with the responsibility for:

- The production system design part of the PI process
- Co-ordination of the material supply chain
- Transferring the production process to high volume factories
- Co-ordination of changes related to the product or the production process

The role of a PI center is similar to that of a lead factory, but the PI center does not necessarily have high volume production. Instead, a PI center is more like a design department for production systems within an EMS (a producer) that is participating with several product owners (OEMs) and suppliers within an EE. Ferdow's (1989) manufacturing network, according to Shi and Gregory (1998), focused on the strategic role of each factory instead of the function each factory played in the network. The manufacturing network studied in this case focused instead on each factory's function as a lead factory co-operating with several server factories responsible for high-volume manufacturing and with other lead factories within the company. The PI center that was introduced has a similar role as the studied lead factory within the OEM, and it is also acting in a manufacturing network with high volume factories (server factories) within the EMS.

World class manufacturing

The interviews were performed within a consumer electronics manufacturer that was transforming from an OEM to an EMS. Several managers were interviewed regarding what world class manufacturing means for them and how to manage the organization to reach global competitiveness within the consumer electronic industry. The interviews were very informal, i.e. resembling a dialogue between two colleagues. The aim of the case study was to obtain information and material to use when determining the focus of this research.

In order to support world class manufacturing, there is a need for finding a way to combine three important processes that are necessary for developing a production system with high performance that delivers products with low refinement cost. These three processes are in this case study identified as new technology, product development, product introduction and volume production. Applying Miltenburg's (1995) manufacturing levers for a production system – human resources, organization structure and controls; production planning and control and sourcing; and finally, process technology – gives a system of processes and levers that need to collaborate.

A way to combine the three important processes and the theoretical levers with the focus of a low refinement cost can be seen as a pyramid (see Figure A.1). The refinement cost is the additional cost that is added to a product in a production process, i.e. costs for assembly, transportation, test, etc.

The basic processes to develop a product – the pyramid bottom in figure A.1 – need support from the levers at the next level to reach the target for refinement cost and ultimately the possibility of profit. For a company with global manufacturing for consumer electronic products, the specific criteria/key factors for their line of business could be defined according to Schonberger's (1996) world class manufacturing principles (see Section 2.1.3) in combination with Miltenburg's levers for production systems. For example, the question of how human resources can support the three bottom processes (see Figure A.1) in the most beneficial way with the aim of minimizing the refinement cost must be addressed.

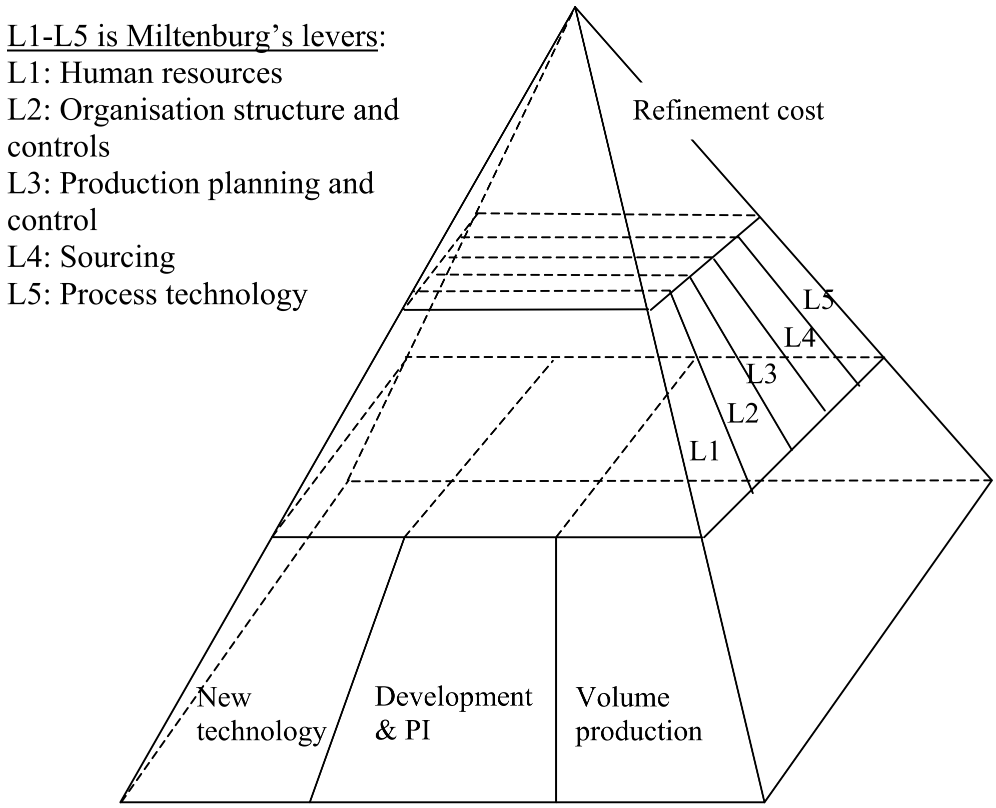

Figure A.1: The pyramid supporting product development for low refinement cost (Johansen, 2002)

Furthermore, a world class manufacturer needs a product that is designed for producability, so that the product has a design that supports low refinement cost and that the production system delivers on time and with high quality. It is important to take care of the function and industrial design of the product by giving constructive feedback to those responsible for design. One way of giving feedback could be utilization of DFx tools as early as possible in the PR process. A world class manufacturer needs to conduct risk calculations and sensitivity analysis on each new product introduction in order to decrease the risk of having resources connected to products that do not reach the market in planned volumes.

Collaboration between different competencies
A workshop illustrating collaboration was facilitated at a management meeting within an EMS company. The represented competence areas from the organization are illustrated in figure A.3. The workshop was performed during two days with all the involved managers within one region of the multinational company. The aim of the workshop was to interactively demonstrate how people within an organization increasingly could collaborate over distance in order to utilize the competence more efficiently. The managers represented six different competence areas (three different design departments, test, production engineering and project management). Furthermore, the managers also represented five different, geographically separated units.

Figure A.3 illustrates how the competence groups were placed in six different conference rooms. The main conference room was used as a meeting area, where one person acted as the production unit (Person P) and one person as a facilitator for the aim of the new organization (Person F). Furthermore, one participant assumed his normal role as the coordinator for incoming projects (Person C), while another acted as three different customers (Person B). Person P and the researcher had developed the cases to be studied, while Person B and F knew their roles and were prepared. All others involved were unprepared.

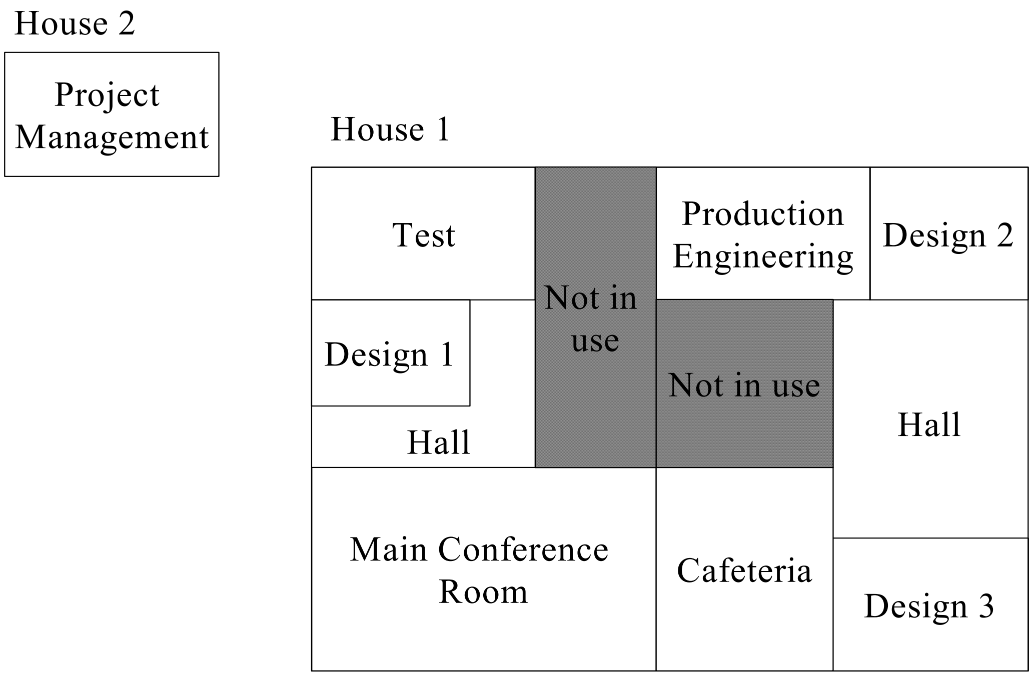

Figure A.3: The layout for the workshop

The researcher presented the case to the workshop participants, instructing all managers to work in their ordinary management groups in different conference rooms and answer the following three questions:

1. Identify the opportunities with CDM for the customer.
2. Summarize the difficulties connected to CDM for the company.
3. Design a quotation that facilitates a customer demand including a draft over the project organization.

During the same time, Person B contacted three “randomly” chosen persons and asked for quotations for three different products. The contacted persons represented the three different design teams, but they were given the “wrong” product in order to illustrate the need for collaboration between the different groups. Design 3 noticed immediately that the quotation they got fit Design 1 best, so they turned to them and asked them to take over. Design 2 contacted Person C and gave the quotation to him for coordination. Design 1 kept their first quotation and the one they got from Design 3, but after some discussion they turned it over to Person C for coordination. After a short time Person C acted as a living mailbox between the different actors. All design groups realized that they needed test competence and contacted them. The project management group realized that it was as usual; they were not contacted by the operating groups so they went out and ask if there was a need for product introduction coordination. The production-engineering group was not contacted in the early phases and decided to market themselves in two of the design groups. This proved to be a success, and after the marketing tour they were involved in the projects. The design group they did not market them selves in, on the other hand, sent their project manager for information sharing.

One reflection from this illustrative workshop was that it is necessary to market or inform, even within one’s own organization, all functions and competencies that are available. The managers got an illustration of how important it is to collaborate between different competencies and geographical parts of the organization. Furthermore, the participants realized that it was their engagement that solved the case, an important lesson to transfer into reality. Finally, they realized the benefits of sitting in their ordinary management groups, since the case illustratively showed the need for and facilitated collaboration over borders.