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MANAGING COLLABORATIVE PRODUCT DEVELOPMENT

A MODEL FOR IDENTIFYING KEY FACTORS IN PRODUCT DEVELOPMENT PROJECTS

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Akademisk avhandling

som för avläggande av Teknologie doktorsexamen i Innovation och design vid Institutionen för innovation, design och produktutveckling kommer att offentligen försvaras tisdagen, 19:e juni, 2007, 14.00 i Filen, Verktyget, Smedjegatan 37.

Fakultetsopponent: professor Lars Bengtsson, Högskolan i Gävle, Sverige.

MÄLARDALEN UNIVERSITY

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Abstract

The increasing complexity of products and systems today has forced new processes, methods, and tools for managing the development of products. It has also forced the development of complex organisations and diverse relationships among functions and peoples within product development organisations. This implies a need for integrated processes. There is a need to study collaborative product development (CPD) from a holistic perspective, where internal as well as external collaboration are studied as integrated parts of CPD settings.

Thus, the main purpose of the research project is to facilitate the efficient execution of collaborative product development projects in the manufacturing industry. Further, the objective is to provide a supporting model for analysing and setting up projects in CPD settings. This will enable successful product development in terms of lowering costs, increasing the perceived quality of the product, and improving the timing to market. The focus is on the CPD projects, linking internal and external collaboration.

A systems approach is applied to the research project to obtain the holistic view needed for addressing the CPD setting. Within the research project, case study research is used as the primary method when gathering empirics. The results from four case studies are tested and analysed in a concluding survey.

The results show that shared visions and goals, the decision-making process, tools and methods, requirement management, and involvement are the most important factors for efficient CPD projects. If the collaborative complexity is high, the first four factors are especially important. The results are presented in a model to be used as a support when setting-up and managing CPD projects. The model is applied together with a process for managing CPD projects.

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Abstract

The increasing complexity of products and systems today has forced new processes, methods, and tools for managing the development of products. It has also forced the development of complex organisations and diverse relationships among functions and peoples within product development organisations. Both the increased complexity of products and the increased competition on today's global market implies a need for integrated processes. There is a need to study collaborative product development (CPD) from a holistic perspective, where internal as well as external collaboration are studied as integrated parts of CPD projects.

Thus, the main purpose of the research project is to facilitate the efficient execution of collaborative product development projects in the manufacturing industry. Further, the objective is to provide a supporting model for analysing and setting up projects in CPD settings. This will enable successful product development in terms of lowering costs, increasing the perceived quality of the product, and improving the timing to market.

A systems approach is applied to the research project to obtain the holistic view needed for addressing the CPD setting. Within the research project, case study research is used as the primary method when gathering empirics. The results from four case studies are tested and analysed in a concluding survey.

The results show that shared visions and goals, the decision-making process, tools and methods, requirement management, and involvement are the most important factors for efficient CPD projects. If the collaborative complexity is high, the first four factors are especially important. The results are presented in a model to be used as a support when setting-up and managing CPD projects. The model is applied together with a process for managing CPD projects. The input for the final model consists of the output from: an actors-and-interface model, a total-collaborative-complexity model, a key-factors' model, and a checklist of key factors important for CPD.

Keywords: *Collaborative product development, Systems approach, Project management, Case study, Survey, Integration, Distributed product development, Decision-making, Systems model.*

Sammanfattning

Dagens komplexa produkter och system har resulterat i ett ökat behov av nya metoder och arbetssätt för att hantera produktutvecklingsprocessen. Utveckling av komplexa produkter och system har också inneburit att organisationerna dessa utvecklas i blivit alltmer komplexa. Detta medför ökat samarbete mellan olika funktioner inom och utom organisationen. Leverantörer, partners och kunder skall koordineras och aktiviteter integreras i produktutvecklingsprocessen. Det finns ett behov av att studera produktutveckling i samverkan från ett helhetsperspektiv, där hänsyns tas till både interna och externa aktörer i produktutvecklingsprocessen samt de faktorer som påverkar processen.

Syftet har varit att effektivisera produktutvecklingsprojekt som sker i samverkan mellan olika aktörer. Målet har varit att tillhandahålla en stödjande modell för analys och uppstart av produktutvecklingsprojekt. Modellen skall möjliggöra framgångsrik produktutveckling i termer av sänkta kostnader, förbättrad kvalité samt kortare tid till marknad. Avhandlingen fokuserar därmed på olika aktörer i produktutvecklingsprojekt och gränssnitten däremellan, på de nyckelfaktorer som påverkar produktutvecklingsprocessen i en samverkanskontext samt hur en modell för detta kan utformas.

Forskningen antar ett systemsynsätt och inom ramen för detta perspektiv har fyra fallstudier och en enkätstudie genomförts. Enkätstudien bygger på resultatet från de fyra fallstudierna.

Resultaten visar att det finns ett antal nyckelfaktorer som är extra viktiga att beakta vid produktutvecklingsprojekt som sker i en samverkanskontext. Dessa nyckelfaktorer är: gemensam syn på strategi och mål, beslutsprocessen, verktyg och metoder, kravhantering, involvering av konsulter, samt involvering av produktion. Om komplexiteten i integrationsprocessen är hög är de fyra första faktorerna avgörande för utfallet i projektet.

Resultaten presenteras i en modell med tillhörande process som syftar till att stödja produktutvecklingsprojekt i en samverkanskontext. Modellen består i huvudsak av fyra delar: (1) verktyg för att identifiera aktörer och gränssnitt i projektet, (2) verktyg för att avgöra komplexiteten i projektet, (3) en modell med nyckelfaktorer, samt (4) checklista över nyckelfaktorer.

Acknowledgement

Several people have made this research journey possible for me. This is an attempt to express my gratitude to those. First, I would like to express my gratitude to my supervisors, Professors Mats Jackson and Björn Fagerström. In particular, I thank Mats for always contributing with new ideas and energy, for fruitful discussions and for believing in me for the past five years, even when I myself did not. I thank Björn for his tirelessness, his sense of humour, and his distinctiveness, which helped me see clearer. You both are an inspiration to me, keeping me going.

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Västerås, May 2007

Sofi Elfving

Publications

This thesis is based on the following papers, appended in the back of this thesis.

Paper A Elfving, S. (2004). Understanding Complexity of Product Development in Small Companies: a Case Study. 4th International Seminar and Workshop on Engineering Design in Integrated Product Development. EDIProD2004. October 7-9, 2004. Zielona Góra: Poland.

Paper B Elfving, S. and Jackson, M., (2005). A Model for Evaluating and Improving Collaborative Product Development. International Conference on Engineering Design. ICED'05. August 15-18, 2005. Melbourne: Australia.

Paper C Elfving, S. and Funk, P. (2006). Enabling Knowledge Transfer in Product Development and Production: Methods and Techniques From Artificial Intelligence. 1st Nordic Conference on Product Lifecycle Management. NordPLM'06. January 25-26, 2006. Gothenburg: Sweden.

Paper D Elfving, S. and Fagerström, B. (2006). Efficient Collaborative Product Development: Critical Aspects and Parameters Influencing the Outcome of Collaboration. International Conference on Project Management. September 27-29, 2006. Sydney: Australia.

Paper E Elfving, S. (2007). Important Factors for Project Performance in Collaborative Product Development: A Survey Investigating Contextual Settings. Submitted to The International Journal of Product Development.

The work of writing the papers has been distributed as follows between the authors:

Paper A The case study was conducted and the paper written by Sofi Elfving.

Paper B The case study was planned and conducted by Sofi Elfving and Mats Jackson, and the paper was written together.

Paper C The work of writing the paper was distributed between Sofi Elfving 75% and Peter Funk 25%.

Paper D The work of writing the paper was distributed evenly between Sofi Elfving and Björn Fagerström.

Paper E The main part of the survey was planned and conducted by Sofi Elfving, as was the paper.

Additional publications by the author, but not included in the thesis.

Bengtsson, M., Elfving, S. and Jackson, M. (2007). The Factory-in-a-Box Concept and its Maintenance Application. Submitted to The Journal of Quality in Maintenance Engineering.

Eriksson, J., Fagerström, B. and Elfving, S. (2007). Efficient Decision Making in Distributed Product Development. Accepted for publication. International Conference on Engineering Design. ICED'07. Paris: France.

Elfving, S. and Hellström, A. (2006). Need for Change in Engineering Design: How to Increase the Number of Women in Business. 5th International Seminar and Workshop on Engineering Design in Integrated Product Development. September 21-23, 2006. Zielona Góra: Poland.

Elfving, S. (2004). Managing Collaborative Product Development in Small Companies. Licentiate thesis No. 32. Department of Innovation, Design and Product Development. Mälardalen University. Sweden.

Elfving, S. and Hägg, A. (2004). To Join Industrial Alliances – Strategic Decision or Not? Proceedings of the 5th International Symposium on Tools and Methods of Competitive Engineering. TMCE'04. April 13-17, 2004. Lausanne: Switzerland. Tools and Methods of Competitive Engineering. Volume II. Eds. Horváth, I. and Xirouchakis, P. Millpress. The Netherlands.

Andersson, C. and <u>Elfving, S.</u> (2004). Design of Information in a Virtual Factory Influence Collaborative Product Development. Proceedings of the 5th International Symposium on Tools and Methods of Competitive Engineering. TMCE'04. April 13-17, 2004. Lausanne: Switzerland. Tools and Methods of Competitive Engineering. Volume II. Eds. Horváth, I. and Xirouchakis, P. Millpress. The Netherlands.

Andersson, C. and <u>Elfving, S.</u> (2003). Shifting Communication Paradigm Changes Course of Product Development in Clusters. Proceedings of the International Visual Literacy Conference. IVLA'03. October 1-5, 2003. Newport: USA. Changing Tides. Eds. Griffin, R. E., Lee, J. & Chandler, S.

<u>Elfving, S.</u> and Jackson, M. (2003). Improving Producability of New Products through Concurrent Engineering. Concurrent Engineering – Advanced Design, Production and Management Systems. CE 2003. July 26-30, 2003. Madeira Island: Portugal. Eds. Cha, J., Jardim-Goncalves, R. and Steiger-Garcao, A. Balkema Publishers. The Netherlands.

Table of Contents

PART 1

The Research Setting

It Begins

The micro company had a splendid idea, solid patents and a tremendous willingness to put that idea into the market. However, they lacked the appropriate resources to realize it. Their product development process was complex and fuzzy. Rather than a process, it was more of an ad-hoc happening, as in many small companies. There existed no means of formalising their profound knowledge and experience within the business into resources. They lacked the ability to set up a process for it. The company needed to grow both economically and organisationally to accomplish their goal. There is a Catch-22. The development of the product relies on the ability to manage barriers and enablers that come through growth. The growth of the company relies on the success of the product. We have seen it before.

Nevertheless, the company continues to put effort in their network of contacts, building new relationships and withdrawing from “the bank of favours”. Managing relationships becomes vital for the development of the organisation and, not the least, the progress of the development of their upcoming innovation. There exists no suitable product development model or appropriate support for the company. Without economic means or supportive tools, the company continues to strive for its goal, determined to succeed.

The company’s struggle planted a tiny seed of interest and curiosity in me, a willingness to dig deeper, to understand how collaboration in product development could be managed, and how their situation could be improved. That is where it begins.

Chapter 1
Introduction

This chapter introduces the reader to this doctoral thesis, to what the thesis is about and why. First, an introduction of the research and problem area is presented, a background. The introduction ends in needs and challenges, which aim to justify the importance of the research. Further, the background and problem statement are narrowed down to a purpose and objective for this thesis. The purpose and objective are then conceptualised in four research questions. Finally, the delimitation sets the framework for the research project.

Collaborative Product Development

The market demand for companies to offer innovations and maintain cost efficiency has resulted in an increased complexity of internal and external relationships during product development. In an endeavour to save time and reduce costs, collaborative product development has expanded during the last decades (Leek et al. 2003).

The theoretical concept of collaborative product development (CPD), as we know it, first started to appear in 1994, in a journal paper "Multimedia Comes of Age" (Cassidy 1994)[1]. However, collaboration in the context of product development has been addressed much earlier than that, e.g., von Hippel (1988) who champions "know-how trading" between firms. In 1995, the CPD concept appeared in many more publications by authors such as Bruce, Leverick and Littler (Bruce et al. 1995). At this time, the focus was upon buyer-supplier relationships, the complexity of collaborative product development, and success factors. Later on, collaborative product development appeared frequently in journal articles and conference papers,

[1] When doing research on the concept "collaborative product development" in the ELIN database (Electronic Library Information Database), which includes 23 different publication providers, the earliest hit was in 1994, in an article by Peter Cassidy, "Multimedia Comes of Age" in the CIO journal. The hit peak was in 2001, with 24 hits that dealt with collaborative product development. Of these 24 hits, 15 of the articles were published in scientific journals.

with a peak in 2001. This, however, does not preclude similar or equivalent concepts from having existed earlier.

In 1995, Bruce et al. (1995) described the view of CPD[2] as an effective means of reducing development time, and lowering organisational risk. Further, the authors stated that collaborative product development is an evolutionary process, as the form and scope for its initiation, and continuation may change over time. Collaborative product development is further defined by the Product Development Management Association (1996) as:

> …when two or more companies decide to collaborate in product development as mutual partners, and that it differs from the concept of outsourcing by the level of partnership, as collaborative companies are linked in the process of delivering the final solution to the intended customer or the user.

This definition highlights CPD as solely external. Del Rosario et al. (2003) describe collaborative product development as the application of team-collaboration practices to an organisation's product development efforts. Further, collaborative product development encompasses concurrency, attention to the life cycle, suppliers, and information technology, in a customer-focused environment.

In this thesis, the concept of collaborative product development is not used only for the external collaboration between two or more firms, but also includes the in-house collaborative elements, e.g., the integration of functions. A product development project involving internal and external collaboration constitutes the collaborative product development setting.

Challenges

The twentieth century implied great technological development in the West. Two world wars contributed, for good and for bad, to a rapid development of complex technical systems. For instance, the production efforts during World War II were a catalyst for efficiency, production, and innovation in U.S. firms (Chesbrough 2003).

Products of today include electronics and computers; embedded systems and mechatronics are concepts borne in the twentieth century. The increased complexity of products implies complex product development processes thus complex organisational forms and more complex projects for managing[3] the

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[2] This research considers the information and communication technology sector.

[3] Management is the act of directing and controlling a large group of people for the purpose of coordinating and harmonizing the group towards accomplishing a goal beyond the scope of

process of developing the products (Williams 1999). This has also forced the development of processes, methods and tools.

High complexity in product development projects puts pressure on the product development organisation. No single person possesses the acquirable knowledge needed to manage the whole product life cycle (Andreasen and Hein 1987). Successful product development is dependent upon marketing, design, and manufacturing knowledge (Andreasen and Hein 1987; Nordström 1995). The need for various competencies implies the complex management of resources. Sequential ways of performing product development is replaced by parallel development. In 1986, Takeuchi and Nonaka introduced the concept of the "rugby" approach – the "ball" is passed back and forward, as the product development team tries to go the distance as a unit (Takeuchi and Nonaka 1986). Thus, cross-functionality in product development is a fact.

Managing the coordination of people and the interfaces between functions in an organisation has been a critical issue for the past decades (Wynstra et al. 2001). In the book "Open Innovation" from 2003, Henry William Chesbrough champions a new paradigm: The Open Innovation Paradigm. He argues that innovative ideas may come both from inside a company and from outside a company. This approach stresses the importance of external ideas and external paths to the market. This offers new ways of creating value (Chesbrough 2003). Thus, many competences lie outside the scope of internal procurement of a company. We are becoming collaborative, beyond company boarders. We live in a collaborative world. We are forced to manage collaborative settings every day. We have to collaborate internally within our organisation, and externally together with other actors on the market, to accomplish innovation. This task is not at all easy.

The twentieth century has also implied globalisation. Globalisation has brought increased competition from various parts of the world. Increased competition has put high pressure on companies in Western Europe to be competitive and increase their competitiveness. During the last decades, manufacturing companies in Europe have truly become conscious of this. Companies choose to move strategic important activities such as production

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individual effort. Management encompasses the deployment and manipulation of human resources, financial resources, technological resources, and natural resources. Management operates through various functions, often classified as planning, organizing, leading/motivating and controlling. (http://en.wikipedia.org/wiki/management, 2007-04-03). In this thesis, managing as a concept is referred to as planning, organising, leading/motivating and controlling, thus how an organisation or a part of an organisation is managed, or a set of activities is carried out, by whom, and when.

abroad to low-wage countries, losing important competence involving how products should be produced and manufactured. This phenomenon is surprisingly evident within the Swedish manufacturing industry, with a significant loss of employment opportunities, thus undermining small municipalities.

An important but an underestimated aspect of this change is the relationship between production and product development. Success in product development and production depends to a great extent on the close interaction and co-operation between the two activities. Integrated product development (IPD), and concurrent engineering (CE), are some, among several, approaches that focus on the interaction between the two. A conclusion could be drawn from this situation: product development will follow the footsteps of production if we do not find other ways to compete than with low wages. Product development is one of the most important activities in a company, as it introduces new products and increases overall competitiveness. Diversifying one's competitive priorities has become vital for survival.

Performance has been the main measurement of successful product development; cost and time have been secondary. Today the focus has shifted from performance towards time and cost as more important. Time to market has become increasingly vital for the survival of the firm, and the timing of the product launch and reducing product cycle time are key tasks today (Utterback 1994; Gupta and Souder 1998; Williams 1999). Shorter lead-times reduce schedules and increase the need for concurrent activities and cross-functional collaboration. Present trends have revealed collaboration[4] as the next phase for improving product development.

Both the increased complexity of products and the increased competition on today's global market implies a need for integrated processes, and collaboration in product development is said to be vital for a company's success (Littler et al. 1995; Sherman et al. 2005). Booz, Allen & Hamilton Inc.[5] has studied cross-border relationships for more than a decade. The company champions collaboration as the "new age", stating (Harbison and Pekar 1995, p. 3):

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[4] The concepts collaboration and cooperation are in this thesis used synonymously.

[5] Booz Allen Hamilton Inc. is a consulting firm that helps government and commercial clients with services in strategy, operations, organization and change, and information technology. They have published several books on strategy, growth, and technology (http://www.boozallen.com/, 2007-05-05).

> …that only through allying can companies obtain the capabilities and resources necessary to win in the changing global marketplace.

Collaborating in complex processes, (e.g., product development) is not easy. A collaborative product development[6] environment does not always ensure success. To the contrary, collaboration can make product development more costly (Littler et al. 1995). David H. Freedman, editor for Inc. Magazine, argues (Freedman 2006, pp. 61-62):

> The effectiveness of groups, teamwork, collaboration, and consensus is largely a myth. In many cases, individuals do much better on their own. Our bias toward groups is counterproductive. And the technology of ubiquitous connectedness is making the problem worse.

Nevertheless, cross-functional teams are common in larger companies (Prasad 1996), although many find it hard to make sure that the teams successfully contribute to the product development outcome (McDonough 2000). Consequently, collaboration in product development has many faces, and the challenges confronting those who decide to collaborate in product development are numerous. The number of actors involved, the types of activities the actors are collaborating on, how the collaboration occurs, with which means, and of which frequency, all influence collaboration.

Needs in Collaborative Product Development

As previously discussed, the focus of this research, thus the research area, is collaborative product development. The success of product development in general has been studied extensively (e.g., Link 1987; Johne and Snelson 1988; Littler et al. 1995; Cooper and Kleinschmidt 1996; Cooper 2001). Authors from various areas, however, address collaborative product development in different ways.

Research on information systems applied in collaborative product development settings[7] and collaborative environments is rather extensive and addressed by several researchers. Examples include Huang, Huang and Mak (2000); Kumar and Midha (2001); Törlind (1999), Ramesh and Tiwana (1999), and Öhrwall-Rönnbäck (2002). Consequently, research on tools and methods for sharing product specific content among actors and team members in

[6] Collaborative product development involves two or more actors with a mutual goal of developing a product for a perceived customer.

[7] Collaborative product development setting is here referred to as a set of actors interacting in forms of for example a team or a group in a project, with the mutual goal of developing together a product for an intended customer.

product design, e.g. in virtual teams, is emerging. Systems that manage product content or data have been referred to as Product Data Management Systems (PDM). However, areas such as Computer Supported Collaborative Work (CSCW) and Workflow Management (WFM) have increasingly contributed to research and development within the area of collaborative product development. Decision Support Systems (DSS) are used in virtual collaborations between organisations (e.g. virtual enterprises (VE)) or within an organisation among organisational functions (Huang et al. 2000) (e.g., CE or IPD) to support the every day work and facilitate the decision-making.

Research on agent-based systems within the area of Artificial Intelligence (AI) has also emerged during the last decades. The methods and tools developed within the area may constitute enablers in both product and process development. Content Management (see Gsell 2006) is an additional emerging area and unquestionably an important part of a collaborative setting. Apparently, research on computer supported collaborative work is well covered and is now the focus of many established research groups.

Nevertheless, in order to develop a well functioning supporting computer system for collaborative environments in product development, there is a need to understand the fundamental barriers and enablers for successful collaborative product development[8]. Significant efforts have been made to develop computer support facilitating collaboration; however, the systems have created difficulties and barriers in collaborative product development. Consequently, the computer system may be a barrier as well as an enabler in collaborative work (Huang et al. 2000; Sosa et al. 2002).

Surprisingly, few studies have paid attention to fundamental collaborative aspects in product development by applying a more holistic view. Hillebrand and Biemans (2004) are one exception. They focus on the relationship between internal and external collaboration in product development, and also argue for the need for future research within the area. Further, Fraser et al. (2003) address product development collaborations using a maturity approach, and argue for integration of both internal and external collaboration. However, little attention has been paid to similar problems, for instance situations where both phenomena are present, and how those are linked together and are influenced by different aspects or contextual variables.

[8] Successful collaborative product development is here referred to as the efficient execution of the product development process in a collaborative setting resulting in an output of a desired product.

Research within those different domains is perceived as quite separated, and addressed by different scientific areas.

Extensive focus has been placed on internal interfaces in product development within an organisation by engineering/product design researchers (see Andreasen and Hein 1987; Ulrich and Eppinger 2003). External collaboration with partners and/or suppliers, in forms of networks, has for a long time been the object for research within business administration and organisational theory (e.g., Axelsson and Easton 1992; Harbison and Pekar 1995; Perks and Easton 2000; Elmuti and Kathawala 2001; Håkansson and Ford 2002). Thus, inter-organisational issues are often separated from intra-organisational issues, although they seem interdependent (see Dubois and Wynstra 2005).

Supply chain issues have been extensively addressed within the purchasing area (Fraser et al. 2003). However, recently, the focus of supplier collaboration has also been addressed from the product development perspective (e.g., Peter 1996; Culley et al. 1999; Handfield et al. 1999; Wynstra et al. 2001; Fagerström and Jackson 2002). Still, there are challenges related to fundamental aspects of collaboration in product development contexts. For instance, Littler et al. (1995) argue that:

> …collaborative product development needs to be treated more critically than at present and attention has to be given to managerial and other factors that influence the outcome of the collaborative process.

Further, Fagerström (2004) argues that a lot of research is conducted on information exchange within collaborative product development (as addressed previously), but few studies address the exchange of engineering design knowledge. Moreover, McDonough (2000) concludes that additional research is needed to clarify and understand the effect of contextual variables on product development performance. The importance of relating contextual variables to product development and especially in CPD has also been addressed by Bruce et al. (1995). The main challenge within the area is that increased complexity in technology implies increased complexity in organisations and the management of resources. The concept of collaborative product development and the complexity of it, emerge as increasingly important areas for companies to act upon and manage. Thus, how may we manage the complexity in CPD settings and how may we reach successful collaborative product development? Consequently, there are needs to fulfil to be able to approach this challenge. Some of those needs are summarised below:

- To have a holistic view of the CPD area by focusing on both internal and external factors and variables, linking them together
- To address fundamental aspects in CPD (e.g., managerial factors)
- To consider the exchange of engineering design knowledge in CPD settings; knowledge management
- To explore the effect of contextual variables on performance in CPD
- To explore fundamental aspects of CPD influencing decision support systems.

Interviews with project managers in product development projects reveal that collaboration is considered a complex task to manage in projects and fundamental aspects such as integration, communication and trust, seldom are highlighted as barriers in the initial phase of the CPD projects. Consequently, it is not counted on or acted upon, sometimes resulting in project delays or even failures (see Andersson and Elfving 2003, 2004).

Collaborative product development brings many opportunities; nonetheless, collaboration takes time and is costly. Thus, efficient execution of CPD projects demands management of barriers. This in turn demands a more holistic view and supporting tools, in the form of methods, models, and/or processes. Early awareness of barriers and problems and preventive actions may increase the probability of success. Thus, the need for linking internal and external collaboration when managing product development projects in a swift and easy way, and to set up and evaluate both risks (barriers) and opportunities (enablers) in the initial phase of a CPD project is yet to be fulfilled.

Purpose and Objective

The research presented in the thesis focuses on fundamental aspects affecting collaborative product development settings. The focus is on interfaces between actors in the CPD setting and the factors influencing the relationships between those actors in different types of collaborative product development projects. This focus has been translated into more manageable parts: a research purpose, an objective, and research questions. The purpose is more visionary, aiming to grasp the challenges companies developing products are faced with. The objective includes several steps, and is more precise, addressing the expected effects of this research. The objective has been separated into four research questions, addressing different parts of the objective, thus enabling expected effects. The process of addressing the research questions, the objective and the purpose may be illustrated as a funnel with filters. It filters the input (the research results) into a more precise output (contribution) to the research area, see Figure 1. The filter constitutes three parts which the results have to pass through. These parts are: (1) the overall research purpose and the expected contribution of new knowledge to the research community and to industry, (2) the objective areas and its' corresponding research questions, and (3) the quality assessment of the research.

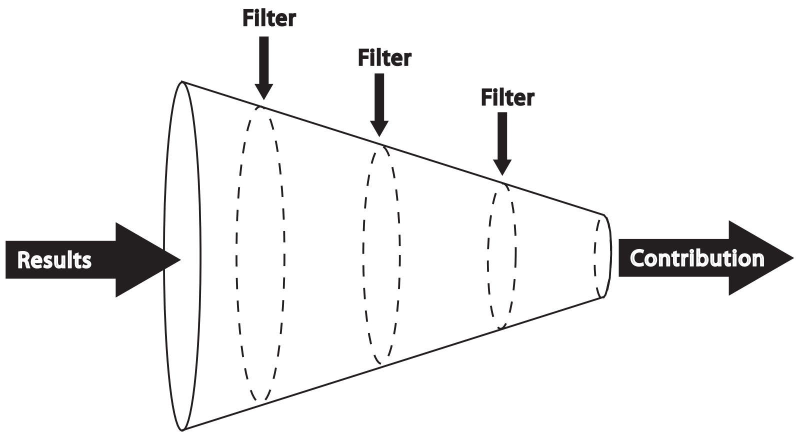

Figure 1 • The research funnel as visualised during the research process.

The purpose originates from the prevalent situation of increased competition from the global market, increased complexity in technology and resources, and the need for the integration of activities and management of interfaces in product development projects. Collaboration brings complexity to the process of developing products; interfaces and relationships have to be managed, knowledge exchanged, and risks have to be turned into opportunities. The lack of integrated approaches towards CPD settings, and how to manage such settings, provides an opportunity to examine the area deeper.

The purpose of this thesis is thus to examine how different key factors are related to a varying CPD setting, including both internal and external collaboration, providing an integrated approach towards the CPD context. The development of a model for identifying key factors enables efficient execution of product development projects in collaborative settings. Thus, the overall purpose of this thesis may be presented in short:

> The overall purpose of this thesis is to facilitate the efficient execution of collaborative product development projects in the manufacturing industry by focusing on key factors and how they are related to different CPD settings.

To fulfil the purpose an objective was set to specify the expected effects:

> The objective of this research is to provide a supporting model for analysing and setting up projects in CPD settings focusing on key factors, enabling successful product development in terms of lowering costs, increasing perceived quality of the product, and better timing to market.

In order to address the objective and expected effects, four research questions were set, addressing the main challenges for efficient execution of CPD projects: a holistic view of the CPD setting, the identification and management of barriers, transforming those barriers into enablers, and supporting manual tools, methods, models able to work as foundations for computer support. The research questions are presented next.

Research Questions

In this research project, I have chosen to make the issue more specific by addressing four research questions derived from the objective. Each research question has been addressed with the support of further questions depending on the method used during studies (see further *Chapter 2*). The research questions have been treated concurrently when possible.

> RQ 1. How may relevant interfaces be managed in collaborative product development settings in order to support successful collaborative product development projects?

Research question 1 addresses the need for a holistic view of the collaborative product development setting. To be able to answer the research question, different interfaces within a CPD setting have to be identified. This means the actors the interfaces occur between need to be ascertained. To be able to manage the interfaces, barriers and enablers have to be identified.

In this context, an *interface* is the intersection points between two *actors*. This could be between two organisational functions such as design and production or between a main and a sub supplier. Information and data within an interface may partly be managed using computer support. However, an interface always includes humans interpreting information. Information becomes knowledge when a human interprets, understands and believes in the message communicated. Creating new knowledge demands a combination of existing knowledge and input from information. Knowledge is created by the flow of information (for example, a flow of messages or meanings) and the justified true belief of the holder (Nonaka 1994). (For more information on interfaces, see *Chapter 4*. For more information regarding knowledge creation, see *Chapter 2*.)

> RQ 2. What key factors may be identified and related to the efficient execution of collaborative product development projects?

Research question 2 addresses the need to identify and manage barriers related to collaborative product development settings and turn them into enablers to successfully execute a project. To answer this question, factors previously identified in literature as "key" for CPD have to be identified, and complemented with factors considered as "key" in industry today.

By *efficiency* (efficient execution), we mean conducting the project in the right way. *Effectiveness,* on the other hand, is about conducting the right projects. A *successful* collaborative product development project is both effective and executed efficiently. A *key factor* is an area, an activity or other feature considered important for the outcome of a product development project. Thus, the factor constitutes a barrier, i.e. a risk, or an enabler, i.e. an opportunity. *Risk* is related to uncertainty, and may be defined as an issue influencing the probability of success in an activity (Olsson 2006).

> RQ 3. How may identified and relevant key factors relate to project performance in CPD projects?

Research question 3 addresses the need to manage relevant key factors. Consequently, it addresses the need to understand how the key factors relate to each other, how they relate to different contextual variables and settings, and how the different key factors impact on project performance. RQ2 and RQ3 are closely linked together.

By *relationship,* we mean an established connection between two parts, e.g. between factors, factors and project performance, etc. A respondent in the empirical studies possessing profound knowledge and experience on the issue may have addressed the relationship in interviews, analysis of interviews may have revealed the relationship, or else it may have been proven statistically. Time (time-to-market), cost, and quality (technical performance and customer satisfaction) have been the main measurements of *project performance*.

The fourth and last question is to make the attained knowledge accessible and available as a support in collaborative product development projects. To create knowledge and make it accessible and available, it must be possible for industry to access information physically and to understand the information. Thus, to make it supportive, it has to be formalised into a model, method or a tool.

> RQ 4. How may CPD projects be managed with the support of the tools and models developed during the research?

Research question 4 addresses the need for chiefly manual supporting tools, methods, and models with which the product development process could be managed. The design of the supporting tools and models have to be addressed, as well as how such could be used (for example, a process or procedure for analysing a project).

The different research questions presented complement each other and contribute to an overall understanding of the research area. The questions are addressed through literature studies, case studies and a survey. The results are partly presented in a licentiate thesis (Elfving 2004), summarised in the appended papers, and partly in the result section of this thesis (*Chapter 6*). Further, the research conducted within the area of Innovation and Design at Mälardalen University is applied research, as is this research project. Thus, it is important to argue for the expected effects and industrial relevance the results from this research may have on a real product development project.

Scope

The scope of this work has been narrowed during the process. The project started in a relatively wide problem statement, and has since been broken down into objective and research questions. Several delimitations have been made. The delimitations, together with expected results and what to expect from the results, are further presented.

Expected Effects

The research expects to result in a model supporting the execution and management of collaborative product development projects. The new knowledge developed during this research will contribute to the understanding of problems related to CPD in industry today and in the future. The process efficiency, as well as the probability of project success, is enhanced through knowledge about and the understanding of issues related to a holistic approach towards CPD projects. This can be achieved by facilitating easy, swift set-ups of the projects where risks and opportunities, barriers and enablers, connected to CPD projects are examined and acted upon.

To achieve the expected effects, the results have to be adjusted for the people who are about to use the new knowledge. It is important to make it available for the research community and industry. To do so, information has to be presented in such way that it can be transferred and interpreted into new knowledge. It has to be presented in a suitable context. A model has therefore, been developed in order to provide means for identifying contextual settings. The model include interfaces, key factors, and relationships both between key factors and contextual variables and settings and between key factors and project performance in a CPD project. Further, the model functions as a guideline when setting-up the project. Thus, the aim is to highlight important barriers and enablers related to CPD settings in the initial part of a project so they may be acted upon before the project starts. The expected effect of the result aims to minimize risks associated with collaborative settings in product development projects. Preferably, the use of a model and/or process will turn risks into opportunities, thus shortening time to market and reducing costs. Ultimately, a more efficient execution of the project and a successful product development process will occur.

Delimitations

Much may be included in the concept of product development. The research has mainly focused on the development of physical products in Swedish manufacturing industry, i.e. excluded areas such as software and service development. During the different studies that have been conducted, both main and sub suppliers in the manufacturing industry have been studied. Some of the studied actors have been consultants working for the manufacturing industry. The research has included small, medium, and large companies[9]. The distinction has been the types of projects these companies execute, not the size of the companies. However, contextual variables have also been investigated and documented during the case studies and the survey to provide a complete foundation for analysis. All studies have been conducted in Sweden. Within the range of the Swedish manufacturing industry, the following areas have been included:

- Electronic and optical products,
- Transportation vehicles,
- The manufacturing of machines and tools,
- Chemistry and pharmaceutical equipment, and
- Systems development

As argued before, this area could be approached from several different perspectives (from a social, technological, or organisational perspective, for example). This research has its basis in the area of product development; thus, the research is conducted and the thesis is written from a product development perspective. However, this does not only mean a technological perspective. Product development of today is far more complex than decades ago. In addition, it includes far more people and areas. This makes the issue even more delicate; products, peoples, and organisations imply all the perspectives. Nevertheless, my viewpoint derives from engineering, the foundation for my background. In addition, the academic department's focus rests upon this. Therefore, areas such as social psychology and organisational theory have been addressed in the context of product development.

[9] A small enterprise is defined as an enterprise which employs fewer than 50 persons and whose annual turnover and/or annual balance sheet total does not exceed € 10 million. A large company is a company with 250 employees or more that has an annual turnover of € 50 million or more. A medium sized company fall in between the two presented above. Liikanen, E. (2003). *Commission - COMMISSION RECOMMENDATION of 6 May 2003 concerning the definition of micro, small and medium-sized enterprises*. European union. Brussel..

The thesis commences in the initial phase of a product development project when a project team has been put together. In the PMI standard the focus would be in the end of the initiating process and continuing in the planning process of a project (Duncan 1996). Focus is upon managerial aspects of a project and enhanced efficiency for a more successful collaborative product development project.

Thesis Outline

This thesis is divided into eight chapters. Chapters 1 and 2 constitute the research setting, chapters 3-5 the theoretical framework, and chapters 6-8 the results, and conclusion. Lastly, the thesis also consists of the appended papers and the appendix. These are presented further.

Part 1 "The Research Setting" includes the first two chapters of this thesis: Chapter 1 "Introduction" describes the problem area, the purpose, the objective and the research questions. It sets the pace for the thesis. Chapter 2 "Research Approach and Methodology" presents the methodological approach for this research. It explains concepts for a better understanding of the thesis and the research process. Finally, how to validate the quality of research is discussed.

Part 2 "The Theoretical Framework" includes three chapters: Chapter 3 "The Core of Product Development: Managing the Process" sets the main theoretical and scientific foundation for this research by discussing product development and how to manage the process. The chapter concludes with a discussion of key factors in product development. Chapter 4 "The Product Development Process: a Collaborative Setting" presents theory more specifically related to CPD, collaboration and collaborative settings. Chapter 5 "The Collaborative Product Development Setting: Key Areas" introduces the reader to key areas when managing collaborative product development projects. The chapter ends in a summary and conclusion regarding the theory. In Figure 2, the content of Chapters 3-5 "The Theoretical Framework" is described. In sum, Chapter 3 presents the fundamentals of product development, Chapter 4 narrows it further, dealing with the collaborative setting, and, finally, Chapter 5 discusses the key areas in CPD settings.

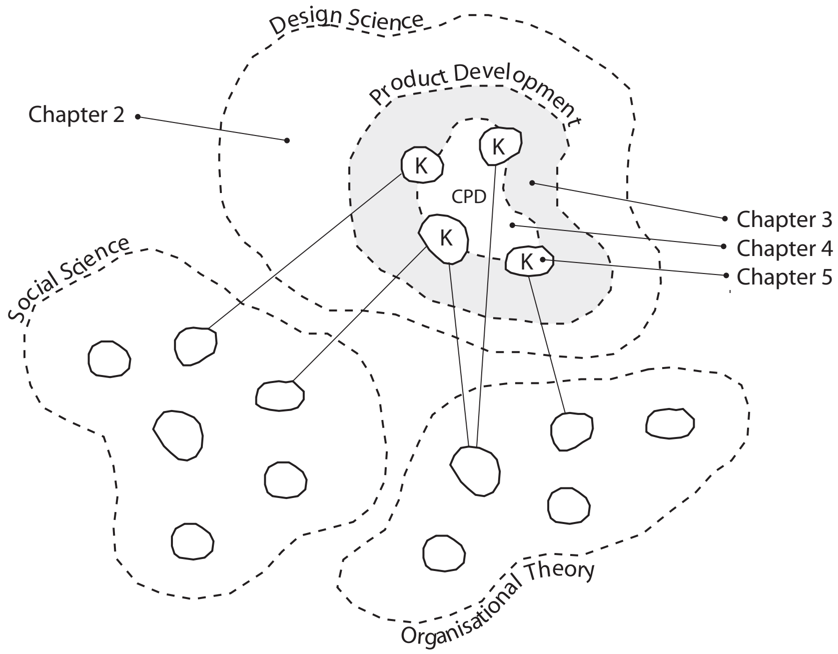

Figure 2 • The different areas that Chapters 2-5 deal with and how they are interrelated. Key areas (K). Collaborative Product Development (CPD).

Part 3 "Results and Conclusions" concludes the main part of the thesis in three chapters, Chapters 6-8. Thus, the purpose of Chapter 6 Results is to present the results from the case studies and the survey. Chapter 7 Managing Collaborative Product Development Settings relates the results to the theoretical frame of reference presented in Chapters 3-5 and makes a synthesis of the results, presented as a model. How the results correspond to the research questions, the fulfilment of purpose and objective and the contribution to the research area will further be discussed in Chapter 8 Discussion and Conclusion. Chapter 8, the last chapter, also summarises the main findings and conclusions from the research presented. The chapter ends in reflections upon the possible need for future research.

During the presentation of the results, there will be references to the related papers. Where needed, there will also be references to the case study descriptions in the appendix. Part 4 "Appended Papers" constitutes the five papers appended to this thesis. Finally, part 5 "Appendices" is the last part, and includes summaries of the four case studies conducted during the research. Further, it includes a more detailed summary of the conducted survey.

Chapter 2

Research Approach and Methodology

This chapter describes the scientific approach and justifies the methods used. First, the scientific base and the author's position on the examined area are presented. The nature of the research is discussed, and the choice of methodological approach is advocated. Moreover, the system approach is discussed in the context of collaborative product development. This part also explains the choice of methods for each research question. The research process is further described in detail.

The Scientific Foundation

This research project originates from a traditional mechanical engineering background. However, many academic departments within the area have evolved and chosen a different focus, towards engineering design, and design research. Since the area has evolved over time, so, too, has the research focus. The importance of studying processes and methods in product development is clear. The increasing complexity of product development, described in *Chapter 1*, not only puts pressure on companies' competitiveness but also on the methodology applied and used when conducting design research, investigating product development in companies. Design research has become the scientific arena for those who study design (for instance, in collaborative product development settings).

Design Research: A New Science?

Design research originated in the 1960s and the strong development of design methods, especially within engineering and parts of industrial design. Design research is still growing as a discipline, and the appropriate paradigm for it is developing. Within design research the aim should be to develop design knowledge, and the source of design knowledge lies within people, processes and products. The knowledge has to be developed, articulated and communicated. This can be done by studying people, processes and products (Cross 1999). In the 1980s, several books were published within the area of engineering design methods and methodology (Cross 1994), e.g., Hubka (1982), Pahl and Beitz (1984), Cross (1994) and Pugh (1991). Still, there are arguments regarding the distinctions between design and science. Cross has made several attempts to clarify the relationship between science and design and the core of design research. In "Engineering Design Methods" (1994) Cross argues for three areas within design research:

- Research into design
- Research for design (design analysis activities)
- Research through design (performing design activities)

Further, different groups of researchers or societies have different views on design research. Mainly, three interpretations of design research have been identified:

- Scientific Design
- Science of Design
- Design Science

Scientific design originates from the movement from pre-industrial, craft-oriented design-based knowledge, towards the modern, industrialised design, based on non-intuitive methods. Science of design is referred to as the study of the principles, practices, and procedures of design. It aims to improve the understanding of design using scientific methods. The definition of science of design differs from design science. Design science has been addressed by several authors since the 1960s and with various focuses (Cross 2001). It has been described by Hubka and Eder (1996, in 4.1) employing a somewhat wider definition than the two other interpretations of design research:

> …a system of logically related knowledge, which should contain and organize the complete knowledge about and for designing.

Design science is intended to deliver taxonomy and good references for research in the area of design theory, methodology, way of thinking, and the establishment of working means for design. A close relationship exists between the theory base, the method used and the object studied. The theory is supposed to provide the foundation for the behaviour of the object and the utilized methods (Hubka and Eder 1996)[10].

The research results presented in this thesis may be referred to as research into design (see Cross 1994) (i.e., studying design processes and searching for design knowledge). The scientific foundation has been *Design Science* as Hubka and Eder (1996) define it. In addition, *Engineering Design* is a part of design science (see Hubka 1982; Pahl and Beitz 1984). Engineering design is discussed next.

Engineering Design Research

The overall aim of engineering design research has been advocated by Blessing, Chakrabarti, and Wallace (1998, p. 1) as:

> …to support industry by developing knowledge, methods and tools which can improve the chances of producing a successful product.

Engineering design is not a new phenomenon, but it is argued as being a relatively young area. Conducting research within the area involves applicability to a great extent and making the research useful for its target group (e.g., to make knowledge about CPD accessible for industry). However, there has been a lack of acceptance for engineering design and its scientific base. For instance, the necessity of design science today is found in the new market situation. Needs are changing, companies have to adapt to those changing demands. The competition will change, and so the prerequisites for it. Political development such as internationalisation, legislations, and regulations effects companies. This development force companies to develop new methods and models in order to remain competitive. However, the world is changing and the need for this kind of research is becoming clear. This is especially true considering the improved numbers of studies aiming to increase the understanding of the design process, both as a cognitive and a social process, and in the context of the organisation (Hubka and Eder 1996; Blessing et al. 1998; Blessing 2002).

Due to the multidisciplinary nature of design research, involving people, products, tools and organisations, each bringing its own research methodology and methods into design research, a design research methodology is needed (Blessing et al. 1998). Blessing et al. (1998) propose a new generic design research methodology, which aims to guide the researcher through the design

[10] Cited by Hubka and Eder (1996) from the original source in German; Klaus, G., Kybernetik in philosophischer Sicht (Cybernetics in Philosophical View) 4th ed., Berlin: Dietz Verlag, 1965.

research process (see Figure 3). At the time of writing this thesis, the methodology is not yet fully available; as such, it lacks some parts to be fully utilised. However, the main criteria and guidelines for the methodology exist. Thus, it may be partially used in design research projects (for example, in research on CPD).

To be able to choose appropriate strategy and approach, there is a need to understand the nature of the research area. Above, the scientific foundation has been presented, preparing the way for an appropriate methodology for research into CPD settings. The framework presented above is partly used in this research project merely as a guideline and checklist for the research process. Due to the lack of a complete design research methodology to adopt, the methodology for this research is influenced by other sciences closely related to design research, e.g. methods from management and organisational studies. There are mainly three research approaches to adopt within the area of management and organisational studies according to Arbnor and Bjerke (1997): analytical, systems or actors approach. The next part of this chapter will concentrate on explaining the nature of the research area, how it is positioned relative scientific movements, and the identification of a suitable approach for it.

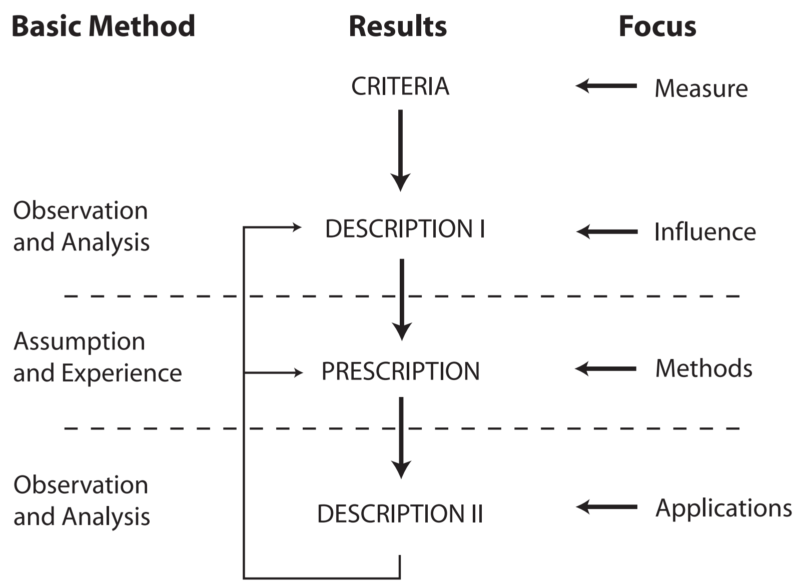

Figure 3 • The design research methodology framework proposed by Blessing et al. (1998).

The Nature of Managing Product Development

Design research is a fairly new discipline, influenced by several scientific movements, each having a rather solid scientific and methodological foundation. Those movements include for instance studies in organisational science and social science. Design research cannot be said to strictly belong to any of the traditional paradigms for knowledge creation, neither positivism nor hermeneutics. Generally speaking, researchers from the positivistic paradigm create explanatory knowledge, while researchers from the hermeneutic paradigm aim to create understanding knowledge. As described earlier, there is still inconsistency in what methods should be applied within the area and what approach[11] is most appropriate.

Research on product development and especially the management movement of it seems to exist in the blurry interface between the two extremes (positivism - hermeneutics), thus influenced by both. An argument by Senge (1990, pp. 11-12) illustrates the issue. He differentiates between an engineering innovation and an innovation in human behaviour. The components of an engineering innovation are called "technologies," while the components of an innovation in human behaviour should be seen as "disciplines". The final goal of a CPD process is to develop and produce technologies and/or products. This is done by managing human behaviours in different ways during the CPD process. Further, Senge argues that a discipline:

> …is a body of theory and technique that must be studied and mastered to be put into practice.

Thus, the question is: are we, the research community, studying a technology, a discipline or something in-between, when studying CPD?

Methodological Approach Studying CPD settings

Arbnor and Bjerke (1997) argue for three approaches related to the two main paradigms in social science (positivism and hermeneutics) relevant for creating business knowledge:

- Analytical approach
- Systems approach
- Actors approach

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[11] Approach refers to the worldview of the researcher, while method refers to different methods applied to address a problem within the approach. A case study is an example of a method, while a systems view is an approach.

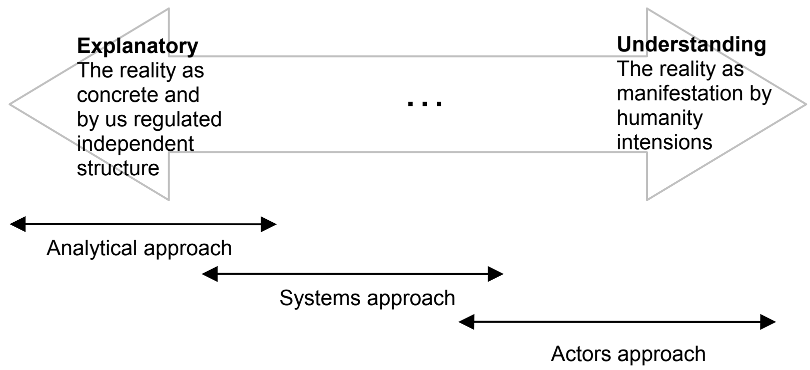

Figure 4 • How the different approaches are related to different types of knowledge creation (Arbnor and Bjerke 1997, p. 46).

The analytical approach is the one most closely connected to explanatory knowledge creation (see Figure 4). Further, it possesses the perspective on reality of being concrete and conforming to laws. The systems approach overlaps the analytical approach, but also stretches into hermeneutics and the creation of understanding knowledge. The last approach, the actors approach, has a more clear distinction from the other two approaches. Here, reality is seen as a social construction and a manifestation of human intentionality. Understanding will never appear as objective knowledge, and no case can be subsidiary to an objective or quantitative law.

As the actors approach focuses on single actors and their acts and social contexts and does not aim to explain anything, only understand social wholes, it is not appropriate for this research. The intention is to look at a product development project comprising several actors, a collaborative setting, interacting with each other and with technologies. Having this and the scientific foundation for this research in mind, the further discussion will revolve around the two first approaches (roughly the two closest to the worldview of the author), the systems approach and the analytical approach.

The analytical approach originates from the classic analytical philosophy that the whole is the sum of its parts. If the different parts are known, these may be added together to get the whole. The analytical approach deals primarily with hypotheses that may be verified or falsified in an all-objective reality. Thus, the knowledge created is independent of the observer/ researcher's pre-understanding of the phenomenon. The approach aims to explain rather than understand what causes a specific effect, i.e., causalities.

Research with an analytical approach mainly results in cause-effect relationships. The models developed are of a logical nature, and the cases presented are representative (Arbnor and Bjerke 1997). Methods used in mathematics and physics function as examples of the analytical approach.

The systems approach developed during the 1950s as a reaction to the analytical approach. Even though the systems approach developed as a methodology during this time, systems theorists were active before that, for instance within the field of business administration. Chester Barnard was one of the first to apply systems theory to organisations. He argued that an organisation is a collaborative business that consists of complex relationships between the organisation's components (see, e.g., Barnard 1938).

During the 1950s, there was prevalent resistance to the analytical approach and its ineffectiveness in managing social problems within, for instance, strong technical development. There was a need to find methods suitable for treating complex problems in society. The systems approach was developed within this context (Arbnor and Bjerke 1997). During this era, the concept of Systems Engineering (SE) ascended (on systems engineering, see *Chapter 3*). However, when systems engineering was faced with complex problems involving human beings it failed. A Soft Systems Methodology (SSM) grew from the failure of systems engineering (see Checkland and Scholes 1999).

The systems approach aims to both explain and understand what forces cause a particular effect, i.e., finalities or finale relationships. The result from research adopting the systems approach is unique or typical cases, and is modelled as systems structures (Arbnor and Bjerke 1997). Easily put, the systems approach and the analytical approach differ in terms of worldview. The analytical approach argues for the whole as the sum of the parts, while the systems approach argues for the sum to differ from the whole. In the systems approach, the parts, the components, influence each other, thus becoming mutually dependent. Every system has a purpose, e.g., the effect of the system, and is limited by its system boundary. The purpose of the approach is to understand and explain the parts in a system from the whole and its characteristics. The knowledge developed within the systems approach is dependent on the system. It is not cause and effect relationships that are searched for. Rather, it is indicator and effect relationships.

The purpose for this research is to facilitate the efficient execution of collaborative product development projects in the manufacturing industry.

With the previous discussion kept in mind, two more or less possible approaches may be used to accomplish this, analytical approach or systems approach. The result of the first approach would not be dependent on the individual and would claim reality as objective. An analytical model for managing CPD would be constructed (see example in Figure 5). The analytical model would deal exclusively with cause and effect relationships. The result from the second approach, the systems approach, would claim that the knowledge created is depended upon the system, the CPD project, and the reality to be objectively accessible. A systems model would deal with indicator and effect relationships and the contextual setting of CPD (see Figure 6).

By comparing the models in Figure 5 and Figure 6, the consequence when deciding upon approach becomes clearer. Increasing the knowledge about and understanding the factors influencing product development in collaborative settings requires the explanation and understanding of factors, actors and relationships. The systems approach provides the appropriate means for this, acting in the interface between positivisms and hermeneutics.

However, to identify relationships between factors, for instance, may demand quantitative data-gathering methods and statistical analysis. These are methods often associated with positivism and the analytical approach. Thus, the research procedure becomes similar to what Arbnor and Bjerke (1997) suggest as the 'relative procedure' in the meaning of methodological approach. It is when results and techniques from one methodological approach are used in another methodological approach. Consequently, the systems approach becomes the 'methodological base approach' used for creating new knowledge about CPD settings. Thus, some methodological procedures become relative and have to be reshaped in order to be applicable in the 'methodological base approach'.

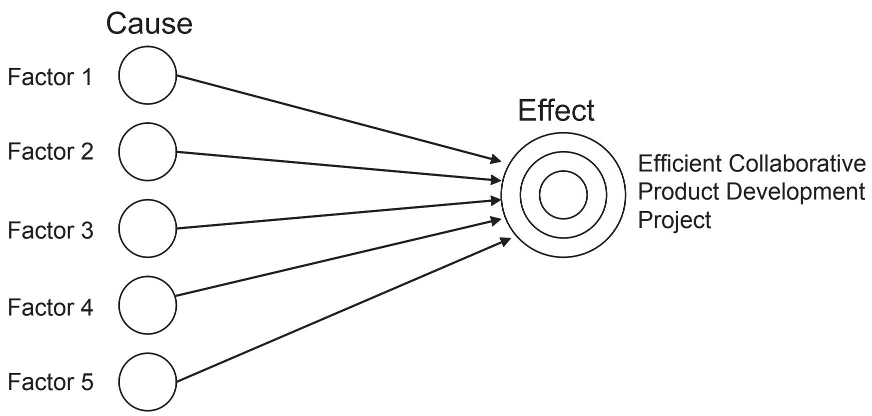

Figure 5 • A model describing factors that influence CPD projects.

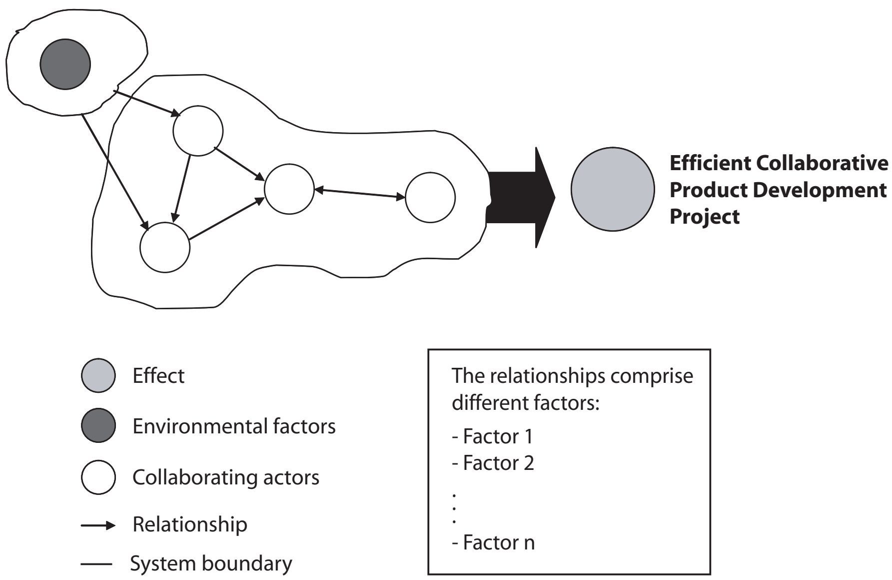

Figure 6 • A systems model describing factors that influence CPD projects.

Systems Perspective on CPD

The differences between the models in Figure 5 and Figure 6 are revealing. If one of the factors is excluded from the analytical model, the effect will still be the same and the other factors will not be affected by the change. We might then draw the conclusion that a single factor is the cause of the effect. If one of the factors is excluded from the systems model, the entire system will change. That is because each component in the system is related to each other. As a result, the factors are related as well. If one factor is excluded, it will influence other factors, other relationships, the effect, and the entire system.

Thus, the essence of systems thinking is a shift of the mindset: seeing interrelationships rather than linear cause-effect chains, and seeing processes of change rather than snapshots (Senge 1990). In other words, systems thinking involves seeing things that happen in circles rather than in straight lines. Patterns are repeating themselves. The basic structure of a feedback system, according to Forrester (1968, p. 401) "…is a loop within which the system condition provides the input to a decision process that generates action which modifies the system condition".

For instance, as a manager you employ an engineer with specific qualities because you lack resources in a project. That is cause and effect. However, seeing it from the systems perspective, you employ a person because there is a gap to fill. The company gets more projects, thus lacks personnel. As a manager you take action, starting the process of finding the best available competency. That may include a recruitment process. When you have found the appropriate competency, you employ that person, filling the gap. An increased number of projects lead to people being involved in, for example, the CPD process, which in turn demands more project leaders. Again you as a manager sense a gap that needs to be filled and the process starts all over again. The circle is closed. Each element in this circle influences another element, and in the end you perceive feedback. Actions that you have taken reinforce or balance other actions. In a reinforcing feedback system, small changes build on themselves. A small action may grow into large consequences. Changing a seemingly small detail in a large technical system may have a large consequence on the final product. Or making a minor change in an organisation may imply major consequences elsewhere in the organisation. A balanced feedback system, seeks stability, and there is a self-correction towards a specific goal (see Checkland and Scholes 1999).

One example of this is having the appropriate resources at hand when executing CPD projects. However, if we make the decision to not fill the resource gap, and instead let other employees take the responsibilities and do the work, it may end up in a loss of efficiency and unmotivated employees. Thus, making a decision in an organisation or during product development implies consequences, good or bad. Having systems thinking can make it easier to perceive the outcome of such decision.

Knowledge Creation Process in CPD

The theory of knowledge, referred to as epistemology, has been addressed extensively in literature. Nonaka (1994) argues for knowledge as "justified true belief". There is a clear distinction between information and knowledge. Information is a flow of messages, and knowledge is created by the flow of information and human actions. In the systems approach, knowledge may be created according to Figure 7.

A CPD system includes components and relationships between those components. The relationships may constitute knowledge transfer between actors, which results in the interpretation of data and information. However, there exist different types of knowledge more or less possible to transfer between actors in a CPD project. Gummesson (2000) argues for two types of knowledge, general and specific. He also advocates personal attributes. General knowledge includes knowledge about theories, models, and concepts, and further, techniques, methods and tools. Specific knowledge includes knowledge about institutional conditions and social patterns. Personal attributes include intuition, creativity, vitality and social ability. According to Davenport and Prusak (1997), knowledge is valuable information from the human mind that includes reflection, synthesis, and context. It is hard to structure and difficult to capture on machines. Knowledge is often tacit and difficult to transfer. Nonaka (1994), on the other hand, defines knowledge solely in terms of 'tacit' or 'explicit', focusing on the process of how to transfer it. Explicit knowledge is easily transmitted, processed and shared. Tacit knowledge is connected to and dependent on the individual and the individual's understanding and experience of a concept or a phenomenon. It is personal and hard to formalise, making it difficult to communicate and share with others (Nonaka and Takeuchi 1995).

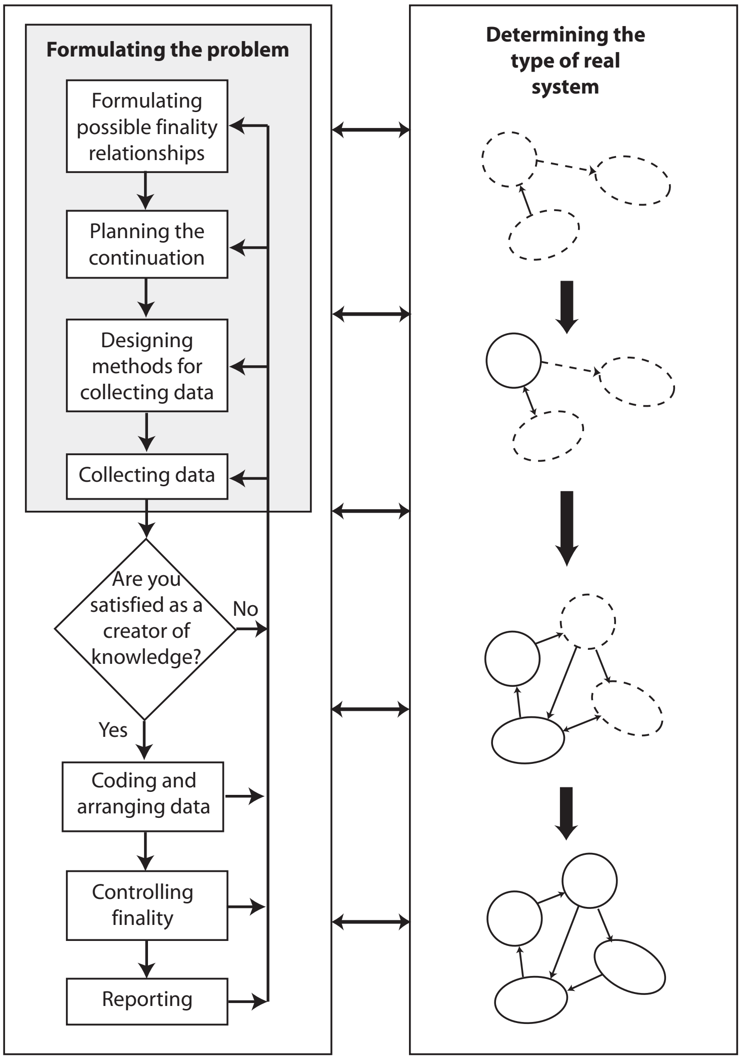

Figure 7 • The knowledge creation process in, e.g., CPD systems (Arbnor and Bjerke 1997).

Tacit knowledge has to be transferred through interactions between individuals and may be translated into explicit knowledge. This process involves the transfer of an abstract concept into a thing. Thus, it needs metaphors to facilitate the translation (Nonaka 1994). Explicit knowledge may also be transferred into tacit knowledge through "an active process of learning" (Best et al. 2003).

General knowledge is relatively easy to access and create for a researcher. It is a question of intellectual understanding of theories, techniques, etc. Specific knowledge, however, is much more difficult to attain. It is mainly acquired through experience (Gummesson 2000). Thus, gaining access to and creating knowledge is a challenging activity for the researcher. In systems approach, knowledge is created mainly by three outputs: systems analysis, systems construction, and systems theory (see Figure 7).

Systems analysis

Systems analysis seeks to represent the real system in a systems model without changing the actual system. The relationships between components and the whole are examined, which also includes identifying internal and external factors influencing the system. Systems analysis has both a descriptive and an explanatory purpose. Systems analysis may be conducted by using data collecting methods such as interviews, direct observations and archival records. Then, the aim is to reproduce the perceived problem situation in an organisation or in another study object (Arbnor and Bjerke 1997). For instance, systems analysis may be studying an organisation, describing the problems within it, and defining both what influences the problems and which part of the organisation the problems concern. Finally, the characteristics of the organisation and the problem are represented in a systems model. This is the foundation for solving the problem. Further, the solution to the problem is represented during systems construction.

The analysis of each case study organisation in this thesis (the organisations studied in case studies A-D) corresponds to the systems analysis. The preconditions for each organisation have been sought and components, being part of either a project or a wider organisation (the systems), have been clarified and explained. Environmental factors and other influencing systems have been studied when possible. The organisation or a specific project has been represented in systems model, some more profound than others. The results of the systems analysis are summarised in *Chapter 6*. A more profound description of each case is presented in the *Appendices*.

Systems construction

Systems construction is representing the real system in a systems model that can be the base for a new real system. The need for a new system may have been identified through an audit of a dysfunctional real system. The systems analysis sets the foundation for the systems construction. The new systems proposal constitutes the systems construction. Systems construction is used by researchers as a mean of change in the real system (Arbnor and Bjerke 1997). The model developed in this thesis may be seen as a preliminary new system.

Systems theory

Systems theory (modern systems theory, not general systems theory) is a result of systems analysis and systems construction. The theory includes systems models and indicator and effect relationships. The theory may be applicable on different classes of systems. The systems in which the theory is about to be applied must, however, be well defined and have similarities with the original system. However, compared to other approaches like the analytical approach, the result of the systems approach, the systems theory, becomes less general (Arbnor and Bjerke 1997).

Planning and Designing the Research

This part will discuss appropriate methods for each research question starting with the systems approach. Each of the four research questions presented in *Chapter 1* will be discussed further. As was stated earlier, the overall purpose of this research project is to facilitate the efficient execution of collaborative product development projects in the manufacturing industry.

Addressing the Research Questions

Research question 1 is: How may relevant interfaces be managed in CPD settings in order to support successful CPD projects? Different methods have been used for addressing this research question. To be able to describe what relevant interfaces exist in a product development project, different methods have been used. There are literature and case descriptions that address interfaces in product development. However, to fully understand these, what risks are associated with the interfaces and how they should be managed, real life cases have been studied. Besides literature studies, case study research has been used for addressing this area. Within the case study research, there has been a need to address people in the organisations, talk to them and try to understand their situation. Interviews have been used for this purpose. Further, documentation has been studied in order to provide a description of the contextual setting for the case studies. To further understand and confirm some of the findings during literature reviews and case studies, there has been a need to address a larger number of projects, something that is not possible to accomplish using case studies. Therefore, a survey involving a web-based questionnaire has been used for this.

Research question 2 is: What key factors may be identified and related to the efficient execution of CPD projects? Having studied earlier research on the concept of critical success factors in product development and CPD, the most common method for addressing this seems to be surveys, some researchers however, utilise case studies in parallel for addressing this (e.g., Bruce et al. 1995). Addressing the research area, different methods have been combined to obtain a fruitful understanding of what factors are important and how they relate to each other and to different product development projects. Literature reviews have served as the input.

To explore what key factors are seen as important in industry today, both case study research and a survey were used. This choice was based on the willingness to identify and understand important factors from a systems approach. The case studies were performed prior to the survey. They enabled systems thinking. They also avoided isolating the issues, thus not leaving the interpretation and understanding of the phenomenon to other researchers. The case studies worked as a foundation and input to the survey. The survey aimed at identifying relationships for a better understanding of the system that constitutes a collaborative product development project. The survey was also used to further understand and confirm the findings in the case studies and to test those findings on a larger number of projects.

Research question 3 is: How may identified and relevant key factors relate to project performance in CPD projects? Primarily one method has been used for addressing the question. The question is traditionally analytical in its approach. To search for relationships between factors and how these relationships vary depending on context, the problem has to be simplified and operationalized into measurable, controllable items. Thus, a survey was used for this purpose. This may seem a contradiction to the systems approach. However, to be able to understand a system and its integrated parts, these types of questions also have to be addressed. In this case, the system is on a lower magnifying level with more specific details, a level where the factors and their internal relationships are searched for (see Arbnor and Bjerke 1997).

Research question 4 is: How may CPD projects be managed with the support of the tools and models during the research? This question has been addressed during the entire research process, and all methods used have contributed to answering it. To better understand the applicability of such tools and models, there has been a continuous discussion together with project managers in several companies. For instance, a workshop was held to discuss the future of product development. It aimed to understand the future need from companies and how these may be incorporated into a model and further transferred to a project organisation.

The Research Process

As shown in Figure 8, the process has been iterative. It went from theory, moving on to case studies (where new knowledge was attained), back to a more prescriptive phase where theories and models were developed. The results, here illustrated by systems models, have been developed continuously. The knowledge process has been influenced by the input for the research project. Examples include the research objective or the culture and traditions for scientific area and the arena in which the research have taken place. The empirics have then been analysed and compared to existing theories. To further test and evaluate the theories and the model, a complementary case study was conducted. The theory and the model were re-designed, and finally tested and explored in the closing survey.

The process can be illustrated as iterative, alternating between empiric and theory, in accordance with the explanation model abduction[12] (see for instance Alvesson and Sköldberg 2006) and further addressed in Dubois and Gadde (2002). The process when performing case studies is also to a great extent iterative (Eisenhardt 1989; Yin 1994), starting from theory, the general (deduction), moving on to the individual case, and back, building new theories (induction). A combination of these approaches is often made, i.e., abduction (Alvesson and Sköldberg 2006). The output of this process is new knowledge in terms of systems models, systems theory, and personal development.

[12] Abduction has been addressed in several areas and by many authors. For instance the American philosopher Charles Sanders Peirce (1839-1914) which work has been republished many times, e.g., in Peirce, C. S. and Buchler, J. (1955). *Philosophical writings of Peirce.* Dover: Dover publications.

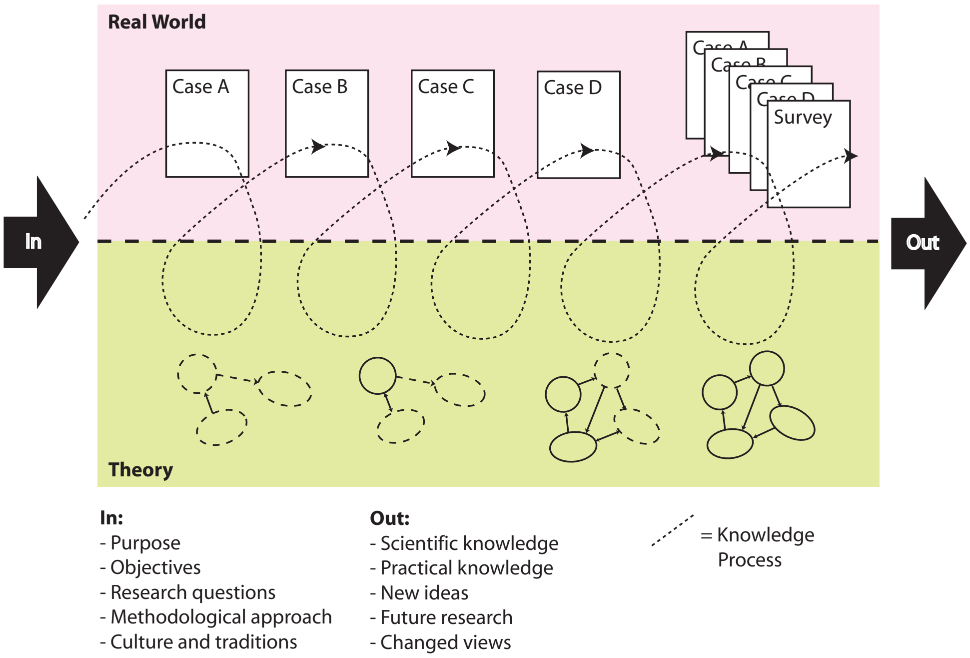

Figure 8 • The research process investigating collaborative product development settings.

The Case Studies

The strategy employed most often to collect primary data in this research project has been case studies. Four case studies have been conducted. A brief summary of the case study contexts is presented in Table 1. The case studies are also summarised in *Chapter 6* and fully presented in the *Appendix*. As the process shows in Figure 8 knowledge has been developed by iterating between the real world and theory. And as argued by Dubois and Gadde (2002, p. 555):

> Case studies provide unique means of developing theory by utilizing in-depth insights of empirical phenomena and their contexts.

Further, three of the research questions are 'how' questions, and like Yin (1994) argues case studies constitute the preferred strategy when 'how' or 'why' questions are being posed. Case study is used as the main strategy in this research because it may deal with qualitative data, it is suitable for investigating current phenomenon in its natural context, it assists in understanding dynamics in systems better (Meriam 1994), and it is a relatively easy way to investigate networks and other inter-organisational relationships (Easton 2000).

Table 1 • Description of the contextual settings, unit of analysis and research questions for the case studies.

Case	Number of Employees	Business Focus	Unit of Analysis	Research Questions
A	25	Electronics development	- The product development process - Requirement specification - Customer relationship - Technical competence - Resources - Project closure - Project management - Quality assurance	RQ1, RQ2
B1	9	Mechanical equipment and prototypes	- Networks - External collaboration in product development - Communication - Tools and methods - Strategy and goals	RQ1, RQ2
B2	23	Electronics and software development		
B3	20	Plastics and prototype development		
B4	600	Electronics development and integrated systems		
B5	< 10	Integrated development in polymer technology		
C	600	Mechanical and mechatronic development	- Collaborative product development projects - Organisation - Trust - Strategy - Process - Goals and requirements	RQ1, RQ2, RQ3, RQ4
D	1600	Construction equipment	- Collaborative product development projects - Partnerships - Strategy - Sourcing	RQ1, RQ2

An important advantage that case studies provide is a holistic view of processes. It is also a valuable method when the aim of the research is to provide practitioners with tools (Gummesson 2000). The outcome of a case study depends upon the understanding of the subject studied, which means the understanding of the theory. Therefore, it is most important to prepare a case study by making a literature review within the field of the study. Yin (1994) argues that the theory is the base when generalising from a case study. A previously developed theory may thus be used as a template to compare the findings from the case study. If more than one case supports a theory independent from each other, the result can be seen as more powerful.

Here, collaborative product development is the current phenomenon and the Swedish manufacturing industry its natural context. The case studies give a detailed understanding of the companies' product development processes and collaboration and, thus, an understanding of the dynamics between interfaces. A case study copes with typical technical situations, and has the advantage of relying upon multiple sources of evidence. It can include both single and multiple case studies and, if desired, quantitative data. Yin asserts that there are five important components of a research design when it comes to case studies (Yin 1994): (1) its questions, (2) its propositions, (3) its unit(s) of analysis, (4) the logic linking of the data to the propositions, and (5) the criteria for interpreting the findings.

Several different data-gathering techniques may be used in case studies (Yin 1994; Gummesson 2000; Alvesson and Sköldberg 2006). Four of those presented below were used during the case studies:

- Documentation (material for decision-making)
- Archival records or remains (stored over time)
- Direct observation
- Participant observation
- Physical artefacts
- Interviews

The four data-gathering techniques mainly used during the case studies were: documentation, archival records and relics, interviews, and direct observations. These four sources are complementary, and, therefore, provide a comprehensive image of the companies' inter-organisational relationships in the product development process.

The most important source of evidence during the case studies has been the semi-structured interviews[13] (see Lantz 1993). This source has been used during all of the case studies. Interviews are one of the most common tools when collecting qualitative data (Meriam 1994). The power of interviews is that they focus upon the case study topic, with the opportunity to guide the respondent into the right area. Interviews provide in-depth knowledge about the phenomena studied (Lantz 1993). On the other hand, a weakness of interviews is that the respondent could give the answer she/he believes the interviewer wants to hear (reflexivity) or that the interviewer leads the respondent to a specific answer (Lantz 1993; Meriam 1994; Kvale 1996). The questions during the interviews could also be poorly formulated and not give the expected answer due to a misunderstanding or the interpretation of the interviewer: 'response bias'.

[13] Question areas in a definite series with corresponding follow up questions. Lantz, A. (1993). *Intervjumetodik*. Lund: Studentlitteratur.

The documentary information has been important during the case studies. The gathering of data has considered: administrative documentation, management documentation, project plans, requirement specifications, contract and legal agreements, etc. The background of each case has been identified (with the support of the documentary information and the observations) and an understanding of the system has been reached. The power of documentation is that data is stable and can be reviewed over and over again. A main problem when collecting it, however, is that there may be difficulties in accessing the documentation if you are an outsider[14]. Archival records and relics have almost the same advantages and disadvantages as documentation. Physical artefacts give insight into cultural features and technical operations. Physical artefacts may however be selective and have low availability.

The direct observations have consisted of field visits during the time of the interviews, e.g. visiting the manufacturing department, the design department, administration, and so on. It has also consisted of observations of annual meetings between actors. The purpose of the observations has been to understand the contextual setting in which the case studies took place. Understanding the context is important when analysing the data gathered from the case studies. Direct observation has the advantage of covering events and contexts of events in real time. However, it is time and money consuming and very selective (Yin 1994). Participant observations provide knowledge of interpersonal behaviour and motives. However, with participant observation, there is a risk that the researcher may manipulate events[15].

Further, there have been direct observation during the case studies in the form of a task analysis (see Jordan 2002) where a communication tool has been tested and analysed. When using a task analysis, the researcher observes her/his own behaviour as a user, within a specific context. Task analysis represents a non-empirical qualitative method answering the question "What?". Unfortunately, task analysis cannot provide statistical data.

[14] An outsider is an independent researcher, not connected to the company, the organisation, etc., while an insider is an industrial researcher.

[15] This can be the case when using action research as a research strategy. John Collier introduced concept action research in the 1940's. Kurt Lewin from MIT (Boston) was also one of the pioneers in the area Westlander, G. (1999). *Forskarroller i varianter av aktionsforskning*. Royal Institute of Technology. Stockholm. Action research has gained approval of being an alternative research method (Svensson, L., Brulin, G., Ellström, P.-E. and Widegren, Ö. (2002). *Interaktiv forskning - för utveckling av teori och praktik*. Stockholm: Arbetslivsinstitutet.).

The analysis of gathered data during the case studies was dependent upon the questions asked during the case study, the data-gathering technique, and the applied approach. Interviews as a data collection method were tested at the beginning of the research project during a pilot study[16]. The purpose of the study was to investigate the phenomenon of inter-organisational relationships between main and sub-suppliers. During the pilot study, interviews were held with management people and design engineers at several industrial companies who had close collaboration with suppliers in the research and development process (see Olsson 2002). The pilot study showed that interviews could serve as a suitable method when investigating this kind of phenomenon. With regard to this, interviews were prepared and made to obtain knowledge (see Elfving 2004).

The interviews were made with the assistance of a questionnaire with areas defined in advance (see Westlander 2000). The further analysis of interviews was primarily performed according to meaning condensation[17] (Kvale 1996, pp. 193-196). The most essential information in the interviews was summarized and interpreted. A more comprehensive presentation of data from the interviews and how the interviews have been analysed may be attained in the appendices, the appended papers, in Elfving (2003), and in Elfving (2004b). The task analysis was performed according to Jordan (2002), and may be attained from Andersson and Elfving (2004) or by contacting the author.

The unit of analysis

As is apparent from the previous part, this thesis deals with the collaborative aspects in product development projects. However, collaborative product development may be studied from several different perspectives (e.g., from a technological, an organisational, or a social perspective). This research project had the small company's perspective as its starting point. From the beginning, it considered how small companies may gain competitiveness through collaboration in the development of new products. While studying this phenomenon, the complexity of managing interfaces in such collaboration became apparent. The project was narrowed down and focused on the

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[16] The pilot study was conducted during a higher course with the participation of 30 master students (Olsson, E. (2002). *Produktutveckling i samverkan*. Department of Innovation, Design and Product Development. Mälardalen University. Sweden.

[17] Meaning condensation implies the reduction of material through the concentration of sentences and that the most important information is kept (Kvale 1996).

collaborative setting and the project as a unit of analysis, where the small company could function as an actor. This did not imply a simplification of the problem; the contrary is true.

Thus, the unit that has been studied during this research is *the project*, and the actors within and the contextual setting for such project. The project includes actors, interfaces, processes, and activities, barriers or enablers for the setting. These actors have relationships to each other, in the interfaces between them. The studies conducted during this research have a more or less narrowed approach to this unit. There are primary three levels of activity in product development: the activity of setting a strategy, managing product development projects, and performing the practical tasks (Andreasen and Hein 1987). These three levels may also be referred to as the strategic, the tactical and the operational level in an organisation. This research has mainly approached the tactical level, how to manage the projects. Some studies have had a slightly different approach. The different studies and the units analysed there are presented in Table 1.

The Survey

A questionnaire survey was conducted to test and verify the theories and model developed according to the research process in Figure 8. The survey content is based on the result from the four case studies and the literature studies conducted during the years 2002-2005. The foundation of the survey emerged through iterations between theory and empirics. The survey aimed to address the identified factors further, and to examine possible relationships between the factors and efficient collaborative product development on a project level. The survey also addressed possible differences between types of projects, in respect to the collaborative setting. For a more complete presentation of the survey, see *Appendix – Survey*.

Further, the purpose of a survey is to collect information and data that may be analysed in order to discover patterns and compare those patterns, e.g. relationships in a CPD setting. Mainly, a survey aims to cover a whole population; however, most surveys aim to collect information of a representative sample of the population (Bell 2005). During a survey, questions are posed to the respondents under as similar conditions as possible. This survey, performed with the aid of a questionnaire, was no exception. Formulating the questions is crucial and no simple or straightforward task. The respondents must understand the meaning of the questions in the same way. This work is time consuming. However, it is a less costly and easy way to collect data compared to interviews (Ejvegård 1996; Bell 2005). Data gathering in surveys may be done using self-administered questionnaires or interviews held with the support of a questionnaire, where each respondent's answer is written down. Independent of the method used, the purpose is to gather answers to the same questions from a large number of people. The objective is to compare answers, making it possible to map relationships and categories from the answers. Surveys may provide input to questions that have the nature of what, where, how and when, but not why (Bell 2005).

Using questionnaires as a data gathering technique demands extensive preparations to make them clear and unambiguous, and the researcher can never be sure who has answered the questionnaire. Neither may contextual data be gathered (Bryman 1989). As with interviews and other techniques, the purpose and research questions have to be established. Further, studied variables and concepts have to be operationalised into questions or statements. The structure and layout of the questionnaire has to be completed. Sampling has to be done, and the population defined. The questionnaire has to be tested and revised. When distributing the questionnaire, whether it is done by letter, the web or in person, a cover letter is needed to explain the purpose and the conditions for the study. Non-responses and skewness have to be analysed and acted upon (Bell 2005).

When analysing processes within a company, survey techniques are not sufficient in themselves. A survey used on its own, when studying processes of decision-making, implementation and change, will be too fragmented and mechanistic. Gummesson (2000) argues that surveys as a method and, for example, questionnaires as a technique may be used to analyse well structured parts of a problem. Surveys as a method might be used to complement the analysis of processes within a company. Further, Gummesson (2000) asserts that interviews and observation provide the best opportunities for studying processes. This supports the choice of methods used in this research. The survey aims to complement the existing research and serves so as to provide an asset, a source of discussion and an indication of directions.

Validating the Research Results

There are different ways of judging the quality of research. The most commonly used concepts are validity and reliability. Validity and reliability are closely related to generalisation. However, these concepts are closely related to positivism, quantitative data and the analytical approach. Thus, the concepts should be treated carefully when dealing with qualitative data such as in the context of systems approach and case study research. However, some views on these concepts are presented further.

Validity is the extent to which researchers are able to use their method to study what they had sought to study, rather than studying something else (or nothing) (Gummesson 2000). Yin (1994) argues for four tests that may judge the quality of case studies. These tests are common within empirical social research, and Yin applies those to case study research. The first test is "construct validity." Here it is important to establish correct operational measures for the phenomenon being studied (i.e., using multiple sources of evidence or by key people reviewing the preliminary case study report). This can successfully be carried out in the data collection phase and when putting together a report. It is also important to establish causal relationships, where certain conditions lead to other conditions. Pattern-matching, explanation-building, and triangulation (i.e., 'internal validity') are examples of this. Internal validity involves ascertaining how the results correspond to reality (Meriam 1994). This test is primarily used when doing explanatory studies. Therefore, it is not fully applicable when using a systems approach. Further, Yin argues for 'external validity'. It is about finding the domain that the study result can be generalised to, and making replications, as for multiple case studies, does this.

However, Gummesson (2000) concludes that the traditional demand for generalisation has lost its meaning as long as you keep searching for new knowledge and do not believe you have found the ultimate truth (rather, you should feel you have found the best truth available for the moment). Further, qualitative research gets criticized for its inability to provide results from which one can generalise. This, though, is dependent on the epistemological standpoint, how you approach generalisation. If the standpoint is that generalisation equates recurring patterns, then generalisation only can be made through statistically secured data (Alvesson and Sköldberg 2006).

Reliability means that two or more researchers studying the same phenomenon with similar purposes should reach the same results (Gummesson 2000). Both, Yin (1994) and Meriam (1994) find that 'reliability' of a study can be improved by assuring that the data collection procedure can be repeated with the same result. The objective of reliability is to minimize errors and biases. To secure the reliability, well-documented case studies are needed (Yin 1994). In this research project, a lot of emphasis has been on formulating and describing the research process (presented in technical reports and in papers). In that way, the conditions for the studies conducted have been explained, making replication more possible. This is a way of dealing with reliability. However, even if the studies are replicated several times, observations and measures can still be wrong (Meriam 1994).

Thus, when dealing with qualitative data and when the purpose is to understand concealed and deeper phenomenon, using concepts like generalisation, validity and reliability is not fully suitable in its traditional meaning. For instance, instead of using Yin's 'external validity,' it is possible to speak in terms of 'transfer of meanings to new phenomenon or systems', or 'expanding to new domains' (Alvesson and Sköldberg 2006). Or, as another alternative, it is possible to use Guba and Lincoln's (1989, pp. 236-243) criteria for judging evaluation adequacy: credibility, transferability, dependability, and confirmability. The criteria for credibility are parallel to those of internal validity. Transferability may be seen as parallel to external validity or generalisation. Dependability, in turn, may be seen as parallel to the concept of reliability. Finally, confirmability can be seen as parallel to the concept of objectivity. These criteria also have techniques for assuring research quality that correspond to traditional positivistic concepts of such assurance.

PART 2

The Theoretical Framework

Chapter 3

The Core of Product Development: Managing the Process

Chapter 3 describes the contextual setting for my research project, i.e., the first part of the theoretical foundation the research rests upon and has as its starting point. First, project management is discussed. Next, systems, product development models and processes are presented and discussed. Finally, related research on key factors is presented.

Projects: The Arena for Product Development

As described in *Chapters 1* and *2*, the theory base and scientific foundation for this research is many-faceted. It is influenced not only by engineering and design science, but also by social science, business administration and organisational theory. Project management is one important area that constitutes the arena for CPD.

The definition of what constitutes a project has changed over time. So has the view regarding project management. Before the 1950s, there were no generally accepted or defined methods for managing projects. During the 1950s, numerical methods were introduced to cope with large-scale projects in the USA. Lately, since the 1990s, a strategic approach has dominated. The strategic approach is a response to the large engineering projects with long timescales common during the time after the Second World War. Instead, swift projects with short timescales have created demand for the strategic approach. Time-to-market is now the predominate need.

In general, a project may be defined as an activity with a start and a finish that is non-repetitive (Maylor 2003). There are several associations that address project management knowledge. Two examples are the Association for Project Management (APM) and Project Management Institute (PMI). The PMBOK (Duncan 1996, p. vii) defines a project: "a project is a temporary endeavour undertaken to create a unique product or service".

Further, several standards have been developed to secure the quality of the process in projects. One of the most known is the ISO9000 standard, developed during the mid 1980s. Later, it was complemented with a standard for environmental systems, ISO14000. Many large companies also have their own standards that have to be followed by suppliers and contractors. One example is the Ford Motor Company (Maylor 2003).

A project may be seen as a transformation of an input into an output (see Figure 9). The project is conducted utilising a set of mechanisms, but is also limited by a set of constraints. The input may be a need or a demand from a customer or the market. The output is the product/service that satisfies that need. The main constraints are time (the time-frame of a project), cost (the budget for the project) and quality (the desired quality of the output or the process). However, these could be supplemented by other constraints, e.g. legal, ethical, environmental, logical, activation and indirect effect constraints. The mechanisms that enable the transformation process are humans, knowledge and expertise, capital, tools and techniques, and technology (APM 2000).

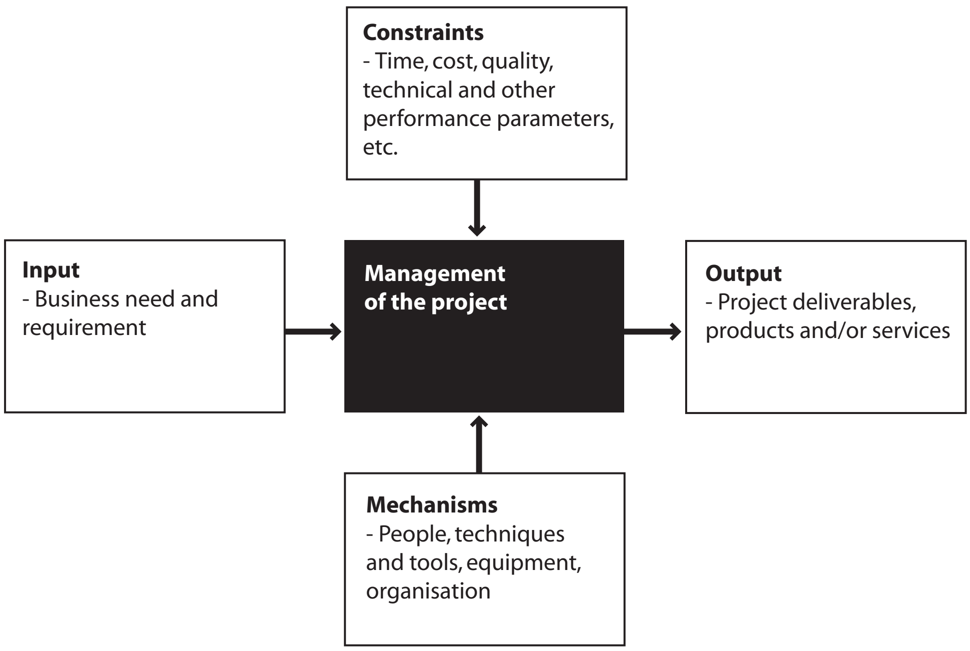

Figure 9 • The project management process as defined by the Association for Project Management (APM 2000).

There are mainly four phases in a project's lifecycle. Each phase encompasses activities. Maylor (2003) maintains the 4-Ds: define the project, encompasses conceptualisation and analysis. Design the project process, includes proposal, justification and agreement. Deliver the project, includes start-up, execution, completion and handover. The 'develop the process' phase concludes in a review and feedback. In each phase, several issues have to be managed. These issues could be classified into a 7-S framework (originally developed by McKinsey & Co. according to Maylor (2003)). The framework includes seven elements used for classifying tasks that also help reduce complexity in a project:

- Strategy – high-level requirements and means to achieve them
- Structure – organisational arrangement
- Systems – methods for work
- Staff – management of resources
- Skills – managerial and technical tools available
- Style/culture – relations and ways of working in the team
- Stakeholders – peoples or organisations with an interest in the process or outcome

A project environment may be summarised by complexity, completeness, competitiveness, and customer focus. As argued in *Chapter 1*, the complexity is increasing in product development projects, both in terms of technology and resources. Maylor (2003) presents three dimensions of complexity in projects: organisational complexity (the number of people, departments, organisations, cultures, etc.), resource complexity (the volume of resources), and technical complexity (the level of technology involved). It is important to state which type of complexity being dealt with, e.g. organisational complexity, technological complexity or resource complexity. Estimating these three dimensions in a project and multiplying them provides an estimated measure of the overall complexity of the project.

However, others have defined project complexity, e.g., Baccarini (1996) defines project complexity in terms of differentiation and interdependency. Further, Williams (1999) argues for a new paradigm for complex projects, stating that "…it is clear that classical project management techniques are unsuitable for dealing with complex projects". Existing techniques and models are argued not that is being suited to deal with feedback loops, systematic and holistic effects, and uncertainty, thus leaves us with a gap concerning project complexity and techniques for dealing with it.

Systems

Hubka and Eder (1996) introduce the Theory of Technical Systems (TTS). It aims to describe, explain and justify the object of designing, which is the product (e.g., a machine). Or as they refer to it: "the technical system to be designed". Here, in this thesis, it is the result from the collaborative product development project. The purpose of technical systems may be derived from the transformation system, which is about people's need and desire to reach a specific state. A transformation process operating on the current state results in obtaining the desired state. The transformation process may be divided into operations. Each operation delivers an output that is the input for the next operation. These operations may be conducted in sequence or simultaneously. Different operators contribute to the transformation process (e.g., humans, information, technology, an active environment, management and goals). Hubka and Eder (1996) conclude:

> Each technical system has therefore the task to deliver the desired effects (as outputs) at the desired time, and in a given environment, with a sufficient lack of sensitivity to secondary inputs (disturbances), and with an acceptable minimum of secondary outputs.

What Defines a System

There are different types of systems. For instance, the human body is a system, and there are technical systems, like machines. Production systems and an organisation may be seen as systems. Systems as a concept derive from the increasing complexity in society, in organisations and among products. Thus, CPD settings may be defined as a system. A system, e.g., a CPD project, is a set of components and the relationships among them. An organisation is an extremely complex system of interacting humans. Thus, a project may be referred to as a complex system (Argyris 1990; Senge 1990; Arbnor and Bjerke 1997).

Some examples of how to define systems are, in terms of, open and close systems, static and dynamic systems, or hard and soft systems. Open systems are studied in the context of their environment. An organisation should be treated as an open system that is influenced by its surroundings. The contextual setting influences the components in the system. A close system is isolated from its surroundings and is not influenced by the contextual setting. An organisation's many dimensions characterize it as a system. Examples of these include teams, personalities, values, norms, and attitudes. This is also the case for a project organisation. Using systems theory, it is possible to better understand an organisation and a project by simplifying it. The real system is used when the purpose is to describe the objective reality. A system model is used when the purpose is to describe a simplification of reality (Argyris 1990; Senge 1990; Arbnor and Bjerke 1997; Checkland and Scholes 1999).

Modeling a System

A model is a development of an existing theory. It aims to explain a particular part of the reality (Ejvegård 1996). There are many types of models, and each model describes a different aspect of the real system. The content of the system model is decided by how it is applied and by the level of details. Each model is only one of many possible aspects. It should be clear whether the system described refers to the real system or a model of the real system.

Each component in a system may be a potential system of its own. As a result, each system is a part of a larger system. Thus, a project may constitute a sub-system to the entire organisation or company. Consequently, the systems model developed may be more or less detailed and on different levels. There are also relationships between the components in a systems model. These can represent different flow of information, flow of material, etc. A systems model may include a time perspective. If it does, the state of the systems model is dynamic and represents a process perspective. The opposite to the process perspective is the structural perspective (Arbnor and Bjerke 1997).

An organisation, e.g., a CPD setting, is best described as a dynamic open system, with an input, an output, and transformation in-between (Argyris 1990). Humans, material and energy are the inputs, while products and services are the outputs. The activities individuals perform constitute the transformation process. Hubka and Eder (1996) adopt the product perspective in the TTS.

Further, the process perspective of product development, Theory of Design Processes (TDesP) will be described. Focus is on the process of designing a technical system.

Design Processes

The Theory of Design Processes is derived from the transformation process in technical systems. Hubka and Eder (1996) use the following definition:

> Designing means transforming the given problem statement into a full description of a technical system.

The goal of the design process and the result of designing are:

> …the optimal quality of the proposed technical system should be reached with respect to the given requirements for the technical system, but within a shortest possible design duration, lowest possible design cost, and considering the organizational constraints of the company.

Generally, a process can be described as a sequence of steps that transform input into output (Cross 1994; Ulrich and Eppinger 2003). Further, product development is argued to be the development of a new product[18] in conjunction with other departments (for example, production, distribution and sales). The processes of production development, product design, and marketing are preferably conducted in parallel (Andreasen and Hein 1987; Roozenburg and Eekels 1995).

A Brief Retrospective View

In former days, when products were rather simple and not that complex, one single person could develop and produce an entire product by her/himself. One person could have quite a good overview of the design process and the knowledge required to manage the process (Andreasen and Hein 1987; Ullman 2003).

In modern industry, the makers of the product are normally not the same as the designers of the product (Roozenburg and Eekels 1995). In the middle of the 20th century, the process of developing and producing products had become rather complex, requiring more than one person's ability. Around this time, companies started to organise the design process in different functions, market, development, production, etc. The different functions or departments were separated from each other. Information was sent between departments. However, little communication occurred between people in those different departments. Information about a product was sent from the market department to development and further to production in a sequential matter.

[18] A product is an artifact to be used by people for its properties and functions it performs (Roozenburg and Eekels 1995, p. 5).

Nowadays, this is known as the "over-the-wall" design process. The "over-the-wall" design process often led to products that did not fulfil the customer's wishes and requirements. This type of design process can be inefficient, costly, and may result in poor quality of the products (Ullman 2003).

In the 1970s and 1980s, the "over-the-wall" trend started to shift towards a more simultaneous process. It implied that the product should be developed simultaneously with the production system. This approach was called simultaneous engineering. In later years, this approach has been developed into what today is called concurrent engineering. CE is a systematic approach to the integrated, concurrent design of products and their related processes, including manufacture and support (Carlson-Skalak 2002). In the 1990s, Integrated Product and Process Development (IPPD) developed (Ullman 2003). Before that, IPD had been introduced by Olsson (1976) and Andreasen and Hein (1987). Concurrent engineering and integrated product development will be discussed further on.

In parallel with other approaches, during the Second World War, an approach for complex systems was developed in the military service. This approach came to be systems engineering (SE), which is a widely used approach in industry today (Kossiakoff and Sweet 2003; INCOSE 2004).

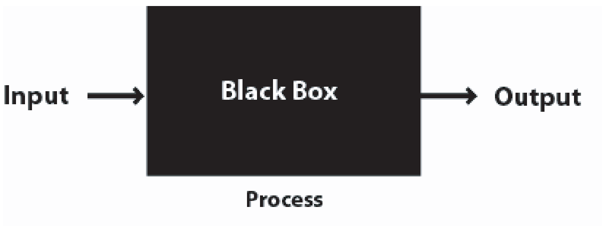

Figure 10 • The black box principle according to Cross (1994, p. 66). Here the process has replaced the function.

How to Describe the Product Development Process

Generally, a process can be described using the black box principle, with the following caveat: here the black box contains a process, not a function (see Figure 10) (Cross 1994). The product development process is different for each company that has one, although the similarities are extensive. Some organisations follow a precise process, while others have difficulty describing it, just as with the black box concept.

Models of the design process are mainly founded upon Simon's theory of rational problem solving from 1969 (Larsson 2001). Simon describes the process of solving problems in a sequential manner with the help of a model. The principles of product development are in many ways similar to his model of explanation: they are sequential and either descriptive or prescriptive (Cross 1994). In addition to Simon's model, the most common way of conducting product development for a long period was sequentially (see Figure 11). Often, this is also the case when small companies develop products today (Larsson 2001). The sequential process can be time consuming, money consuming, and inefficient, leading to a lack of competitiveness because of market introduction being delayed.

As product development demands a multidisciplinary approach, different disciplines have to contribute. Which disciplines depends on the characteristics of the product (Roozenburg and Eekels 1995). This is also the case with the design process. Depending on product and industry, the design process varies. However, the activities performed during a product design project can be structured in a generic way. The phases in a product's lifecycle can generally be described with four phases: product development, production and delivery, use and end of life. The product lifecycle as described by Pahl and Beitz (2005) is presented in Figure 12. Those phases can then be expanded into a process of activities (Ullman 2003).

Many attempts have been made to describe this generic process and the activities it comprises in the form of models. Next, this will be discussed.

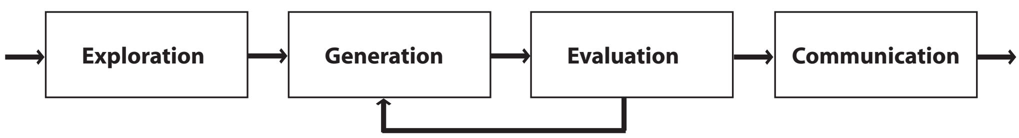

Figure 11 • A four-stage descriptive model of the design process by Cross (1994). This is a simple generalisation of the design process; it consists of iterations and results in the communication of the design to the manufacturer.

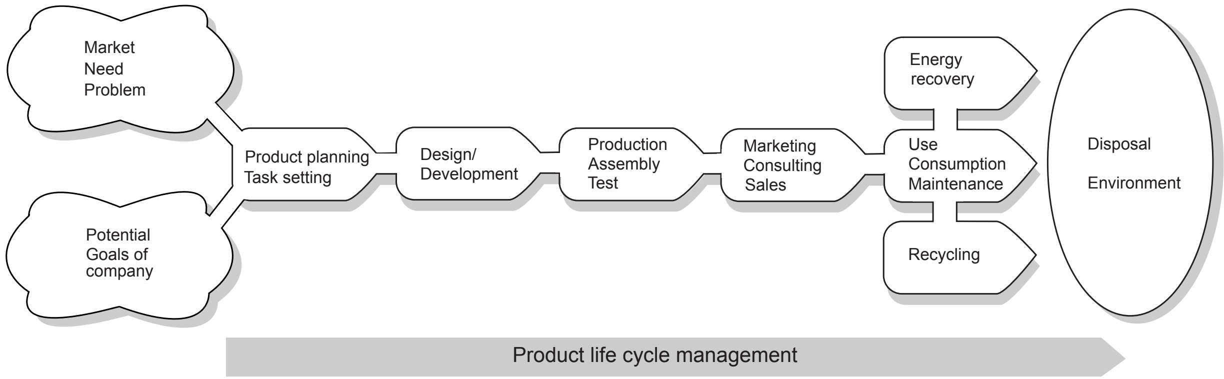

Figure 12 • The life cycle of a product, free after Pahl and Beitz (2005) (Illustration by S. Jonasson and H. Nerlund).

Process Models in Product Development

Models of design and development processes represent the structure of thinking and action in designing (Roozenburg and Eekels 1995). A model is an idealisation of reality (Andreasen and Hein 1987). In this context, it is a representation of the product development process.

Generic and Conceptual Models

Many of the models described in the literature are generic and conceptual, founded on a product's lifecycle. The product development process is a part of the product's lifecycle as presented in Figure 12. As discussed before, the product development process could be described in many ways. Often a representation in the form of a model is used to illustrate and make the process comprehensive. Further, a selection of these models will be presented and discussed.

Ulrich and Eppinger (2003) present a generic model of the product development process in six steps (see Figure 13). It consists of five main phases and one planning phase. In each phase, there is an opportunity to iterate back in the same phase or even to previous phases if new conditions are posed. Each phase produces an output that becomes the input to the next phase. The product development process is generic, but is most similar to a market-pull process (the product developed is based on market needs). The process has to be customised to fit each type of product developed or project conducted.

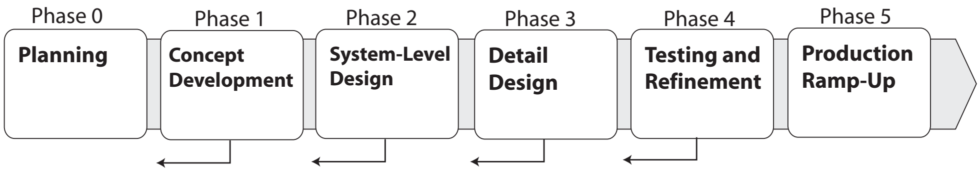

Figure 13 • A generic model of the product development process, free after Ulrich and Eppinger (2003).

Further, they argue that product development is an interdisciplinary activity requiring contributions from nearly all the functions of a firm. However, three functions are argued to be especially important, and should be engaged in parallel during the product development project: marketing, design, and manufacturing. Marketing facilitates the identification of product opportunities, market segments, and customer needs. It is the mediator between the company and its customers. Design is responsible for the physical form of the product, which includes engineering design and industrial design. Finally, manufacturing is responsible for the production system in which the product is produced. Manufacturing is comprised of purchasing, distribution and installation, activities that together are sometimes defined as the supply chain.

Ullman (2003) also presents a generic model of the design process (Figure 14). Ullman asserts that there are generally five phases, consisting of tasks and reviews that have to be accomplished in a mechanical design process:

- Project definition and planning
- Specification definition
- Conceptual design
- Product development
- Product support

Further, gate-models are widely used in Swedish industry. Cooper (2001) has conceptualised Gate-models into a trademarked Stage-Gate™ process. The Stage-Gate™ process is an operational and conceptual model for moving a product development project from idea to launch. It includes eight key goals and fifteen critical success factors (Cooper 2001). Cooper argues that the process is a blueprint for managing product innovation, effectiveness and efficiency. The process consists of a set of predetermined stages. Each stage starts with a checkpoint, a gate. These stages are: discovery, scoping, building the business case, development, testing and validation, and launch.

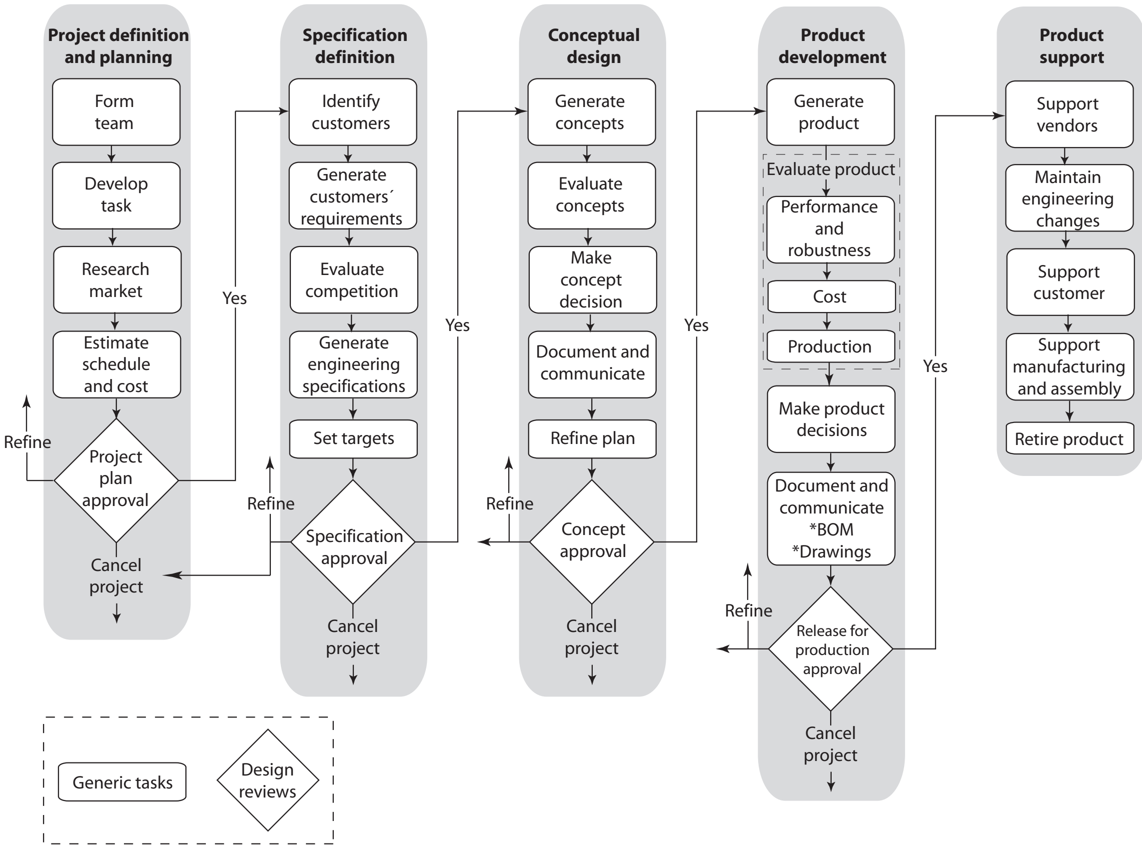

Figure 14 • The mechanical design process. Free after Ullman (2003).

The gates, which serve as quality control of the process, have the same format independent of where in the process the gate is. The gates consist of deliverables, criteria and outputs. The Stage-Gate™ is argued as being a macro process – an overarching process, in contrast to project management, a micro process. Project management methods, however, are applied within the stages of the Stage-Gate™ process. The Stage-Gate™ process is dependent on a cross-functional team. That is, people from different departments work in parallel during a project.

Models for the Integrated Development of Products

As described earlier, many product development approaches of today adopt an integration perspective. Many disciplines co-operate and interact during the development of a product. As argued earlier, the ideal integration of a product development project is when one person alone performs the project. However, this is not an option due to the complexity of product development activities today. Besides the linear organisation, many larger companies have a project organisation, usually with several ongoing projects simultaneously, each having temporary resources and separate project leaders. Cross-functional teams with representatives from all the departments execute the activities in each project (Prasad 1996). In this way, the process of developing a product becomes collaborative and simultaneous. Several approaches have developed simultaneously within this perspective. Concurrent engineering and integrated product development are two of them.

Concurrent engineering

The original definition of concurrent engineering was developed in 1986 by the Institute of Defense Analysis (Carlson-Skalak 2002, p. 4):

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

Many other definitions have been developed since then. Carlson-Skalak (2002) has listed some of the attributes that characterize a CE design process:

- Customer focus and involvement
- Early and continual involvement of suppliers in the design process
- Cross-functional, self-directed, empowered teams
- Incremental sharing and use of information
- Systematic and integrated approach
- Concurrent design teams
- Early use of Design for X tools
- Use of modern tools such as CAE, CAD, CAM, FEM, etc.
- Continuous improvements of all processes

Concurrent engineering, widely used in industry, is an overall definition of the integrated development of products conducted in a collaborative environment. Organisation and management support have an integrated way of working. In it, supporting tools are being used for product development and collaboration and where a relevant use of information systems is present (Norell 1992; Prasad 1996).

What is essential in CE is to increase collaboration between different functions in the product development process, thereby bringing new knowledge into the product. It is particularly important that functions not usually considered as having a close connection to the product design (e.g., marketing/selling) are involved early in the process. Then the product can be adjusted to their demands. However, to integrate those functions in practice is evidently difficult. Ultimately, many companies fail to do so. The early involvement of manufacturing is also one of the main purposes when adopting CE (Norell 1992).

The main benefit from CE is often said to be development and production lead-time reduction and, in addition, reduction of time-to-market. It also results in quality and engineering process improvements. The list of benefits can be made long in the cases when CE is fully implemented. However, mixing CE with sequential processes may cause problems and a loss of efficiency. The implementation should be done with the full commitment of management (Carlson-Skalak 2002).

The CE process may be divided into five stages: project planning, product design development, production process development, production preparing, and production service, where product design development and production process development occur simultaneously.

Integrated product development

Integrated product development is, according to Andreasen and Hein (1987), an idealised model of the product development process. IPD highlights the interfaces between marketing and design and design and production as problem areas that have to be dealt with. According to Prasad (1996), IPD's different phases are conducted corresponding to each other with early involvement of all departments (engineering design, manufacturing, marketing, etc).

IPD is addressed to companies characterized by the Western project philosophy. Corresponding to Western philosophy, IPD is carried out in teams by engineers who are specialists in an area. IPD is built on the belief that no single person can possess the necessary knowledge and experience for the task of developing a product. It is intended for companies with several organisational levels and which experience problems getting overall objectives and strategies established. This means that the organisation has grown to a size which necessitates its division into functions, departments, divisions, and so on. Thus, IPD mainly applies to medium-sized or large organisations. Small organisations can benefit from IPD, especially from the integration part. IPD is not limited to a specific product or market (Andreasen and Hein 1987).

The IPD process starts with a need situation, whether the idea is radically new or not. Throughout the process, there are three parallel main areas: market and sales, development and design, and development, establishment, and production. These three areas are divided into five phases that have to be passed before the product is finished. In addition, an initial phase precedes these five phases': the recognition of need.

The other phases are (1) investigation of need, (2) product principle, (3) product design, (4) production preparation, and (5) execution (see Figure 15). The IPD model by Andreasen and Hein differs somewhat from the original model of IPD by Freddy Olsson (Olsson 1976; Mekanförbundet 1985). However, it is built on the same principles. The main difference is that Andreasen and Hein exclude the area of Business and Economics from the model. They assume that a company about to use IPD already has established product development and, therefore, already has a well established financing (Andreasen and Hein 1987).

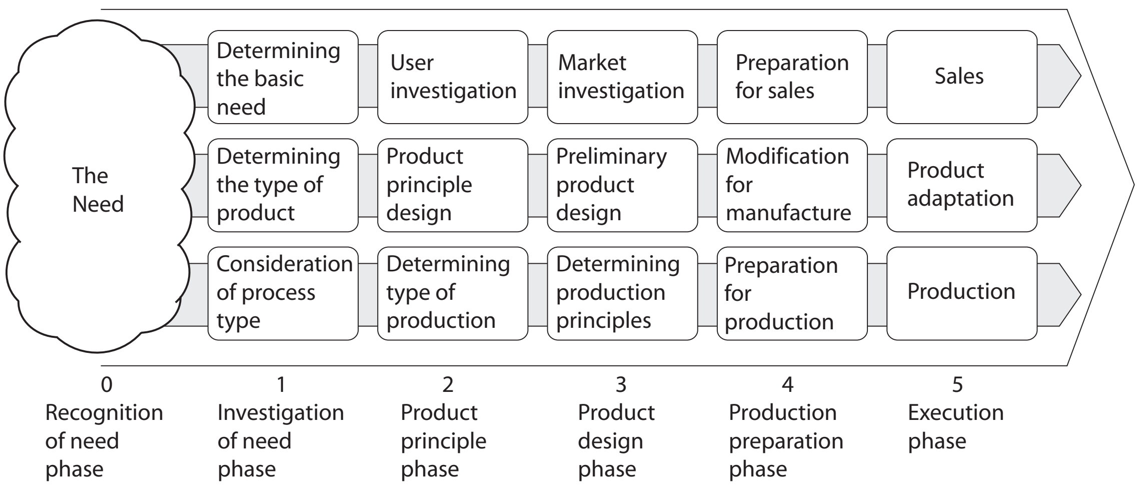

Figure 15 • The model for integrated product development. Free after Andreasen and Hein (1987).

Models for Complex Systems

During the Second World War, in the context of the arms race, great pressure was put on military service and civil contractors. During this time, tools and techniques were developed to support the increasingly complex systems and the project organisations supporting the systems (Kossiakoff and Sweet 2003; INCOSE 2004).

Systems engineering

The rapid growth of technology during the 1950s, 1960s and 1970s forced systems engineering into the market. Soon, processes were standardised, and a new discipline was created (Kossiakoff and Sweet 2003; INCOSE 2004). Like with concurrent engineering there are many definitions of systems engineering, but they all have the complex system in common:

> Systems Engineering is an interdisciplinary approach and means to enable the realization of successful systems (INCOSE 2004). Systems Engineering is about creating effective solutions to problems, and managing the technical complexity of the resulting developments (Stevens et al. 1998). The function of systems engineering is to guide the engineering of complex systems (Kossiakoff and Sweet 2003).

According to INCOSE (2004), systems engineering integrates elements of many disciplines, such as system modelling and simulation, decision analysis, project management and control, requirements development, software engineering, specialty engineering, industrial engineering, specification writing, risk management, interpersonal relations, liaison engineering, operations analysis, and cost estimation. Moreover, Kossiakoff and Sweet (2003) imply that systems engineering bridges the traditional engineering disciplines, making systems engineering differ from engineering in general. Besides bridging disciplines, systems engineering differs in several other ways. A systems engineer emphasizes the total operation of a system and guides (e.g., selecting the path for others to follow), rather than executing activities.

Kossiakoff and Sweets (2003) argue that systems engineering may be seen as an inbuilt part of project management, where the systems engineering part aims to guide the engineering part of a project, e.g., setting objectives, guiding its execution, and evaluating results. It serves as a support for the management of planning and control. However, literature within the field also advocates systems engineering as the dominant approach, with project management as a dependent part of systems engineering (Stevens et al. 1998). Regardless, systems engineering and project management should be seen as two parts interacting in the process of developing complex systems.

In systems engineering, the V-model is commonly used to explain the verification and validation process in the development of a complex system (see Figure 16). The V-model puts the activities conducted during the development process in relation to a project (INCOSE 2004). The left hand of the model shows the definition, decomposition, and validation process, while the right hand of the model shows the integration and verification process. The purpose of the verification process is to confirm that the specified design requirements are fulfilled by the system developed. The purpose of the validation process is to provide evidence that a system produces services that comply with the stakeholders requirement (Strandell 2005).

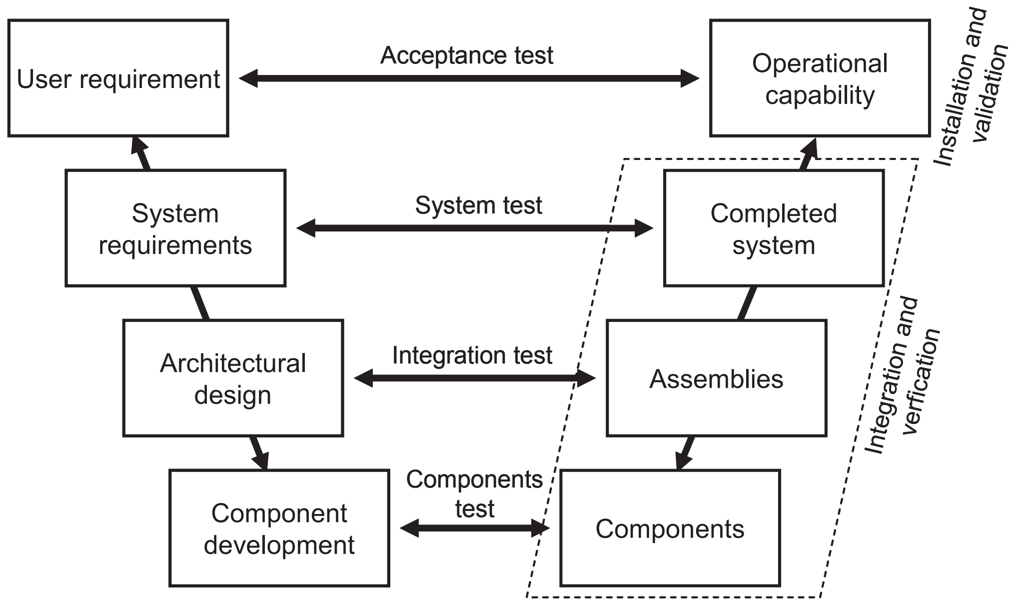

Figure 16 • The 'V'-model in systems engineering: integration, verification and validation of requirements, adapted from Stevens et al. (1998).

Other Approaches

Besides the well-known approaches and models presented here, there are those that have been hived off and developed separately. One of those approaches is Dynamic Product Development (DPD).

Dynamic product development

The dynamic product development theory was founded on the belief that a company's product development process will always be dynamic with no clear boundaries between the different phases and iterations between them will always exist. Ottosson (1999) demonstrates the need of a more situation-adjusted process. DPD originates from IPD theories as presented by Olsson (1976) and Andreasen and Hein (1987), and is basically about developing qualitative products in a dynamic and resource efficient way. The major difference between IPD and DPD is the user focus. In IPD, it is the customer that is paid attention to. In DPD, the main focus is upon the end-user and the usability. There are both similarities and differences between DPD and CE at detail level. In DPD, the user is in focus, while in CE the customer is. As for IPD and CE, DPD takes an integrative approach, a dynamic innovation organisation, where the project leader also is a board member (see Figure 17) (Ottosson 2006). Further, the DPD approach promotes that a minimum staff is used for each activity. Thus, the number of peoples in the product development project will vary. Consequently, having the right number of staff in each phase means higher efficiency and lower costs (Figure 18).

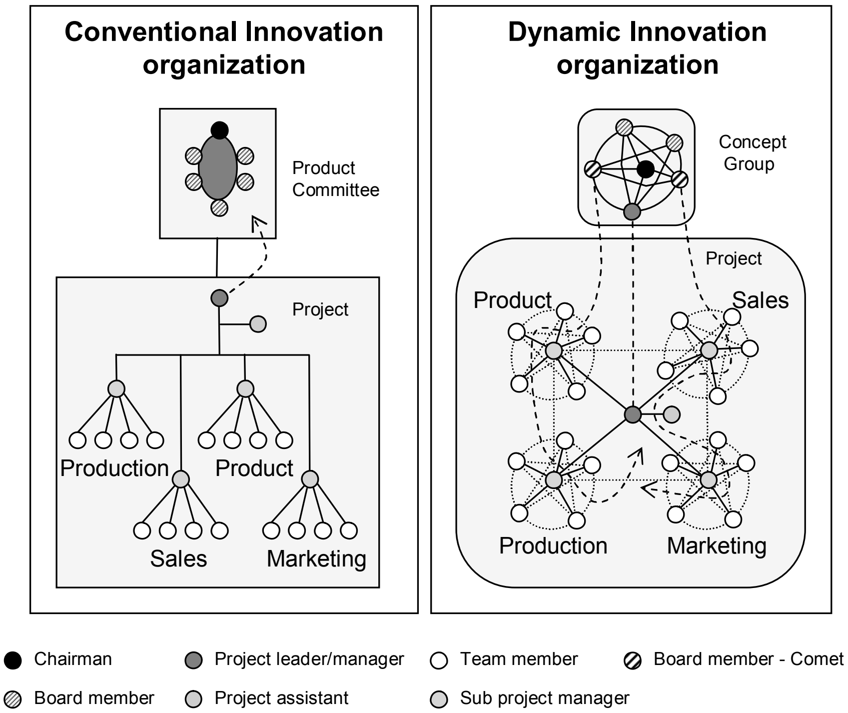

Figure 17 • Differences between conventional innovation organisations and the dynamic innovation organisation. Reproduced with permission of the author (Ottosson 2006).

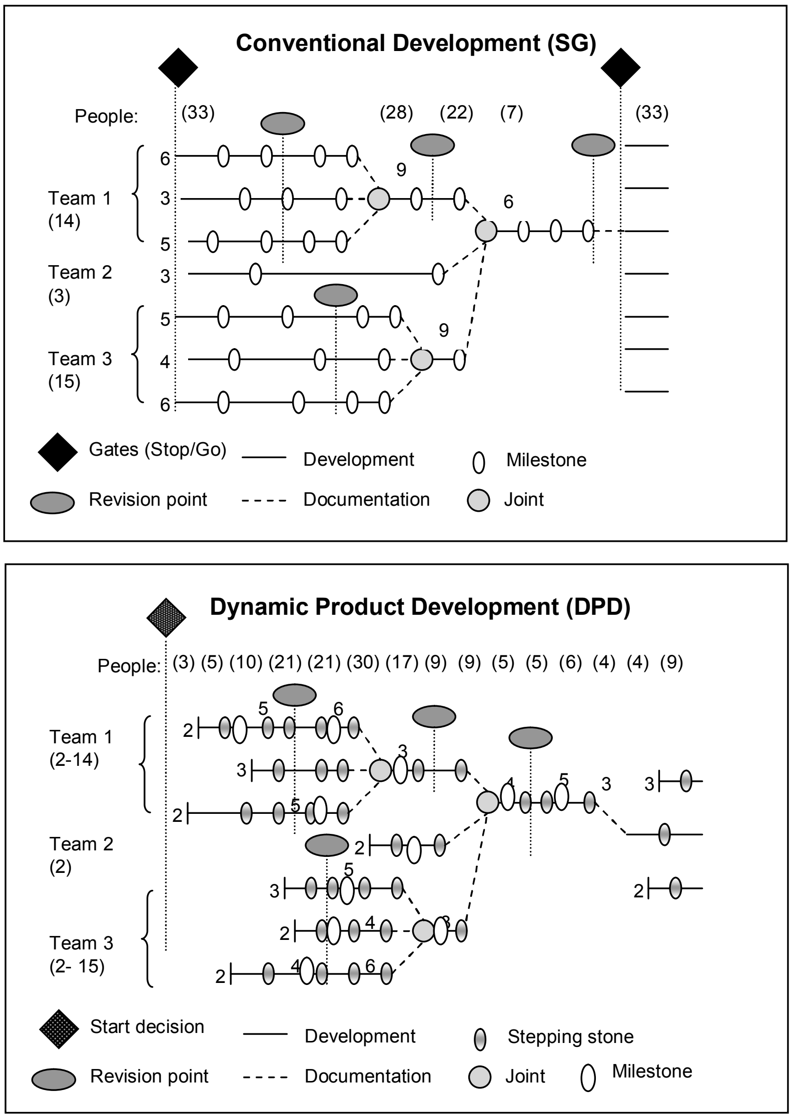

Figure 18 • Differences between conventional development and the dynamic product development approach regarding teams and team members. Reproduced with permission of the author (Ottosson 2006).

The concept DPD was established in the 1980s and has been developed further since then. DPD is mainly supposed to be used for the development of radical products and where there are no known solutions to use in the development (in other words, when creativity is an important feature in the process). Ottosson champions a holistic theory that combines known theories and solutions. The creativity comes first, before a comparison to existing solutions and patents. DPD includes rules of thumb that in some ways differ from other product development methodologies. It is not important in which order different tasks are being performed in DPD. Rather, the importance is that they are carried out. With this approach, problems like bottle-necks are reduced.

In parallel with Ottosson's approach, a dynamic view of integrated product development has been developed, mainly in Germany. Vajna and Burchardt (1998) argue for dynamic thinking when adopting integrated product development.

Lean product development

Lean Product Development, has its origin in Japan, and the Toyota Production System (TPS). Lean production has been the entrance to the lean philosophy, a philosophy including much more than production. The Lean Enterprise (LE) is a holistic approach towards continuous improvements and learning, long-term thinking, waste reduction, and teamwork.

Lean product development emerged from Lean-thinking at Toyota in Japan. Lean-thinking was applied to product engineering to gain competitive advantages. Toyota formed new types of teams with strong leaders, new career paths, and new reward systems. Strong team players were rewarded rather than people with brilliant competence in a single area such as product, process or industrial engineering. The lean engineering approach led to leaps in productivity, product quality, and responsiveness to customer demands. Companies applying lean product development are argued to provide wider range of products, shorter model cycles, and reinvestment in new technologies (Womack et al. 1990).

Like in several of the product development approaches presented so far lean product development demands an integrated approach and commitment from marketing, purchasing, engineering, manufacturing and suppliers, e.g. internal as well as external integration of actors (see Morgan and Liker 2006). It also includes several techniques that correspond to collaborative product development thinking. Karlssson and Åhlström (1996) argue for some of those techniques, for instance early and deeper involvement of suppliers - black box engineering (see Fagerström and Jackson 2002), cross-functional teams, and strategically management.

Summary of Product Development Approaches

An extensive theory base exists within this area, and not all theories can be applied. An attempt is made to sum up this chapter by structuring some of the different approaches, models and processes. This is done in Table 2. In the table, the content of the different authors' approaches are categorised. As may be seen in Table 2, there are no clear boundaries between the different approaches, processes and models. Many of them merge. They have much in common. All include variants of the following phases: recognition of need, planning, concept development, detail design, testing and validation, production preparation, and launch.

Table 2 • A summary of the different product development theories discussed in this chapter and how they relate to different approaches.

Authors	Type of Process	Phases	Focus
Ulrich and Eppinger (2003)	Product design/Generic	1 Planning 2 Concept Development 3 System-Level Design 4 Detail Design 5 Testing and Refinement 6 Production Ramp-Up	Marketing, design and manufacturing
Cooper (2001)	Stage-Gate	1 Discovery 2 Scoping 3 Building the business case 4 Development 5 Testing and validation 6 Launch	The quality of execution, market-orientation, resource focus. The gates where the decisions are made.
Ullman (2003)	Generic	1 Project definition and planning 2 Specification definition 3 Conceptual design 4 Product development 5 Product support	General approach
Andreasen and Hein (1987)	Integrated Product Development	1 Investigation of need 2 Product principle 3 Product Design 4 Production preparation 5 Execution	The interfaces between product design, production and marketing.
Ottosson (1999)	Dynamic Product Development	1 Concept development and administration 2 Product development 3 Process development 4 Marketing and sales 5 Production	Creativity and end-user. Dynamic organisation.
Carlson-Skalak (2002)	Concurrent Engineering	1 Project planning 2 Product design development 3 Production process development 4 Production preparing 5 Production service	The interaction between product development and production. IT-tools.
Cross (1994)	Generic	1 Exploration 2 Generation 3 Evaluation 4 Communication	General approach

Cooper (2007) argues that the focus of projects has shifted from technology development towards product updates, and modifications during the past 15 years. One reason is the short-term profits. The Stage-Gate™ process, for instance, is intended for new product development projects, not platform projects[19], fundamental research projects[20], or radical innovations. Thus, to categorise and determine the type of projects may be important for identify the preconditions for a project.

Key Factors in Product Development

This part introduces the reader to factors commonly described in product development literature. One should keep in mind the following: success at the business level may differ from success at the project level (Cooper and Kleinschmidt 1996). Depending on how a study is designed and which level the authors choose to focus on, the resulting key factors will vary.

Much has been written about factors for success and failure in product development literature, and there are a wide range of factors influencing the outcome of product development (Johne and Snelson 1988). Twenty years ago, Link (1987) identified factors influencing product development. Examples included: products offered significant cost savings and benefits for user, well managed development stages, adequate stock availability to meet demand, etc.

Since then, focus has shifted more towards organisational factors. Ten years later, Balachandra and Friar (1997) have undertaken an extensive survey mapping key factors in product development. After reviewing over 60 articles and studying whether there is a general agreement on factors leading to success or failure in product development, the findings showed four major categories and some 72 factors in existing literature. The major categories were: market, technology, environment, and organisation. Balachandra and Friar (1997) also suggest that there are contextual variables for success or failure in product development. They include the nature of innovation, the nature of market and the nature of technology.

[19] A platforms project is built on capability. The capability spawns many new products projects. Thus, it is much quicker and more cost effective than starting from scratch each time (Cooper 2001).

[20] Fundamental research projects are those where the deliverable is new knowledge. There is no specific or defined new product in mind in the beginning (Cooper 2001, p. 151)

Table 3 • Overview of key factors in new product development (NPD)

Link (1996)	Cooper & Kleinschmidt (2001)	Cooper (2001)
Compatibility of new product with marketing skills	A high-quality new product process	Unique superior product
Product offered significant cost savings and benefits for user	Adequate resources of people and of money	Strong market orientation
Post-launch conditions close to forecast	A defined new product strategy for the business unit	Look to the world product
Appropriate targeting and pricing	Commitment to R&D spending	Pre-development work
Adequate promotion and advertising	The use of high-quality cross-functional project teams	Sharp and early project definition
New product compatible with technical and production facilities	Senior management commitment	Well-conceived and properly executed launch
Acceptable post-launch product quality	An innovative climate and culture	Right organizational structure, design and climate
Well-managed development stage	Senior management accountability for new product results	Top management support
Product required little change in behavior or attitudes of user		Leveraging core competencies
Market was large or rapidly growing		Market attractiveness
Level of external market research		Go/kill decision points
Product extremely novel		Controllable new product success – completeness, consistency and quality
Stock availability adequate to meet demand		Resources in place
Level of competition in the market		Speed is everything (not on the expense of quality)
Product could be tried on small scale		A multistage, disciplined new product process

The factors presented by Cooper (1987) and Cooper and Kleinschmidt (1996) are on a business unit level (used in the Stage-Gate™ model). Those factors include sharp and early project definition, top management support, go/kill decision points, the use of high-quality cross-functional project teams, and senior management commitment (see Table 3). To identify those factors on a business-unit level, Cooper and Kleinschmidt (1996) use a framework consisting of five blocks of characteristics for measuring new product success or failure. The blocks are the following:

- Process – the firm's new product development process and the specific activities within this process
- Organisation – the way the project is organised
- Strategy – the firm's total new product strategy
- Culture – the firm's internal culture and climate for innovation
- Commitment – senior management's involvement with and commitment to product development.

Finally, other authors that later addressed key factors of product development are Connell et al. (2001) and Ledwith (2000). Ledwith (2000) presents categories similar to both Cooper and Kleinschmidt (1996) and Balachandra and Friar (1997). Those categories are organisational factors, development process factors, marketing and new products characteristics, and skills and capabilities.

Further, Connell et al. (2001) presents a model of how critical factors influence project success (see Figure 19). They present five important factors that must be managed to succeed in product development:

- Executive direction – top management support and participation
- Project team – employing strong project cross-functional team
- Innovation strategies – using an appropriate strategy for each different case
- Internal factors – to obtain correct internal infrastructure and organisational design
- External factors – such as economics, political, customers, creditors, etc.

The emphasis is on securing the management support, to have the "right"-people needed, to have the appropriate strategies, and understanding the environment.

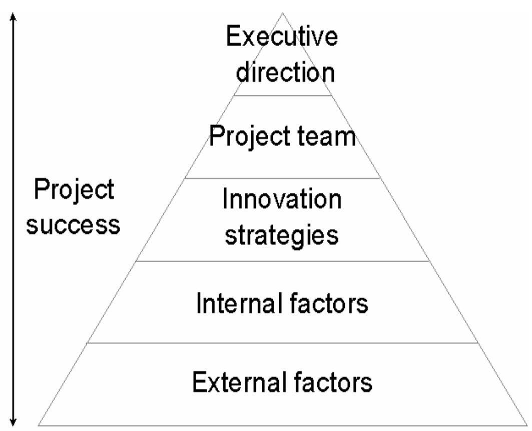

Figure 19 • The pyramid of critical factors. Factors that there must be competence in and consideration of in a project in order to succeed (Connell et al. 2001).

Key Factors in Collaborative Product Development

Littler et al. (1995) addressed the issue of key factor contributions to successful collaborative product development by conducting a survey in the UK manufacturing industry (information and communication products). Several questions were addressed in the study. Examples include the effect of collaboration on product development, the risks of collaborative product development, and factors affecting the outcome of collaborative product development. It was concluded that, for this specific sample (106 companies), collaboration was not considered to have a positive effect on product development. The main risks identified were leakage of information, loss of control, longer development time, and conflicting aim and objectives. The main factors affecting the outcome of collaborative product development were identified as:

- Frequent consultation between partners
- The relationship perceived as important by all parties involved
- Existence of a 'collaboration champion'
- Benefits perceived as evenly distributed
- Collaborating partners contributing as expected
- Substantial degree of trust between collaborating partners

The last four factors were of unique or heightened relevance for collaborative product development projects in particular. The first two were strongly associated with product development success in general and could not be associated with a collaborative setting specifically.

Chapter 4

The Product Development Process: a Collaborative Setting

This chapter aims to describe the collaborative setting that this research project is a part of. Three main items will be discussed. First, reasons and challenges for collaboration are presented. Internal collaboration is also discussed thus, with a focus on collaboration and integration within an organisation. Second, external collaboration is discussed thus, with the focus more on different actors involved and organisational forms employed for external collaboration. Last, an integrated approach towards internal and external collaboration in product development is presented.

Why We Should Collaborate in Product Development

People have always, in some way, collaborated and built relationships to survive. The relationships may be between individuals or between groups of individuals; what is essential is that individuals interact. For hundreds of years, favours and favours in return have been a way to deal with problems.

An argument from Booz, Allen & Hamilton Inc. is "…a new age of collaboration", and that allying with others is necessary to win in the constantly changing marketplace (Harbison and Pekar 1995). Increased demand from the global market on companies to provide technical innovations and maintain cost efficiency has consequently resulted in an increased complexity of different relationships (Leek et al. 2003a). Collaboration provides an opportunity to handle these increased demands.

In the endeavour to save time and reduce costs, collaboration in product development has expanded during the last decades. Many companies, especially small ones, seem to understand the benefit from collaboration and share resources, which may be rewarding in the process of developing products. Few companies can evaluate and cover all possible competitive positions and new designs all on their own. Thus, companies may choose to outsource some of their functions. Outsourcing important activities (e.g. to suppliers or customers) demands functioning collaboration between the parties involved (Quinn 2000). However, outsourcing in its traditional form differs from CPD by the level of partnership, as collaborative companies are linked in the process of delivering the final solution to the intended customer or the user (Product Development Management Association 1996). Nonetheless, adopting a wider perspective on collaborative product development by including both internal and external collaboration in product development paves the way for new approaches and insights.

Information, communication and collaboration

Collaboration is dependent on communication between individuals. To have collaboration, in the easiest form, communication and exchange of information is needed. To exchange knowledge, a higher level of collaboration is needed (see Nonaka and Takeuchi 1995). For collaborating at a distance, Pettersson (2002) presents a usable information model (see Figure 20). Depending on how distributed the collaboration is, different means of communication is needed.

Means of communication, thus collaboration, may for instance be in its simplest, but very efficient form, face-to-face meetings, moreover, telephone, fax, e-mail, video conferencing, the Internet, Intranets, Extranets, online workspaces etc. (see for instance Park and Favrel 1999; Sosa et al. 2002). Although we are a part of the "information age", engineers in design teams prefer manual and verbal methods of communication to acquire information. This suggests that human relationships will still require face-to-face meetings and informal connections.

But, when collaborative product development involve actors located at remote places, it is clear that there is a need of other means and methods to communicate, e.g. online workspaces (Court et al. 1997; Court et al. 1998; Leek et al. 2003). During collaborative product development via for instance an online workspace, the different actors are not passive receivers of information, the actors are taking own actions in finding the information they need. In an online workspace the information provider can be the actors or the project manager, and the other actors, the members of the team, can be both providers and interpreters of information.

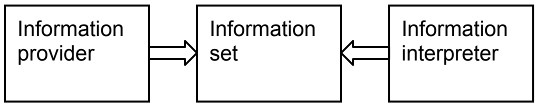

Figure 20 • An information set model describing communication. An information provider makes one or more information sets available for people who need the information, information interpreters (Pettersson 2002).

Reasons for Joining Forces

There are many reasons for why we choose to collaborate. It may be as a part of a sourcing strategy or an urgent need for complementary resources. Some of these reasons, commonly presented in the literature, are introduced below (Quinn 2000; Elmuti and Kathawala 2001; Hoffmann and Schlosser 2001):

- Growth from creating and entering new markets is among the top reasons for collaboration, especially in terms of partnerships and alliances. Cooperation with a company already established in a desired market is an attractive alternative.
- Obtain new technology, best quality or cost, and specialist talents. Companies search for complimentary skills, to learn from each other, and to improve competitive advantages.
- Reduce risks and share costs. Many companies find the financial risk too great for a single company to undertake. In such cases, companies can come together and agree to spread the risk among them.
- Speed. New ideas and innovations may be introduced to the market faster if parts of the innovation process are outsourced or collaboration with more flexible and agile companies established (for example, small companies).
- Resource limits. Collaboration (e. g., the formation of alliances or close collaboration with suppliers) helps in overcoming lacking resources relative to future needs. The competitiveness within the alliance is obtained through externally provided resources, synergies, and by facilitating fast learning and changes.

As can be seen above, there are many motives for collaboration. In 1995, Bruce et al. (1995) described the view of collaborative product development as an effective means of reducing development time and lowering organisational risk. However, collaborating in complex processes like product development is not easy. A collaborative product development environment does not always ensure success, and there are many challenges related to it.

Challenges when Collaborating

There is a need for collaboration, but the complex situation apparent when two or more companies work closely together makes it difficult to manage. There are numerous challenges when working in a collaborative setting involving different actors. Depending on the subject for the collaboration, the challenges may differ. Some challenges related to collaborative settings are presented next (Davenport and Prusak 1997; Wit et al. 1998; Elmuti and Kathawala 2001; Wynstra et al. 2001):

- Shared cost and profits. The first is one main reason for collaboration. However, there will most likely be disagreement regarding who is responsible for what costs. Further, there may be disagreements when sharing profits in alliances.
- Organisational cultures and social behaviour. There may be differences or undefined operation procedures and attitudes that may lead to mistrust. Engineers who feel threatened may undermine the integration process with, for example, a supplier.
- Trust, communication and risk sharing. Building trust takes time, and one can only trust a person, not a company. This may lead to unclear agreements and different expectations.
- Common goals, objectives and definitions. One of the goals in the collaboration will most likely dominate, and other goals will become secondary. Common definitions are crucial within and between organisations for a common understanding and transfer of information and knowledge.
- Coordination. Lack of coordination is especially crucial if it appears between management teams.
- Information systems. Incompatible information systems between actors in the collaborative setting may cause problems. One example of this is different CAD-systems.
- Technical capabilities, knowledge and skills. One actor’s in-house technical capabilities may differ from another actors’ expectations.

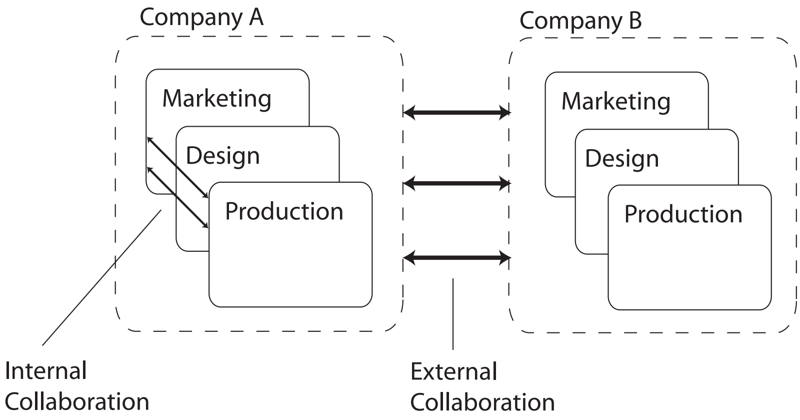

Figure 21 • How the two approaches, internal and external collaboration, differ in terms of focus. The picture is schematic. Several other functions obviously exist within a company.

As for the reasons for collaborating, the challenges for collaboration are many and diverse. Some arise especially when having a main and sub supplier cooperation, some when joining an alliance, and so forth. Further, two approaches towards collaboration are discussed, internal and external collaboration (see Figure 21).

Internal Collaboration

Internal collaboration can be referred to as the interaction between individuals and functions within an organisation, e.g., the collaboration between design, manufacturing, and sales (Hillebrand and Biemans 2004). As shown in Figure 21, internal collaboration is commonly associated with the collaboration between marketing, design and production. However, there are many more functions or actors within an organisation that are influenced by and influence the process of developing products.

Integration of Functions

Internal collaboration has always been associated with communication problems when it comes to an organisation focusing on product development. Collaboration has changed over time depending upon the type of product development process that is applied. Lately, the entry of integrated product development and concurrent engineering has influenced the way of organising, from functional organisations to project or matrix organisations, with a high degree of interaction between functions (Hillebrand and Biemans 2004).

Integrated product development by Andreasen and Hein (1987) has a clear focus upon internal collaboration during product development. Integrated product development is described under the assumption that there are five areas of integration:

- Market, product and production tasks must be solved at the same time.
- Three timeframes shall be satisfied: reaching targets, long-term planning, and the result of product development, running production and sales.
- To create an agreement about aims, means and results among people from different levels in the company (strategic, tactical and operational).
- Interplay between different product development projects, a controlled project portfolio.
- Controlled interplay between development activities.

Integration differs from coordination, integration is a means to coordinate activities and functions in the product development process. Coordination refers to the mapping of activities and monitoring of deliverables (Öhrwall-Rönnbäck 2002). The ideal integration in an organisation is one person managing everything. However, this model is evidently not applicable. When a company is growing, it will inevitably be separated into functions. The purpose is usually to ensure the most appropriate competency and knowledge within each function (Andreasen and Hein 1987). This is, for instance, something confronting a growing small company. Splitting the company into manageable functions may be a barrier for those small companies.

Several variables may distinguish different projects in a company. Examples include the area and degree of renewal and the degree of in-house/outside development (Andreasen and Hein 1987). In nearly every product development project, internal collaboration occurs. An in-house project may have the lowest level of collaboration (e.g., between R&D and production). Integrating activities between those functions may be sufficiently difficult.

Cross-Functional Teams

Integrating functions by establishing cross-functional teams is a popular approach for managing internal collaboration. Different studies, however, have gained conflicting results as to their effects. McDonough (2000) presents an overview of relevant literature on the subject. The review reveals that functional diversity in cross-functional teams is negatively related to project performance on the one hand. On the other hand, studies have shown that functional diversity helps speeding up the product development, especially in its early phases. Thus, it is not evident that simply combining different functions into a team guarantees success. There are many more mediating factors when managing cross-functional teams (McDonough 2000).

Further, an overall conclusion from a number of studies is that collaboration may turn out to be successful in quite a few different ways (Hillebrand and Biemans 2004). However, a poor interplay between functions may have severe consequences for the eventual outcome. For instance, lack of respect between functions may result in poor decisions. One person may pretend to understand the market needs without respecting the competency and knowledge marketing and sales possess. A product's functions may be decided upon, without the support from design and a review of the technical possibilities (Andreasen and Hein 1987). These are all issues related to the collaboration and integration between functions within an organisation.

Further, there are many theories concerning key factors dealing with internal collaboration. Some important aspects when dealing with internal collaboration in the form of cross-functional teams are presented below. In several ways, these aspects coincide with the challenges for collaboration in general (Prasad 1999; McDonough 2000; Carlson-Skalak 2002; Starbek and Grum 2002; Hillebrand and Biemans 2004):

- Communication. Boundary people who transfer information between groups and organisations. The communication can be improved through training and social activities.
- Expertise, senior management support and champions. The right expertise from functional areas and supporting senior management.
- Team leadership. Leadership has the purpose of balancing expertise and creativity for the good of the team, being an enabler and empowering the team to make decisions.
- Team behaviour. Team behaviour includes cooperation, commitment, ownership and respect.
- Resources. The purview of the management and methods or strategies for handling conflicts.

If taking cross-functional team one step further, we starting to approach the concept of virtual teams.

External Collaboration

Lately, information technology has made it possible to collaborate over great distances (e.g., virtual teams). Virtual teams differ from cross-functional team in terms of the distance between the members of the team (geographically dispersed) and comprise members from different functions, organisations, and cultures. Geographic distance usually has a negative impact on product development efforts. However, there are both challenges and opportunities when working in distributed environments (Larsson et al. 2003).

Further, three enabling conditions for virtual teams have been identified by Gibson and Cohen (2003):

- Shared understanding. In terms of commonality in beliefs and expectations about goals, processes, tasks, skills, and so on.
- Integration. How different systems and structures may work together to create value.
- Mutual trust. Shared psychological state and acceptance of vulnerability based on the intentions of the team.

Many studies have focused on external collaboration in terms of the supply chain, i.e., buyer-supplier relationships. Further, customer partnerships (Souder et al. 1997; Campbell and Cooper 1999) and how to manage these forms of collaboration (Hillebrand and Biemans 2004) have also been studied. The more complex the products are, the more complex the relationships (Leek et al. 2003), internal as well as external. Collaboration between companies has developed into a powerful tool to increase competitiveness, especially within complex and turbulent environments (Hoffmann and Schlosser 2001). However, external collaboration places substantial pressure on the organisation. The external partners bring different levels of complexity into the organisation. Many main suppliers are reforming their operations, moving towards external collaboration as their key activities.

Integration of Actors

Sub-suppliers become more important as they develop and produce an increasing amount of the components for the end product. Research shows that companies become more reliant upon the suppliers during the product development process (Peter 1996). Projects are being carried out where suppliers have full responsibility for the development of a product (in other words, development projects with suppliers integrated). The customer-supplier interface now plays a key role in the design and development of new products. This results in sub-supplier influence on product price, performance, and quality to an ever-increasing degree. It also shows that suppliers are a vital source of knowledge and know-how, and can make significant contributions to a company's overall performance (Peter 1996). However, it is likely that the potential for integrating suppliers is not used to its full potential (Culley et al. 1999).

Early supplier involvement (ESI) is often applied when the main supplier provides a certain knowledge or skill. The timing when involving sub-suppliers is crucial for a main supplier. Generally, sub-suppliers can be involved in four different phases in the product development project, with different roles to play. The role of the sub-supplier in the concept phase can be active, with discussions about specifications, functions and interfaces, or more passive for evaluation purposes. Later, selection of suppliers is often used when the main supplier finalises a complete specification or functional specification. This results in less potential for sub-suppliers to influence the design (Fagerström and Jackson 2002). Fraser et al. (2003) presents a collaboration framework and a collaboration maturity grid to be used for assessing collaborative activities in a company in terms of four maturity levels. The framework and grid are applied on a strategic level. Further, Hammer (2007) presents a process and enterprise maturity model, where the maturity of the organisation is evaluated and rated against four maturity levels. Five process enablers and four enterprise capabilities are argued for; where of the including mechanism is integration.

Cross-functional collaboration can have the form of ad-hoc liaison for supplying parts, to full integration (Wynstra et al. 2001). Fagerström and Jackson (2002) present an integration model for main and sub-supplier collaboration (see Figure 22). The model shows that sub-supplier integration may occur on different integration levels. The level depends on when the sub-supplier is integrated in the main supplier's process. Four integration levels are discussed: closed specifications, detail engineering, concept selection, and concept/ technology development.

Involving the customer in the development of a new product is one outcome of a company's willingness to understand the customer's need. Findings show that, in a short-term perspective, customer involvement in product development has no commercial benefits compared to in-house development (Campbell and Cooper 1999). There may be other incentives for partnering with customers (for instance, long-term strategic ones). However, to fully benefit from customer involvement companies have to invest in relevant competencies enabling customer integration (see von Haartman and Bengtsson 2005). There are also reasons to believe that there are other mediating factors affecting performance in such contexts (Campbell and Cooper 1999). For instance, mergers and acquisitions may influence the relationship between a company and its customer or suppliers (Anderson et al. 2001).

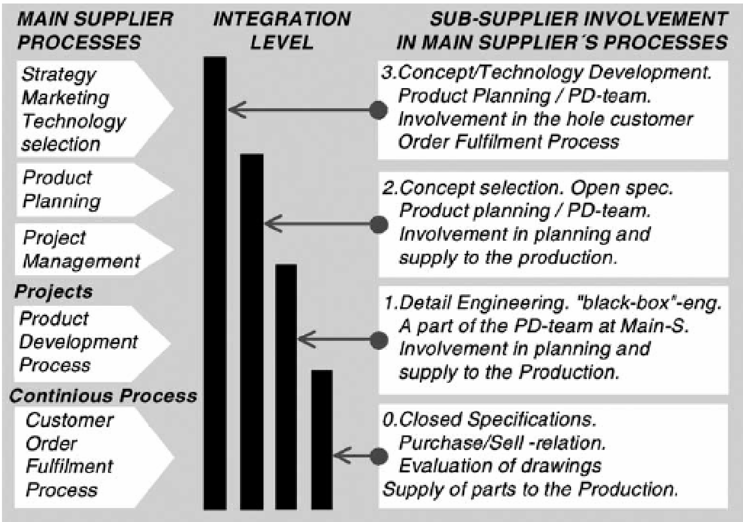

Figure 22 • The integration model for main and sub-supplier collaboration by Fagerström (2004). Reproduced with permission of the author.

Organising for Integration

Different forms of collaboration are commonly administrated using different organisational settings. Alliances, strategic or industrial, are a popular organisational setting for collaboration today, much more than some decades ago (Harbison and Pekar 1995). One of the most common forms of collaboration is the traditional vertical relationship between main and sub-suppliers in which the main supplier is dependent upon the competence of the sub-suppliers. In contrast, an alliance involves companies that are organised horizontally (horizontal relationship) (Wheelen and Hunger 2000). Alliances are in general temporary and normally created when a company is in need of resources that are vital for the development and survival of the company and that cannot be procured through purchasing or obtained internally (Axelsson and Easton 1992; Hoffmann and Schlosser 2001). When a company looks for a partner to join in an alliance with, it must have something to offer and seeks complementary or similar resources (Ahuja 2000; Perks and Easton 2000). Perks and Easton (2000, p. 332) argue:

> It is when the main goals of the relationship become strategic resource acquisition, rather than buyer-seller exchange, that the situation becomes one that is described as a strategic alliance.

Sub-supplier networks are rather common these days. As business relationships generally evolve over time (long-term perspective), networks are generally based upon trust, with the mutual goal of gaining complementary resources to strengthen the involved companies' market positions. However, actors may come and go in networks, making them dynamic (Axelsson and Easton 1992; Anderson et al. 1998; Anderson et al. 2001; Elmuti and Kathawala 2001; Hoffmann and Schlosser 2001). The collaboration has to provide new opportunities for a company or an organisation and result in an output demonstrating synergy. An industrial network may be based upon equality between the companies involved (Porter 1990).

The form of communication and social interaction defines the network. A network has to be understood and analysed recognising it as a system in its entirety and respecting the fact that its boundaries are fuzzy and difficult to handle. Often enough, somewhat informal ways of collaborating may occur, implying an exchange of information, people, and social norms. Networks help management by integrating means of communication with external actors as well as internal (Axelsson and Easton 1992). Håkansson and Ford (2002) describe a network:

> In its most abstract form, a network is a structure where a number of nodes are related to each other by specific threads. A complex business market can be seen as a network where the nodes are business units – manufacturing and service companies and the relationships between them are the threads. Both the threads and the nodes in the business context have their own particular content.

Small companies that collaborate often do so with organisations located in their surroundings. Collaboration often, but not necessarily, takes form of informal networks. The interaction between two or more small companies is both businesslike and social, and requires mutual norms and values regarding social behaviour as an important factor (Larsson 2001).

The Relationship between Internal and External Collaboration

Internal collaboration plays an important role in the organisation. When internal collaboration works well, it provides benefits to not only internal interfaces, but also external collaboration. Some researchers conclude that good internal interfaces are a prerequisite for effective external collaboration. Thus, the level and quality of internal collaboration have to be coordinated with both internal and external demands. This means that external collaboration have to be coordinated internally in order to be successful (see Hillebrand and Biemans 2004). Hillebrand and Biemans (2004, p. 112) conclude that:

> …with limited external cooperation, the organisation's hierarchy may be sufficient to coordinate the external relationships. With more extensive external cooperation, the hierarchical structure will prove to be ineffective, and direct cooperation among the departments involved is required to alleviate the stress on the organisation's hierarchy. Some firms go even further by making key external parties full-fledged members of the internal cross-functional new product development teams.

They also conclude that there exists at least four links between internal and external collaboration. These are: (1) internal collaboration to coordinate external collaboration; (2) similarity between internal and external collaborative norms; (3) external collaboration stimulating internal collaboration; and (4) organisational learning. Further, they argue for a relationship coordinator that should be responsible for coordinating relationships in an organisation or within a project. These relationship coordinators should be responsible for internal and external relationships.

Interfaces in Collaborative Settings

The collaborative product development environment is complex, and does not always ensure success. On the contrary, collaboration can make product development more costly (Littler et al. 1995). Collaboration in product development has many faces and occurs on different levels. Types of collaboration in the context of a product development project include several interfaces that have to be managed. Different actors should be coordinated and their activities integrated (for Design for Integration, DFI, see Browning 1997).

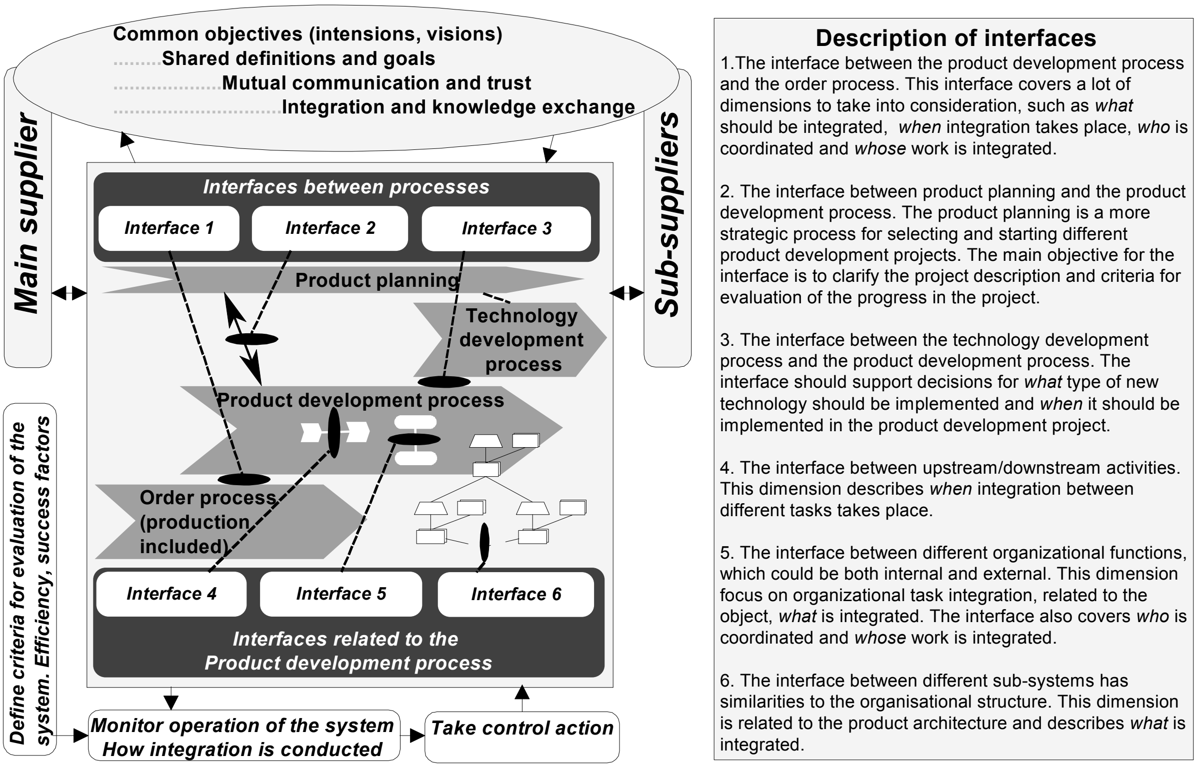

Figure 23 • The interface model for interpretation of main and sub-supplier collaboration by Fagerström (2004, p. 77). Reproduced with permission of the author.

Fagerström (2004, p. 77) has developed an interface model for main and sub-supplier collaboration in product development. Six interfaces are identified and related to two areas: interfaces between processes and interfaces related to the product development process (see Figure 23).

The six interfaces are as follows (Interfaces 1-3 are interfaces between processes, while interfaces 4-6 are related to the product development process): (1) the interface between the product development process and the order process, (2) the interface between product planning and the product development process, (3) the interface between the technology development process and the product development process. (4) the interface between upstream/downstream activities, (5) the interface between different organisational functions, both internal and external, and (6) the interface between different sub-systems.

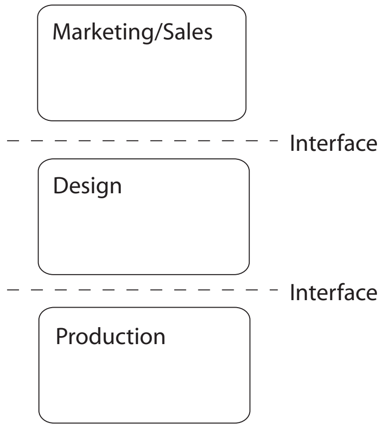

Figure 24 • Interfaces between three different functions within an organisation.

There is some degree of collaboration, internal as well as external, in nearly every product development project today. Thus, there is a need to integrate functions within an organisation (Sherman et al. 2005) and coordinate actors in collaborative product development projects. The more complex the product is, the more competencies (thus, people) have to be involved. Andreasen and Hein (1987) argue that when products and, consequently, the organisation become more complex, the development process evolves from a sequential process towards an integrated process (IPD). In an integrated product development project, there are several interfaces between organisational functions to be managed: marketing, design and production (see Figure 24).

Concurrent engineering holds a similar approach to integration. It aims to manage interfaces between marketing, design and production. The integration is facilitated by cross-functional teams and supported by an information system for managing knowledge, information, and data (Norell 1992; Prasad 1996). This is especially important when managing interfaces in virtual and distributed teams. Further, Lundin et al. (2006) consider the design-manufacturing interface (DM-interface) important. Andersson (2007) presents a framework for integrating logistics during the product development process, specifically addressing the interface between logistics and product development. Lately it has also been addressed by Johansson (2006) and Bramklev (2003). Further, Klevås (2005) has introduced the concept *Design for Packaging and Logistics (DfPL)*. This is also an area that Ottosson (2006) champions. The interface between product development and logistics, see Figure 25.

Several methodologies presented in *Chapter 1* argue for the early involvement of suppliers. Suppliers are external actors in a product development project from the main-supplier's point of view. Main and sub-supplier collaboration occurs in nearly every product development project. Sub-suppliers become more important for the main-supplier as they develop and produce parts of a system (Karlsson et al. 1998). The sub-supplier may be a part of a supplier network. The companies are nodes in the network, and the relationships (the interface) between them are threads (Håkansson and Ford 2002). This introduces us to another interface, the one between two or more suppliers in the form of networks.

Involving the customer in the development of a new product is an outcome of a company's willingness to understand the customer's need. The interface between a company and its customer is well covered in literature and generally positive. Besides suppliers and customers, there may be other actors to collaborate with and needed for integration. Frequently, consultants are involved in product development projects. Consultants bring another dimension of complexity and interface to the collaborative setting. The consultant is often temporary involved in an organisation, and the limited timeframe implies a delicate problem. Moreover, there are occasions when companies decide to collaborate with their competitors.

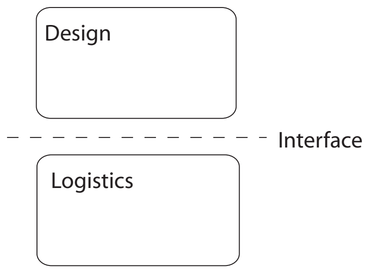

Figure 25 • The interface between design/product development and logistics.

Chapter 5

The Collaborative Product Development Setting: Key Areas

As described in the two previous chapters, many factors influence the outcome of collaboration and product development. Consequently, factors influencing collaborative product development constitute a mix of the two. This chapter will address more thoroughly some of the factors and issues discussed earlier. The theory on, e.g., decision-making and strategies, is extensive. Thus, the chosen literature is linked to my research project. Lastly, there will be a concluding summary of the theory base presented in Chapters 3-5.

Key Areas in Collaborative Product Development

In product development, several areas may be considered as key. This section will further address some of those in detail, starting with organisational behaviour.

Organisational Behaviour

Porras and Robertsson (1992) state that four areas affect peoples' behaviour at work and in organisations (Figure 26). It may be referred to as a behaviour setting. The behaviour setting is a system (Westlander 1999) in accordance with Barnard's definition of the organisation as a system.

As an organisation is defined through its interlinked activities or interlinked behaviour, not through its individuals, the entire organisation will be affected if one factor in the system is changed. Four areas are argued for as affecting people in an organisation: organisational arrangements, social factors, physical setting, and technology. The organisational arrangement includes goals, strategies, structure, administration policies and procedures, administrative systems and reward systems. Social factors include culture, management style, interaction processes, informal patterns and networks, and individual attributes. The physical setting includes space configurations, physical ambiance, interior design, and architectural design. Technology includes tools, equipment and machinery, information technology, job design, workflow design, technical expertise, technical procedures, and technical systems. These factors, together with the environment, influence the system (Porras and Robertsson 1992).

Environmental uncertainty is important for rationality. An organisation is interdependent with its environment, and the system is instable due to external changes in the environment (Barnard 1938; Thompson 1967). The organisation reacts to its environment with observation and interpretation. Furthermore, the environmental context is not given; rather, it is defined according to performance and interpretation. Therefore, as organisations are embedded in their environment, which is continually changing environment continually influences the organisation (Pfeffer and Salancik 1978; Argyris 1990; Cyert and March 1992). A fundamental task for an organisation is how it can efficiently deal with information and decisions in an uncertain environment (Nonaka 1994).

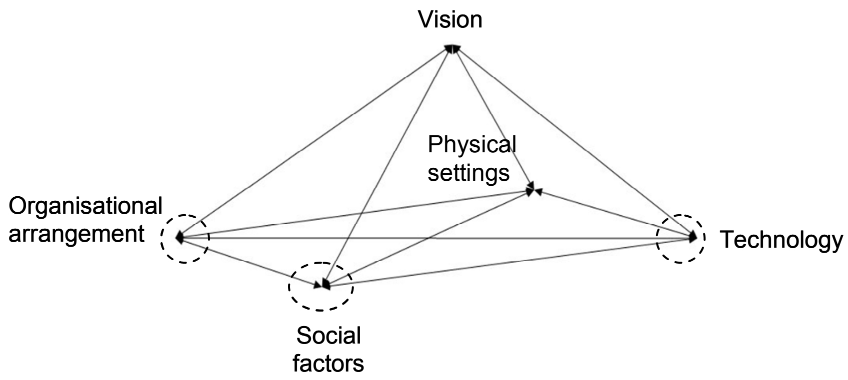

Figure 26 • The organisational work setting by Porras and Robertsson (1992).This thesis mainly covers the three areas highlighted in the figure.

Decision-making

During the product development process, hundreds of decisions are made. Some decisions may be related to the product development organisation, e.g., team staffing, reward systems, metrics for performance, and tools and processes for product development. Some to the product-planning phase, e.g., product mix, project prioritising, choice of technology etc. Others are related to the project management, e.g., timing and sequence of development activities, milestones, prototypes, coordination among team members etc.

(Krishnan and Ulrich 2001). Methods and tools may support many of those decisions, however not all.

Ullman (2001) argues that it is important to emphasis decision-making because a decision is a commitment to use resources, and that decision-making is key to managing the design process. However, decisions made early in the design process have a great impact on the committed costs of the project, and there are a lot of noise influencing those decisions. Design changes in the later phases due to poor decision-making can be very expensive. In particular, inappropriate decisions regarding the production of the product could potentially be very expensive. The product planning and the engineering process requirements become one of the company's most important priorities.

Simon[21] (1997) argues that the decision-making is the heart of administration, and that the administrative process is a decisional process. Co-ordination and communication are central to the decision-making process, and decisions are dependent on each other. Organisational decisions are based on assumptions, incomplete information, few alternatives, and conflicting demands. Group behaviour needs adoption of decisions and coordination. There has to be coordination of the organisation itself, and coordination of the members in the organisation. Moreover, each activity has to be coordinated.

An organisation is constantly exposed to a large number of alternative behaviours, conscious or unconscious. Constantly, a number of decisions have to be made. The task of making the decisions includes: the consideration of all alternative strategies, the determination of all the consequences that follow upon each strategy, and the evaluation of these consequences (Simon 1997).

An organisation's strategy and goals may be established in a top-down manner where top-level management push the overall strategy or goal down in the hierarchy. In this way, feedback from the operative staff has problems reaching the top-level management. Consensus about the organisation's long-term strategy and goals may be reached through a bottom-up approach, where top management has an active dialogue with operative staff. Values and norms direct the decisions made in an organisation. Thus, to establish strategies and goals in the entire organisation becomes vital for the organisation and the efficiency of the employees.

[21] First published in 1947, i.e., Simon, H. A. (1947). *Administrative behavior: a study of decision-making processes in administrative organization*. New York: Macmillan.

As Simon (1997) argues, the physical task of carrying out an organisation's objectives falls on the person at the operative level, the lowest level of the administrative hierarchy. The non-operative staff of an organisation influences the decisions of the operatives. In a small organisation, this influence may be direct. In other organisations, there are several levels of intermediate supervisors in-between. Each decision a person in the organisation makes involves a goal and a purpose. The goal and purpose differ depending on the level in the hierarchy.

Strategies and Goals

Strategy as a tool for success is widespread. It may be described as a set of plans and policies by which a company aims to gain advantage over its competitors. Generally, a strategy includes plans for products and the marketing of them to a particular set of customers (Skinner 1969).

Outsourcing, for instance, is a strategic decision. It may aim to gain competitive advantages by letting a partner or a supplier do the assembly of a product or parts of the development, i.e. the decision to join an industrial alliance can be both strategic and non-strategic. A strategic decision differs from a non-strategic decision in terms of where and how the decision is made. The decision ought to be made in the top-level of an organisation to be strategic. It should be long-term and well analysed, and agree with the business or corporate strategy. To choose not to have a strategy is also a strategy.

The business strategy is broken down into several functional strategies that enable a linking of the business strategy to low-level goals and activities. The product or market strategy in a company addresses what product will be offered, who the target customers will be, how the product will reach those customers, and why the customers will prefer our products instead of the competitors (Wheelwright and Clark 1992). Within manufacturing industries today, the emphasis often is to work reactively, by being operationally efficient rather than strategically effective. Managers must begin to think and act strategically instead of only in a reactive manner (Hill 1995).

Strategic decisions involve making trade-offs. As such, the essence of strategy is choosing what not to do. Without trade-offs, there would be no need for choice and thus no need for strategy. Making trade-offs in a project, for instance, is a prioritisation of the goals and objectives of the project (Maylor 2003). Organisations should put effort into actions concerning building and setting goals. However, the task of building and developing support for common goals within a project with people from diverse functions or different companies is not an easy task. A company's goals and objectives need to be made more explicit, linking across different strategies, both on a tactical and an operative level.

Product and Project Planning

Product planning is a crucial activity closely linked to product strategy. Product planning ought to decide the number of product platforms, enhanced products, and new product introductions (Wheelwright and Clark 1992). Product planning is closely linked to project and project portfolio management. If the strategy is carried out in the traditional way, the strategy is only a concern for senior management, implemented in a top-down manner. Having a more holistic, strategic approach implies a close link between the organisational and the project strategy, as the project level provides input to the organisational strategy (Maylor 2003).

The product planning phase occurs before the traditional development process (i.e., before the 'investigation of need' phase in Andreasen and Hein's process model). The project portfolio is decided upon with the purpose of providing an appropriate mix of projects. Examples include research projects, breakthrough development, platform development or derivative development (Wheelwright and Clark 1992).

Johne and Snelson (1988) argue for mainly three types of product development projects: development of existing products (revision), development of existing product based on known technology, and development of new product based on new technology. Cooper (2001) exemplifies three types of product development projects: platform development, new product development projects, and fundamental research projects (which aim to develop new knowledge). Similarly to Johne and Snelson (1988), Shenhar and Dvir (1995) classify projects based on the level of technology:

- Low-tech, e.g., known technology
- Medium-tech, e.g., some new technology or feature, still low level of technology uncertainty
- High-tech, e.g., integration of new technological, high level of technological uncertainty
- Super-tech, e.g., new or emerging technologies

The planning of products/projects eventually ends up in the execution of projects and the need to implement the strategies, goals and other plans. The end product ought to correspond to the goals, the product strategy and thus the business strategy. So far, presented areas are closely linked together in the management of projects. To link the strategy, goals, and product planning to the product demands a well-defined requirement management process is needed.

Requirement Management

The activities linked to managing requirements when developing a product depend to a great extent on the product being designed and produced and on the actual design process applied. However, some generic activities can be identified: establishing product requirements, documenting requirements, and following up on requirements (Andersson 2003).

Developing a complex product implies the complex management of requirements from different stakeholders. The design of a product often starts with some general project objectives and a set of stakeholder needs. The stakeholders (internal or external) act according to their interest and use their power to influence the product in the direction they desire. An important internal stakeholder is production. In order to get a well-balanced product, it is necessary to take a broader approach, considering not only end-users, but also all the other stakeholders throughout the product's lifecycle (Nilsson and Fagerström 2001). The stakeholders' different needs and the product strategy and goals will be translated into more detailed requirements and constraints. The production department (a stakeholder) will generate requirements that will impact on the product and its production. However, production requirements are important and should not be seen as constraints on what the designer can do. Rather, they should be looked upon as enablers (Nilsson and Jackson 2004). To enable the implementation of production requirements into product development, extensive communication and information exchange is needed.

Information and Communication

Much information is circulated in an organisation. Information is transferred between teams, functions, machines, and so on. The success of a company is dependent on how well product design information is managed and communicated (Eppinger 2001).

In product development, there is a desire to create useful information to be used in activities. The information is valuable if it decreases the risk in the product development process. However, the quality of the information is difficult to determine. It takes time to identify the output from the information (1997). In a world where collaboration and interaction are common, the transfer of information and the creation of new knowledge are most important. The fast changing environment of today puts great pressure on well-functioning collaboration between product development and production in a manufacturing company. It also places substantial pressure on the tools, methods and processes used for the communication and transfer of knowledge. Browning (Browning et al. 2002) argues that the key to managing interfaces in integrated product teams (IPT) effectively relies upon the interaction among IPTs and functional groups, and the smooth transfer of information across these interfaces (see also Öhrwall-Rönnbäck 2002).

Communication is widely discussed within management literature dealing with collaboration, and is especially important in internal collaboration (Norell 1992; Prasad 1999; Carlson-Skalak 2002; Starbek and Grum 2002; Hillebrand and Biemans 2004). As internal and external collaboration are closely linked, thus, communication is used to stimulate the collaboration with external partners. According to Ahnfalk and Lindström (1997), communication is one of the most important factors for success in inter-organisational relationships. Therefore, it is important to obtain efficient communication in relationships. Creating a solid foundation of business values can further do this. Having a functioning system (management, information processes, etc.), the right tools (computers, software, etc.), qualified staff that has the ability to communicate and interpret the values of the company, and to use the systems and tools can also serve to this end.

Teams rely to a great extent on supporting technologies for communication (Hinds and Weisband 2003). Focusing on manufacturing industry, there often exist as many approaches of how knowledge could be created, transferred and stored, as there are functions in a company. It has been claimed that it is a common misunderstanding that technology alone will solve information problems (Davenport and Prusak 1997).

Information and communication systems

To manage the product development process when collaborating involving different actors, there is a need for supporting methods and tools. As a company, you may out-source, in-source, or apply distributed product development as main and sub-supplier collaboration to increase efficiency and productivity. Such collaborative product development is often supported by an information or communication system (Quinn 2000). As a member acting in a collaborative product development setting, you would have a need for a functioning, supporting tool to realise well-functioning communication. Such a tool should manage both synchronous and asynchronous communication between actors (Törlind 1999).

Communication systems of today have enabled much better coordination of highly dispersed activities than before (Quinn 2000). The popularity of the Internet and its potential has opened doors for web-based communication tools (for instance, online workspaces and virtual workspaces). Different means of electronically based communication such as telephone, e-mail, video conferencing, Internet, Intranets, and Extranets[22] increase the options for collaborative product development, especially when the development is distributed and when activities are co-ordinated and product information developed and communicated. Sosa et al. (2002) present drivers and barriers for technical communication[23] in dispersed product development teams. Their results show that the frequency of technical communication is driven by or positively influenced by interdependence among teams and the organisational bonds the team feels. However, the findings also demonstrate that distance, time-zone difference, and cultural/language differences are barriers. Independent of communication means used, the communication frequency decreases with the distance.

Knowledge Transfer and Experience Reuse

Working with product development and production in industry brings forward several problem areas concerning how to deal with the need to create, transfer and store knowledge. Knowledge is, according to Davenport and

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[22] Park and Favrel (1999) define an extranet as a platform for accessing information, similar to an Intranet. Park, K. H. and Favrel, J. (1999). Virtual enterprise - Information system and networking solution. *Computers & Industrial Engineering*. 37(1-2). pp. 441-444.

[23] According to the Society of Technical Communication (www.stc.org, 2003-09-22), technical communication is defined as "Effective communication for a technical world."

Prusak (1997), valuable information from the human mind that includes reflection, synthesis, and context. It is hard to structure and difficult to capture on machines. Knowledge is often tacit and difficult to transfer. Within an organisation, there are huge amounts of information that has to be stored and transferred between systems, between humans, and between systems and humans. The communicated information may be seen as one person's experience and knowledge that has to be interpreted and understood by others. Nonaka (1994) argues that the way organisations process information in an input-output way is static. Learning within an organisation is dependent on an individual's knowledge creation process, involving the creation of both tacit and explicit knowledge.

Senge (1990, p. 63) argues: "Cause and effect are not closely related in time and space". Thus, as we learn from experience, but seldom experience the consequences of our decisions within an organisation, there is a problem. Explicit knowledge is easily transmitted, processed and shared. In a manufacturing company, product information such as requirements are documented and stored in the requirement specification. Sketches and drawings are developed and stored using different CAD-tools and PDM-systems (product data management). Explicit knowledge may also be exchanged during face-to-face communication at seminars, gatherings, etc. However, a great deal of the information and knowledge in a company cannot easily be grasped or stored. Tacit knowledge has to be transferred through interactions between individuals. However, it may be translated into explicit knowledge (see Figure 27). This process involves transferring an abstract concept into a thing and thus needs metaphors to facilitate the translation (Nonaka 1994).

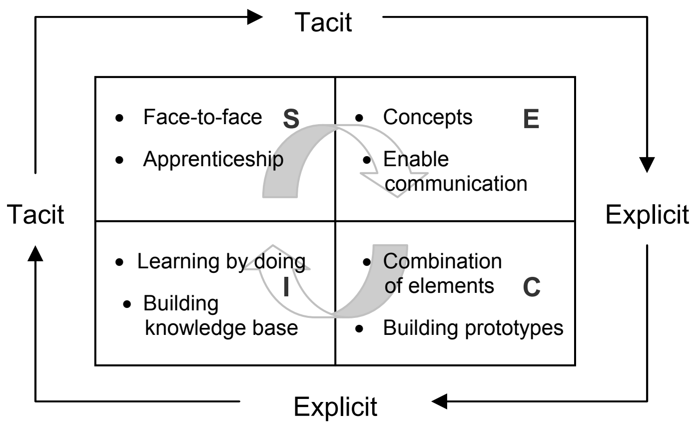

Figure 27 • The SECI-model (Nonaka and Takeuchi 1995), where the four knowledge conversion modes are described. From tacit to tacit, tacit to explicit, explicit to explicit and explicit to tacit knowledge. The conversion is done in different contexts, between individuals (S), collective (E), in groups (C) and on-the-job training (I).

Artificial intelligence in knowledge management

Methods and techniques from Artificial Intelligence (AI) have been used for knowledge management purposes for quite a while. For instance, expert systems met with high commercial interest in the late 1980s (Nurminen et al. 2003). Nokia Research Centre developed a range of expert system applications between 1986 and 1990. One of the applications was design synthesis. The idea was to collect design rules from experienced engineers, thus allowing the transfer of the knowledge to more inexperienced people. This turned out to be very difficult. Updating and maintaining design rules became a problem (Ibid.). It is important to keep in mind that expert systems will not provide useful knowledge if the knowledge changes too fast to maintain or if experts are unable or unwilling to reproduce what they know (Davenport and Prusak 1997). These limitations are sometimes referred to as "the knowledge acquisition bottleneck".

Intelligent agents are able to independently search for information that has a high likelihood of being relevant for a specific user. Agents are also able to take initiative and notify the user if there is new information of high relevance to the user available. Agent technology can play an important role in the knowledge management of an organisational decision-making process. It can do so by making it possible to transform conventional search and integration mechanisms with self-adaptation ability to day-by-day needs of decision-makers. They learn and improve over time, and are able to automatically analyse incoming information, documents, PMs, experience, and cases. They then disseminate the information immediately to individuals who could benefit from it. They have easy ways of maintaining knowledge and applying knowledge discovery techniques to encourage new knowledge. By doing so, decision-makers are able to access to knowledge management system in an easy manner (Houari and Far 2004).

Case-based reasoning (CBR) is a method that uses prior experiences in a case library to make decisions on current problems. It is meant to reproduce the way in which humans solve problems (Bovin et al. 2005). A Case-based reasoning system structures experience in cases containing a problem description, a diagnosis, how the problem was resolved and how successful the solution was. CBR is an AI technique featuring in a number of successful research projects, gaining promising results and reaching commercial applications (Watson 1997).

Trust and Commitment

Trust is an expectation that others will behave as expected and not be opportunistic (Jarvenpaa et al. 1998). Barczak and McDonough (2003) argue that trust has been an important focus in management research; hence, it impacts positively on performance. However, it has not fully been examined within a product development context. They define trust as a psychological state comprising the willingness to be vulnerable based upon positive expectations of the intentions or behaviour of another. Further, based on previous research Barczak and McDonough (2003, p. 274-275) state that:

> …teams require more trust because of their interdependent tasks. High trust allows interdependent relationships to function smoothly and achieve objectives. Trust holds such relationships together and helps to facilitate collaboration. In sum, trust is a critical ingredient in collaborative relations between specialist groups such as those found in new product development project teams.

Extensive research shows that trust has a positive impact on other factors in product development. For instance, trust is seen as vital for managing collaboration in different forms (see Axelsson and Easton 1992; Littler et al. 1995; Jarvenpaa et al. 1998; Pettersson 1999; Brown 2000; Bstieler 2006).

There are several types of trust. Interpersonal trust and inter-organisational trust are those most related to manufacturing industry and product development. Interpersonal trust occurs among individuals and inter-organisational trust among organisations. Interpersonal trust is based on familiarity, and developed in interactions between people or involvement in social groups. Inter- organisational trust refers to trusting the behaviour of a corporate actor or an organisation (Lane and Bachmann 1998). Many studies focus on trust in collaborative settings, most of them on inter-personal trust (Dodgson 1993).

The commitment-trust theory from relationship marketing by Morgan and Hunt (1994) has been addressed in terms of product development and collaboration in studies by Barczak and McDonough (2003) in 2003 and recently by Chu and Fang (2006) in 2006. Morgan and Hunt (1994) conclude that both trust and commitment are key mediating variables in relationship marketing, concluding, that trust has a positive, direct relationship to commitment. Barczak and McDonough (2003) use this theory to explore new product development teams. They conclude that trust has an indirect yet insignificant impact on new product performance. Instead, trust contributes to generating commitment to a project. Trust does not contribute to project speed. Therefore, trust is not an impetus for reducing cycle time (Barczak and McDonough 2003). Chu and Fang (2006) conclude that trust positively and significantly contributes to commitment in the supply chain. The level of commitment is strongly related to the level of trust.

Synthesis of Theory: Input to the Empirical Findings

As described in the introduction of *Chapter 3,* this research project has its base in engineering design and design science. However, there exists an extensive theory base within the area, and not all theories can be used. The theories and models are summed up in Table 2 in *Chapter 3*. In the table, the content of the various authors' approaches are categorised. Next, a synthesis of *Chapters 3-5* is presented.

Managing the Product Development Process

There are no clear boundaries between the different approaches presented in *Chapter 3*. Many of them coincide. Considering the nature of the research field, the theories presented are more or less applicable. The research area is characterised by collaboration and the risks collaboration causes in a product development project. Hence, a focus on collaborative aspects, such as integration or interfaces between functions and involvement, are important in the choice of a theoretical base. Although several of the presented models describe the process of developing products in such a generic way that it would agree with most companies' product development process, some are more focused on collaborative aspects and integration. Integrated product development and concurrent engineering approaches are two of those.

The Stage-Gate™ process by Cooper (2001) does address cross-functional aspects. Nevertheless, the model focuses solely on new product development projects. There is little room for other types of development projects, such as platform development or research projects. However, recently Cooper has focused on how to manage technology development projects (see Cooper 2007). During pre-project planning in Ulrich and Eppinger (2003), there is an opportunity to introduce a way to evaluate the current collaborative situation in the project, e.g., introducing a model for managing CPD settings. Additionally, this may be done in the late stages of the 'define the process' phase presented by Maylor (2003).

Integrated product development by Andreasen and Hein (1987) is the approach most related to this research project. However, concurrent engineering as an approach may also contribute to the development of collaborative product development. Both have gained success in industry. Integrated product development, however, has its origin in Western Europe, while concurrent engineering has its in the US.

An upcoming possible future approach is Lean Product Development (LPD), with its origin in Eastern Asia and the development of the Toyota production system in Japan. Today many Swedish companies believe in applying 'lean'. Lean production has been the entrance to the 'lean philosophy', which includes much more than production. The Lean Enterprise should be what companies strive for when applying lean, a holistic approach towards continuous improvements and learning, long-term thinking, waste reduction, and teamwork. Lean product development includes several techniques that correspond to collaborative product development thinking. The holistic approach and philosophy of lean applied in a collaborative product development setting may be the link needed to stress both internal and external collaboration focus in product development.

In Figure 28 a schematic overview of different approaches related to different markets is provided. The approaches originating from Europe are influenced by the ones from the US. However, approaches like CE and SE originate primarily from the military industry, while IPD arose as a part of a research project at the Institute of Product Development in Denmark. In Japan, lean product development has developed over a long period of time, on a more or less isolated market. The approaches originating from the three contexts, Europe, US, and Japan, have several commonalities, e.g., integration, collaboration, and the tools and methods used during product development.

Andreasen and Hein's model of the IPD process is essential to the discussion, as is CE with its focus upon information systems. Starting from the product lifecycle presented in earlier, the process of developing a product may be identified. Using IPD as a foundation for that process, a conceptual model of the product development process is presented in Figure 29. The model constitutes five general phases corresponding to several product design theories. The phases are (1) Investigation of Need, (2) Product Principle, (3) Product Design, (4) Production Preparation, and (5) Execution (adopted from Andreasen and Hein 1987). This model is used when discussing the results.

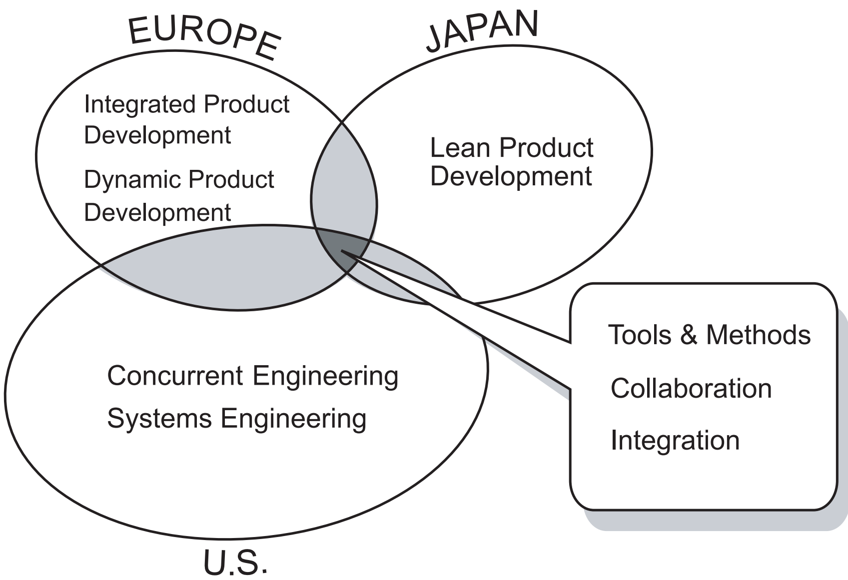

Figure 28 • Different product development approaches originates from different contexts, but have several commonalities. Some are more influenced by other contexts. This is only an example of approaches (Illustration by S. Jonasson and H. Nerlund).

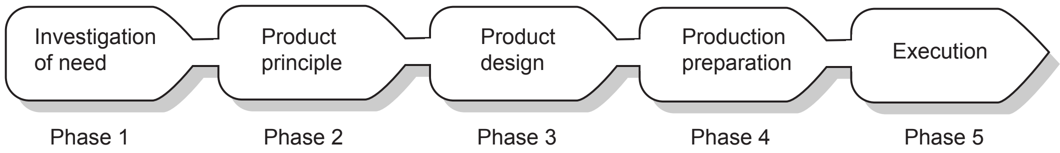

Figure 29 • A conceptual model of the product development process (Illustration by S. Jonasson and H. Nerlund).

It is important to keep in mind that each and every company has its own process when developing products. Moreover, depending on the type of product developed, the process has to be customised to each special project. For instance, many authors differentiated between types of projects, e.g., technology development, platform development, new product development (see Johne and Snelson 1988; Shenhar and Dvir 1995; Cooper 2001). These work as the foundation for defining the different types of projects and collaborative settings in the case studies. Further, Cooper (2007, p. 68) argues, one should "not use traditional methods for non-traditional projects". Thus, the phases in the model presented in Figure 29 are adopted for purposes of putting the results from this research into perspective and into a context.

The Collaborative Product Development Setting

Many companies, especially small ones, seem to understand the benefits collaboration and joint resources can bring to the process of developing products. Today, few single companies can evaluate and cover all possible competitive positions and new designs on the market themselves (Quinn 2000). There is a need for collaboration. However, the complex situation that evolves when two or more companies work closely together, such as disagreements on shared cost, shared profit, social behaviours, etc., makes the collaboration difficult to manage.

Comparing results from studies on cross-functional teams and customer involvement reveals that both types of integration have a significantly negative impact on project performance (see Campbell and Cooper 1999; McDonough 2000). Nevertheless, when considering other aspects as mediating factors for project performance, the picture seems to change. To be able to enter new markets, to obtain new knowledge, reduce risks and increase speed, collaboration – internal, in terms of cross-functional teams, as well as external, in terms of partnering with customers and suppliers – seems to be a prerequisite. As Quinn (2000, p. 17-18) puts it:

> A high percentage of all innovation occurs at the interface between innovative suppliers and customers – with customers making more than 50% of innovations on new products in many industries. Many companies have found that proper attention to outsourcing interfaces upstream and cooperative relationships with distribution partners downstream both lowers innovation cost and enormously expands the value of innovation to customers. Such relationships have benefits for both initial product introduction and subsequent product modification.

Further, collaborative product development as a concept is defined primarily within an external collaborative setting (see Product Development Management Association 1996). Littler et al. (1995) conclude that collaboration adds to the complexity of product development. Thus, it is a risky business. However, when adding more actors into the product development process it becomes more complex and difficult to manage. As Hillebrand and Biemans (2004) argue, the link between internal and external collaboration is important, and the two concepts have to be addressed in relation to each other.

Founded on these arguments, the concept of CPD should include internal as well as external collaboration. Introducing a holistic and systems approach, is one way to meet increasing complexity and challenges.

Key Areas for Collaborative Product Development

Chapter 5 addressed key areas within a collaborative product development setting. This includes organisational aspects, product and project planning, information and communication, knowledge transfer and experience reuse, and, lastly, trust and commitment. These areas are not argued to be as being the only important ones. Rather, they are key, and many of the key factors addressed in earlier chapters may be included in the areas discussed here. The complexity of a research area such as collaborative product development is revealed when trying to reach a consistency of key or success factors characterising it. Again, research on factors influencing product development is closely related to the research on collaborative product development. Collaborative product development adds collaboration as a dimension in the already complex area.

Table 4 • Summary of key factors presented in literature and which relates to collaborative product development settings.

Key Factors	Explanation of Concepts	Discipline
Shared understanding	Shared visions on strategy and goals among team members and actors.	VT, NPD, O
Integration	The integration of activities.	VT, NPD, Co, SC
Trust	Trust between actors in a team and between organisational functions.	VT, CPD, NPD, X, Co, SC
Senior management, experts and champions	The support from and the involvement of senior management, expert and champions.	NPD, CE, X, VT, O
Commitment	Commitment to the project and the tasks.	NPD, CPD, X, CE, Co
Communication	Management of communication between individuals.	Co, SC, O
Culture and Social Behaviour	The cultural and social behaviour of people and organisations.	NPD, X, Co, SC, O
Co-ordination	Co-ordination of people and their activities.	Co, O, SC
Information and Communication Systems	Access to and the efficient use of communication tools.	SC, CE, O
Knowledge and Skills	The relevant competency in the team and the reuse of experience.	NPD, SC
Technology	Access to and use of technology and technology platforms.	NPD, O
Process	Consistency in applied model and the access to and use of processes.	NPD
Decision-making	Consistency and clarity in decision-making process.	NPD, O

NPD=New Product Development, O=Organisational Theory, Co=Collaboration, SC=Supplier Collaboration, VT=Virtual Teams, X=Cross-functional Teams, CPD=Collaborative Product Development, CE=Concurrent Engineering

Collaboration in general is confronted with many challenges. In Table 4, an attempt is made to summarise key factors in the different disciplines of collaborative product development. Collaborative product development, as it is defined in this thesis, seems to have been influenced by several disciplines in which research takes place. Those used for the purpose of this thesis, and the structuring of factors, are included last in Table 4.

Concluding the Theory

In *Chapter 3*, key factors were sorted depending on the area addressed. Table 4 is based on the summary in C*hapter 3*. However, here the factors are aggregated and explained in terms of the actual factors, not areas. When going through theories addressing important factors in product development and collaboration in general, it becomes clear that it is difficult to provide a distinct overview of these factors. However, there seems to be some consistency regarding which factors are 'key' in the different areas.

But, as McDonough (2000) argues, there seems to be a need to put the factors into different contexts. For instance, Littler et al. (1995) have used the context collaborative product development, and present factors influencing that context, whilst McDonough's research is on factors influencing cross-functional teams in new product development. Further, both highlight the importance of *collaboration champions* and *trust*, two factors not addressed by either Link (1987) or Cooper and Kleinschmidt (1996), addressing new product development in general.

Four of the factors in Table 4 are addressed in five or more of the nine disciplines. Trust is an issue discussed specifically by several authors. Trust is argued as being vital, both for collaboration in general and for product development teams. Trust is closely related to communication and commitment in projects. Commitment is also addressed in several areas, mainly in relation to trust, as is communication.

The use of information and communication systems is discussed extensively in collaboration in terms of virtual teams, and in concurrent engineering. The importance of senior management, experts and champions, are addressed in several of the disciplines. Some disciplines separates these factors, here they are merged into one. However, in the collaboration literature studied, it is not addressed explicitly as a factor. Culture and social behaviour is a factor mainly addressed in behavioural theory, but also a frequently discussed issue in the context of teams and the co-ordination of people from different contexts. Further, shared understanding regarding strategies and goals and integration are factors considered important, both in collaborative settings and in product development. Knowledge and skills, technology and decision-making are considered to be important factors, although less addressed in the area of collaboration and product development.

As the focus of the different authors differs, both regarding area and the types of projects addressed, this is to be considered when synthesising key factors influencing collaborative product development settings. One may consider that different factors may affect different types of projects in different ways. The level of, or type of, collaboration may be similar to how the level of integration of sub-suppliers affects the product development project, described by Fagerström and Jackson (2002) (the integration model in *Chapter 4*).

Hypothetically the level of collaboration would have an impact on which factors affect collaborative product development projects and how. Thus, the collaborative setting in a product development project constitutes of several dimensions of complexity.

PART 3

Results and Conclusions

Chapter 6
Results

Chapter 6 presents the main results from four case studies and the survey. The contribution from each study is summarised. The results work as the foundation for a model for collaborative product development, further developed in Chapter 7. Lastly, the focus of and summaries of the appended papers are presented.

Case Study A: Small Company Issues

The first part of this case study was conducted in a small Swedish company in 2002. The aim of the case study was to identify and map critical success factors within the product development process in a small company. The main contribution of the study is the answer to research questions RQ 1 and RQ 2. For more details, see *Appendix A – Case Study A*.

Background

In 2002, the company in which the case study was carried out was situated in a mid-sized city in Sweden. At that point, the company had 25 employees, but was expected to grow. The core competency was within electronic technology development. The company consisted of a project organisation, with top management, a quality assurance team and project teams. The quality assurance team consisted of senior engineers. In addition to leading the company, the top management was also involved in product development. Primarily, the company resorted to customer oriented product development, customers coming up with an idea and the company realising it. The requirement specifications varied in depth and from customer to customer.

In 2006, the company had grown from 25 to 38 employees. The company was still situated in the same location, now suffering from a lack of space. The company was further expected to grow, and during the last year several recruitments have been made. The company's organisation was still the same, as was the case with their core competency and customers.

In 2002, eight product development projects were studied. Each project meant the development of a product in close cooperation with the customer. Throughout, the customers were large companies outsourcing parts of their product development. In 2006, the study was comprised of interviews with people on different levels of the organisation. No specific projects were studied, rather the decision-making process, was in focus.

The System – Contextual Setting, Actors, and Interfaces

The unit of analysis during this case study may be divided into two levels: the overall project organisation (business level) and each specific project (project level). On the business level, the product development process and project management were studied. As far as project level requirement specifications were concerned, customer relationships, technical competency, resources, project closure, and quality assurance were studied. During the first part of the case study, in 2002, the owners and the board of directors constituted the overall project organisation, having a large influence on the projects and the set-up of them (see Figure 30).

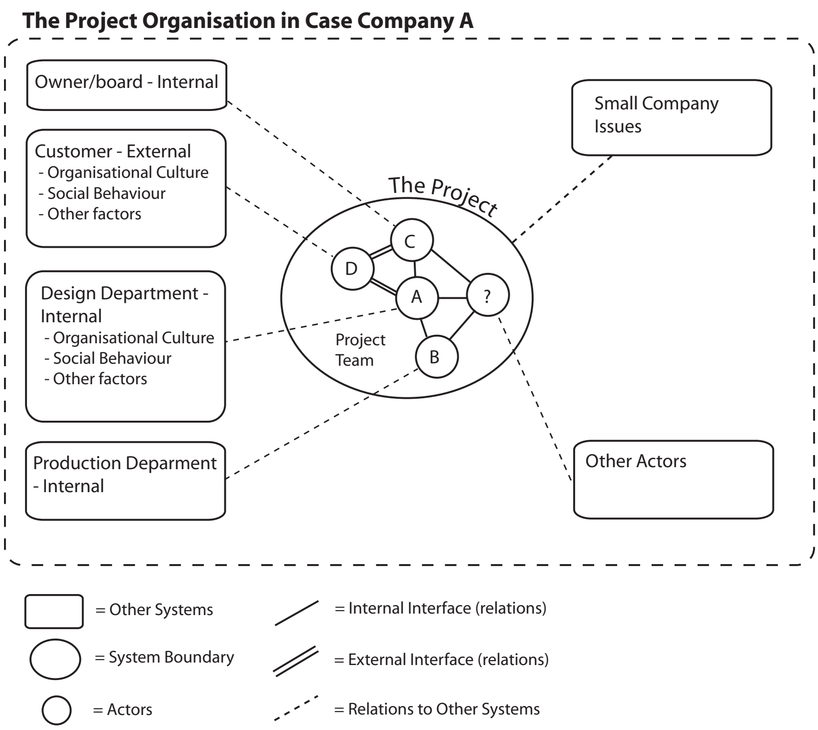

Figure 30 • A first draft of a systems model describing the project organisation in case company A.

A project manager managed each project. The managers had expressed dissatisfaction with time and cost fulfilment in the projects, and wished to explore why several of the projects failed to reach goals. In the company, there were no professional project managers. Rather, the engineer free at the time or seen as most suitable was appointed to the project manager position.

Project duration must be considered as quite brief, ranging from 2-12 months. The core team consisted of one to two people. The production department was involved occasionally, as was the customer. In some projects, the customer was considered as "a source of problems". When visiting the company, one is struck by a feeling of energy and that many activities were going on at the same time. People seemed to work closely together, and to communicate easily. The coffee room was the place where things happened and important decisions were made.

Findings

The analysis of the interviews, and the observations showed that product requirement specification, the design of test specification, and technical competence were the factors that affected the rapidity in the product development process the most. Product requirement specifications and technical competence had a dramatic influence on development time. However, both management control and customer relations were also critical.

The scheduling of project resources and time is one phase that could be seen as critical. It seemed to be at this point that the problem with product development time was initiated. That would imply that there was nothing wrong with the company's product development process, but rather with its project planning. The planned development time should instead be based upon earlier successful projects with corresponding plans. The study also showed that small projects had small margins and, therefore, were sensitive to changes. Changes in a small project can thus bring on problems and affect development time. Small margins make the project vulnerable and, thus, demand fast decisions. To eliminate possible problems in the termination of projects, a number of criteria to be fulfilled in the termination process were defined; (1) all tests must have been finished and approved by the customer; (2) a complete production documentation must exist; (3) the product must have been delivered; and (4) the customer should be satisfied.

In 2006, the case company perceived various problems: much dependency on requirement specification, development teams based on similar characters within the same area of expertise, top-down managed teams (lack of trust), lack of joint view of project, inefficient meetings, project time and budget exceeded, and engineers' time spread across multiple projects.

The purpose of this case study was primarily to serve as an introductory feeler for the research project. It was a first glance at the small company development context, which demonstrated the complexity of product development. A first comparison between theory and empirics was performed, and some critical factors were identified. Reflections upon the study were that the company had recurrent problems in allocating enough and proper resources to their projects. In addition, the collaboration between the company and their customers on the projects was not well managed. They had few close partners. The company was surprisingly independent, but was confronted with, according to literature, common small company problems. These included limited resources, engineers' time spread across multiple projects, and little documentation of designs and of lessons learned.

The findings are included in a systems model, describing the reality in terms of project organisation, influencing systems, important key factors, collaborative setting, and actors (see Figure 31). The total collaborative complexity was perceived as high.

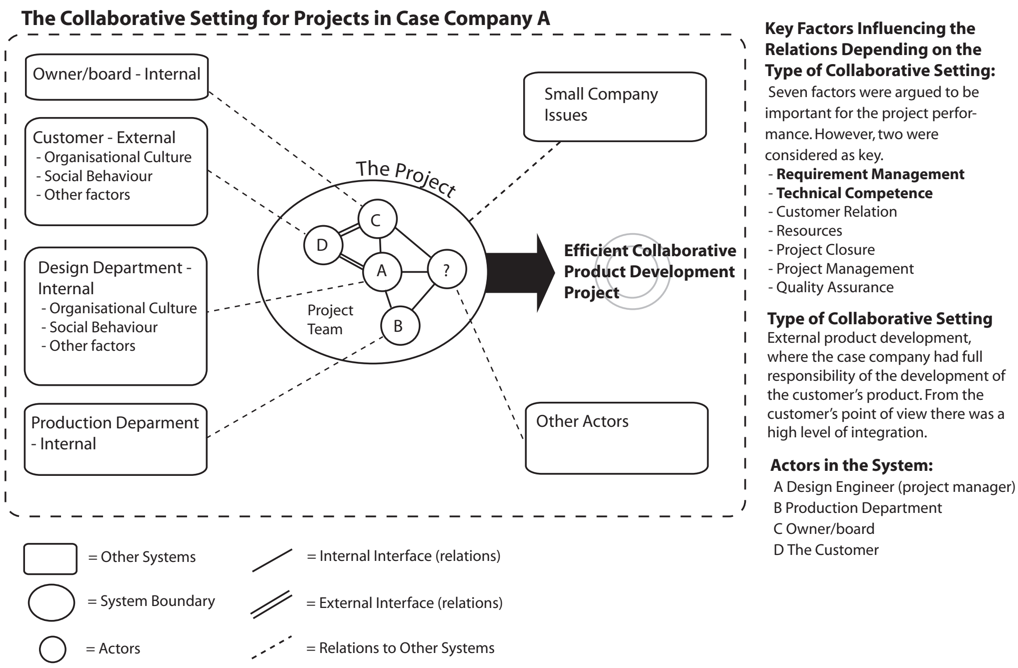

Figure 31 • A systems model describing the projects studied in case study A.

Case Study B: Distributed Networking

This case study was conducted in a network of Scandinavian companies in 2003. The aim of the case study was to study the collaboration among the network members during product development, and their use of a virtual project place, as a means of communication. The case study mainly addresses research questions RQ 1 and RQ 2. For more details, see *Appendix B – Case Study B*.

Background

In 1996, an inquiry on the subject of founding a network was sent out to companies within the plastic (polymer) and tools industry in Sweden. In 1998, a web-based cluster/network was created. The network had at the time about 70 member companies in Sweden, Denmark and Norway.

The network was web-based and covered five different business areas: apparatus; machinery; tools; development, and, components. The members of the network developed and produced products or parts of products for larger customers. The network had no employees; the idea of the network was to have companies as members. The network had a so-called "business centre" in Stockholm, Sweden. Here members could get together and discuss and create businesses during frequent meetings. In the network, the physical and virtual meetings were of great importance for co-operation since the companies within the network were located at remote places. One of the network's goals was to have a functioning virtual factory[24] that could be used frequently by members and by customers during the product development process.

During the case study, we studied how the companies in the network were collaborating in the product development process via the virtual workspace, "the virtual factory". We suspected that the design of the virtual workspace would influence the product development processes negatively and therefore make the work within the network inefficient. Thus, the manager of the network and representatives from five different member companies were interviewed and observed. The interviews and observations were made on a business level, addressing issues concerning the process of developing and producing products in general within the network. The virtual workspace was analysed and tested.

[24] An online workspace where actors may meet virtually and exchange data and information.

The System – Contextual Setting, Actors, and Interfaces

In the network, there were mainly three types of actors, the "cluster engine" (the coordinator of the network), the member companies, and the customer. During gatherings of the companies, it became evident that each member company brought their own organisational culture and social behaviours into the network, with little willingness to adapt to the contextual setting of the network. A "virtual factory", or a virtual workspace, was the means of communication that would make the network function. In reality, this was not the case. In Figure 32, the different actors and the relationships between them are presented. Several member companies expressed dissatisfaction at the use of the communication tool.

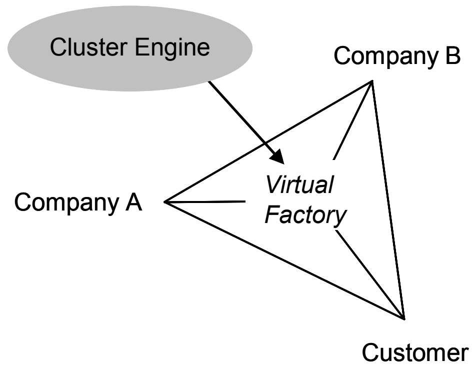

Figure 32 • The components of the network and the relationships between them.

Studying Figure 32, the "cluster engine" is an information provider. There is a flow of information directly between the companies and the customer or via the virtual factory. There is also an internal flow of information and technical communication within the companies.

Further, the respondents expressed a lack of trust within the network. One reason why users of a virtual workspace can lose trust in the organisation is that they do not experience a natural bond to the system. This can result in a lack of motivation, and the organisation and project may lose their trustworthiness. The virtual workspace can then be perceived as a fictive place and the projects as unreal and unreliable.

Findings

The answer to the questions of what was the major reason for joining the network appears to be:

- Lack of resources (capacity)
- A need of direct contact with the customer (to discuss for example development issues)
- To communicating products to the market

None of the companies used the virtual factory as a tool in collaborative product development. This was primarily because of a lack of contemporary projects in the network, along with the difficulty of handling and comprehending information in the workspace. The respondents found no use of a virtual factory if only one or two actors were involved in a project. In those occasions, they used e-mail and telephone. Some of the respondents argued that extra manpower was needed if the workspace should be used as a means for communication. Some companies do not have any experience of operating in virtual workspaces since they exist in a context that does not support such IT-tools (e.g., lack of technical support or information systems tradition). Finally, the respondents believe that the present workspace did not fulfil its purpose.

If the means of communication is based on principles of information design, the network can produce more efficient product development processes. These may lead to new opportunities in developing products, and result in more satisfied customers. If available means of communication is not satisfactory to the users, companies collaborating, but located at different places, supported by a virtual factory, will not lead to efficient product development. Information design influences product development both positively and negatively depending on how well defined the design of information is in the media of use.

Case Study C: Integrating Product Development

Two studies were conducted at case company C, the first in 2002, the second in 2004. The first study aimed to explore the role of the production department in a product development project. The second study aimed to study more in depth one product development project, the actors involved in the project, and what influenced the success of the project. Case study C addresses all research questions more or less, RQ 1-4. For more details, see *Appendix C - Case Study C.*

Background

Case study C involved a large company within the mechanical and mechatronic industry. The company had about 600 employees. The main part of development and production is situated in Sweden. However, in recent years there has been an increased interest in the Asian market, and a production facility is under development in Shanghai. The case company is a part of a larger group. The company had a high degree of interaction between the different functions, but had some difficulties managing the collaboration. Despite physically separated production and design departments, the development of products had been carried out in a collaborative manner with especially improved early involvement of the production organisation.

The production department took most of the initiatives as a step towards the better integration of production into product development projects. The production department had not been satisfied with the commitment to the product development projects. They had problems getting their demands connected to the development of the product. The production department had focused on training and improving the competency and product development knowledge among personnel in the last two development projects.

The System – Contextual Setting, Actors, and Interfaces

Several different actors were involved in the development projects (see Figure 33). However, the main focus was on the design department, and the production department, and the interface between those. There was a willingness to involve logistics, but this aim was not fulfilled at the time of the case study. The company had made a great effort to rationalise and improve the production facility. Thus, the production department seemed to have a rather strong position within the company.

However, the collaboration between design and production was still not satisfactory. The two departments were located in different buildings, but in the same city. There was a short distance between them, but still there were problems related to communication and trust. Finally, the development projects had improved over time when it comes to openness and dialogue, which contributes to the overall commitment from the organisation.

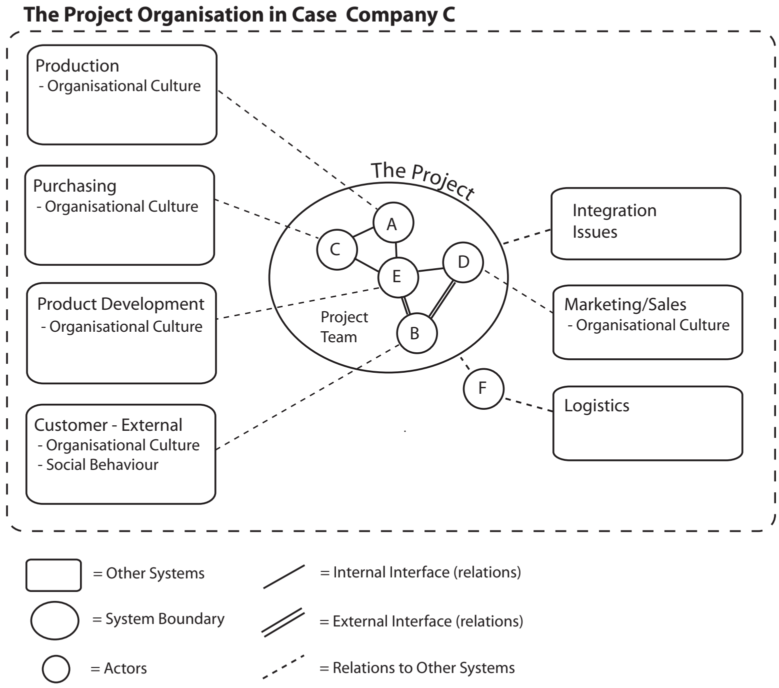

Figure 33 • The project organisation in case study C. The project involved several actors, with the intension to involve logistics.

Findings

The presentation of the results from this case study is divided into two parts. Each part corresponds to the two studies, separated in time, conducted at case company C.

Part 1: 2002

It was quite obvious that the production organisation had succeeded in improving the specification of their requirements and getting them accepted in the project organisation. The engineering department noticed dramatic changes in which kind of demands that were specified and the way they were managed in projects. Both general and specific production requirements were formulated in the projects. Typical general production requirements were reductions in throughput times, assembly man-hours, numbers of articles, and numbers of variants.

Examples of more specific production requirements in the projects were efficient material handling through modularisation, late customer-order point, performed DFAA-analysis (Design For Automatic Assembly), and customisation in only one module.

Further, the *producibility* had been in focus throughout the development of new products. For instance, several DFA-analyses (Design for Assembly) were performed, several investigations were made in relation to the automation of the assembly process, and a reduction of articles was made. All this implied customisation performed in-house.

The *cooperation* between people from different departments had, in relation to other projects, improved in the two projects. Our explanation for this was that the requirements were well and clearly specified and communicated. Resources were reserved and worked with in close cooperation with the design engineers to fulfil production requirements. In this way, a much better climate of communication was created between departments and people in the organisation. It was stated that cooperation in the two projects had been successful or more successful than earlier projects due to the development of strategies and the formulation of requirements. The organisation knew what they wanted to achieve in the projects.

Thus, a conclusion was that there was a need for production requirements to have a better coupling to the business and product strategy of a company. This can be done if key targets for products within production are developed in regards to the business strategy, and then implemented in the requirement specification of the projects.

Part 2: 2004

Several key factors were identified during the second part of the case study. Interviews were held regarding six areas: organisation, strategy, requirements and goals, process, tools, and trust.

Organisation - During interviews, the team arose as an important success factor. The respondents emphasised the importance of having a product development team that is focused and dedicated throughout the entire project. The social aspects were pinpointed as very important. Difficulties were also addressed, particularly when working cross-functionally, bringing different ways of working from different functions (e.g., differences in how to lead and manage projects between production and design departments). Geographical location of the project team was pointed out as important to create auspicious conditions for product development. Decision-making and directing of projects, the clarification of rights, duties, and authority were important. The early involvement of the production department in the product development was a key issue for success. This was also the case with the degree of collaboration of customers in the development process. It was most important that the production department took on responsibility for making producibility goals an integrated part of the development of a product.

Strategy - The choice of technology base, or platform, was a strategic decision for the company, and implied common technical solutions, tools, and methods. In this way, both development and production were able to handle variations and changes in a better way. It was most important to have support from management, project leaders, etc. In this case, assemblers and other staff working with the manufacturing of the product did not have problems adapting to and supporting a strategy. The way of working with the strategy was important. The strategy had impact on product development, and it influenced the product development early on in the process. Working with planning, operation, and communication is strategically important. Requirement specifications are characterised by the strategy if it is a satisfactory specification. Interviews highlight the importance of having strategy as a beacon. A product plan is based upon a strategy, and is the basis for the commitment of resources. Interviews indicate that the product plan was not built on long-term decisions that complicated the product development.

Requirements and goals - Within projects, there are problems concerning the inability to set measurable goals. The interviews indicated that there was a need for fewer and more measurable goals and to prioritise and concretise requirements to simplify the development. The respondents describe an immediate need to make the process of dealing with the requirements continuous.

Process - Studying the decision-making process in the case company, it was clear that decisions were not made at the appropriate time. Designers made designs based on idea sketches, not based upon evaluated, supported concepts as it should be. People feel that they lack a process or model to follow despite the fact that a well-documented product development model exists. Again, they felt a beacon was needed. People operating in product development asked for a management system that everyone agrees upon and which would include methods, checklists, etc. Today, simple tools were overlooked.

Tools - The respondents were satisfied with the tools being used in the organisation at the time. However, the focus was on using the tools, not the actual accomplishment and not the result of using the tools. Thus, a twisted view of how and why the tools are being used was developed and maintained.

Trust - In the case company, trust was extremely important in the collaboration with the sub-suppliers that had the responsibility for developing specific parts. Respondents argued that competency infuses trust, and thus competency and knowledge are main enablers for trust. Further, trust is built on a long-term basis but may be undermined quickly.

From the above presented areas five overall dimensions were defined based on the interviews: *project management*, *strategy and goals*, *requirements*, *development process*, and *trust*.

The main outcome from the interviews about types of collaborative settings mostly concerned the three project types with the highest degree of internal collaboration: internal development projects, industrialisation projects, and development projects with suppliers. Interviews verified the previous division of projects (see Figure 34). Some examples emerged of how such projects might look. An internal development project could concern ongoing research, which often is quite sensitive to external observation. An industrialisation[25] project may involve the customisation of products. Development projects take place in collaboration with suppliers. The supplier is not responsible for a product in its entirety.

Summarising the input from interviews, five different types of collaborative settings were identified. They were: internal development projects, industrialisation projects, development projects with involved suppliers, development projects with integrated suppliers, and development projects with full going partnerships. A more thorough presentation of the analysis and the results may be attained from *Paper B*. A summary of the factors, the relationships between factors and the types of settings may be seen in Figure 34.

[25] The concept industrialisation refer to the introduction of the product into production (Bellgran, M. and Säfsten, K. (2005). *Produktionsutveckling: utveckling och drift av produktionssystem*. Lund: Studentlitteratur.).

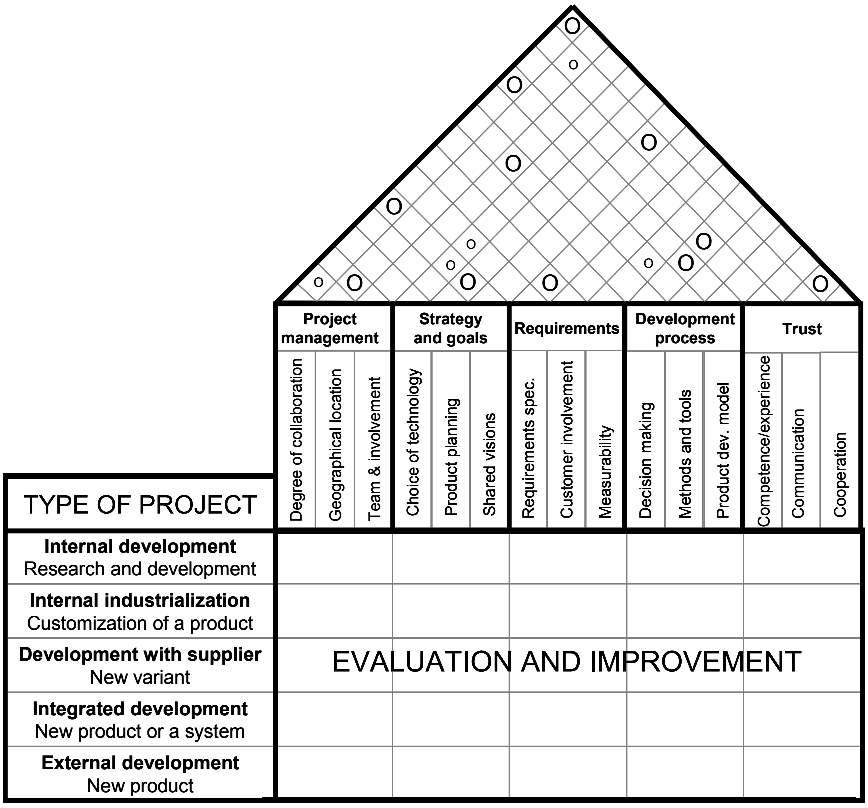

Figure 34 • An early draft of a model for managing collaborative product development projects.

Case Study D: An Industrial Alliance

This case study was conducted in 2003. The aim of the case study was to identify critical parameters involving the decision to join an industrial alliance for product development. The case study mainly contributed to address research question RQ 1 and RQ 2. For more details, see *Appendix D – Case Study D*.

Background

The case study was conducted at Volvo Construction Equipment Components AB in Sweden (hereinafter referred to as Volvo). The purpose of the case study was to study the alliance between Volvo and a competitor. The competitor developed, among other products, transmissions in this case to articulated haulers. Volvo had the global responsibility for developing and manufacturing drive train components. The head office was located in Eskilstuna, where they also manufactured axles and transmission for wheel loaders and articulated haulers. At the time of the case study, Volvo CE Components had approximately 950 employees. The competitor was an Austrian company that developed systems for, among other things, agricultural machines, and had about 630 employees. In the year of 2000, the competitor was purchased by ZF, a German company. ZF has about 55,000 employees all over the world, and develops drive train components for cars, boats and other commercial vehicles, etc.

For a long time, Volvo developed and produced the product in-house. But the customers demanded a simpler variant of the product, Volvo had to consider whether to make or buy. This was due to a lack of capacity and resources. Volvo wanted to reduce the costs, but had the requirement that no competitive priorities should be affected negatively. The competitor, who already had an approximately ten-year relationship with Volvo, showed interest in developing the product. On the basis of a belief that competitor could cut the prices more than its competitors and the already close relationship with Volvo, Volvo chose them as a partner. During July 1996, Volvo and the partner conducted a pre-study of the new product, and that was the beginning of the new partnership, the alliance.

The System – Contextual Setting, Actors, and Interfaces

The units of analysis during this case study were collaborative product development projects, partnerships/alliances, strategy, and sourcing. The project included both internal and external actors from Volvo's point of view. Within Volvo design department, production department and purchasing were involved. The partner may be seen as an external actor. The partner also had different functions involved in the development of the product. The collaboration was controlled and managed through three different contracts. Both companies seemed to have great experience regarding how to manage such co-operative efforts. In Figure 35, the project organisation and the different components in the project are presented.

Findings

The alliance between Volvo and the partner consisted of a trustful partnership, with good communications between the two organisations. In the beginning of the project, great efforts were put in building trust and securing each organisation's rights. The complex project organisation as shown in Figure 35 demanded that the communication must work between the functions and the different actors.

Volvo's main reason for the buy decision was a lack of resources and capacity. There was also a financial reason: making the product was more expensive than buying it. Volvo made the decision on the premise that it would increase its competitive advantages. But they did not base the decision on parameters like long-term survival, logistics or impure flow. A summary of that analysis may be seen in *Appendix D – Case Study D*.

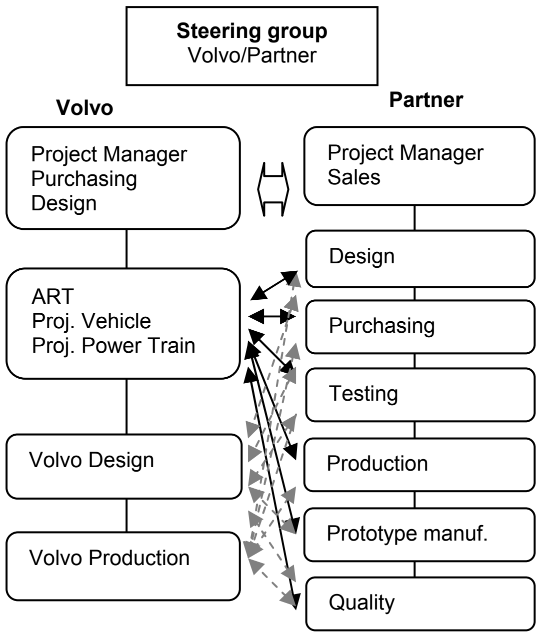

Figure 35 • The project organisation for managing the industrial alliance.

Concluding the Case Studies

In this part, key factors identified in the case studies are summarised and discussed in relation to the literature. Further, actors, interfaces and types of collaborative settings identified in the case studies are summarised.

Key Factors

Trust, or the lack of trust, is a recurrent issue in the dialogue with the companies in the case studies. Most of the respondents seem to be well aware that there must be trust between actors, irrespective of the type of collaborative setting. The co-operation will fail otherwise. However, none of the respondents are taking any specific actions to improve trust between actors. Nonetheless, according to literature, trust is mediated by several other factors (e.g., *communication* and *shared values*) (see for instance Morgan and Hunt 1994). Actions taken to improve communication in a project may thus improve trust, and communication has been identified as an important focus area for the case companies. In spite of the focus on trust in the different collaborative settings, it is difficult to create trust and make it function as an enabler for the co-operation, especially in the case with the network, Case B. Many companies are involved, and only a few of them have a really close collaboration. A long-term relationship seems here to be the factor that makes the difference when it comes to communication and trust. One manager for a company in the network concluded:

> Still there is no accumulated trust for the other companies in the network, except for a few. To have confidence in each other and to trust is essential to being able to collaborate satisfactorily.

The collaboration in the network did not function well, and the outcomes of the initiated projects were poor. The manager proceeded:

> The final product is influenced a lot by good communication. The product must communicate to the user, and the producing company must communicate with the customer. Without communication in the network, the effectiveness will be low. The profitability and the quality of a product will be influenced considerably. Surprisingly often, fine products are dropped because of poor timing and poor communication. Too many think in terms of "we have always been doing it like this, and we will continue doing so". You have to look back, and learn from both success and failure.

Thus, trust is seen as important for successful collaborative product development both in theory and in the case studies. The importance of a *mutual strategy* when collaborating is repeatedly discussed, and this is one area in which several of the interviewees in the case company expressed a shortage. In internal cross-functional collaboration, this appears as a minor problem (they act within the same organisational culture and environment). However, in the case of the network (the one that lacked communication and trust), this becomes a big issue. Different actors have different incentives for the joint development of products. To follow a mutual strategy and to have common goals is much about having shared values and visions, an issue addressed by several authors (Cooper and Kleinschmidt 1996; Connell et al. 2001; Gibson and Cohen 2003).

The importance of a formalised *product development process* within a company is expressed frequently. However, depending on the size of the company or the collaborative setting, a formalised process is more or less difficult to obtain. In the case of small companies like those in case studies A and B, the product development process is less formalised and more ad-hoc. This works out fairly well in Case A, when the small company has the main responsibility for the development of the product. All projects studied in case company A applied a more or less ad-hoc process.

In Case B, both small and large companies were supposed to collaborate, each having their own way to carry out product development projects. There was no agreement on a suitable product development process within the network, and the different roles among the companies were undefined. The boundaries of the network could be considered as fuzzy. Most of the product development models presented in *Chapter 3* would be difficult to implement in such a small organisation. For instance, as Andreasen and Hein (1987) argue, IPD is not attended for small companies. However, DPD by Ottosson (1999) may be a manageable representation of the product development process for those small companies.

In case C, the product development process was very well formalised and documented in the company's overall information system. However, as the company belonged to a company group, the company was partly bound to the processes and tools of that company group. According to the project managers interviewed at the company, this led to an insufficiently tailored product development process that was difficult to comprehend and apply. Tailoring the process for the appropriate project types is important and argued for by, e.g., Cooper (2007). In turn, this led to different procedures being applied in different projects, depending on who the project manager was. According to the project managers, this had no evident impact on the collaborative part of the product development.

In Case D, a partnership between two competitors, the product development process had little impact on the outcome of the co-operation. The partnership was regulated in contracts and legal agreements, specifying the roles of the actors. During the product development project, one of the two companies had the major responsibility of the development. Therefore, defining each actor's role within the project may be seen as crucial. Had it been a usual main and sub-supplier relationship, it could have been defined as level 1 integration according to Fagerström and Jackson's (2002) integration model.

In Cases B, C and D, the *physical setting* and *geographical location* evoke important issues. The issues concerned mainly the distribution of actors. In Case D, the actors were located in different countries, in Case B in different parts of Scandinavia, and in Case C the actors were separated in different buildings. Although the settings seem quite diverse, the projects in the case companies dealt with similar problems regarding the location. The companies experienced problems with communication and trust building when there were few face-to-face meetings. The network, case B, used a virtual communication tool, trying to overcome problems caused by the geographical distance between the member companies. However, the use of the communication tool did not work as expected (see Andersson and Elfving 2004).

Integration of functions and activities was addressed in several of the projects studied in the case companies. In particular, there was a wish to integrate production to a larger extent into the design process than the case companies actually did. However, those who had tried had experienced the work as tough and not at all straightforward (in accordance with, Andreasen and Hein 1987). None of the companies expressed any far-reaching plans for further integration of other functions than production and marketing. These two were the main focus. However, one of the two companies in Case D proceeded in the process of integrating other functions with product development after the time for the case study, e.g., logistics and product development. Supply chain management is today advancing in the same company.

Requirement management was addressed as a source of problems in the case studies. The managers in the companies traced many of the experienced problems to the requirement specification. Several of the engineers interviewed expressed that they regarded requirement management as complex. In case company A, they had problem getting the specifications to address the right level of requirements and goals. However, they did not have a well-prepared process or tools for working with the requirements. A rather simple tool like function analysis or a more advanced one like QFD (Quality Function Deployment) might have been helpful here. None of those were applied.

In Case C, there were problems setting measurable goals. There was also a need to prioritise and conceptualise requirements. These work as data underlying decisions. Thus, the requirements have to be well formulated and prepared with a high degree of traceability for the *decision-making* to function. The decision-making process was in focus during the second study in case company A (in 2006). It revealed unclear boundaries between the different levels where decisions were made (i.e., strategic, tactical, and operational levels). The company is still growing into a more complex organisation with more levels than before. Thus, as the company was and still is in a critical state of growth, these problems could be expected (compare to Andreasen and Hein 1987).

From the findings in the case studies and in literature, a draft model of key factors was sketched, building the foundation for the upcoming survey (see Figure 36).

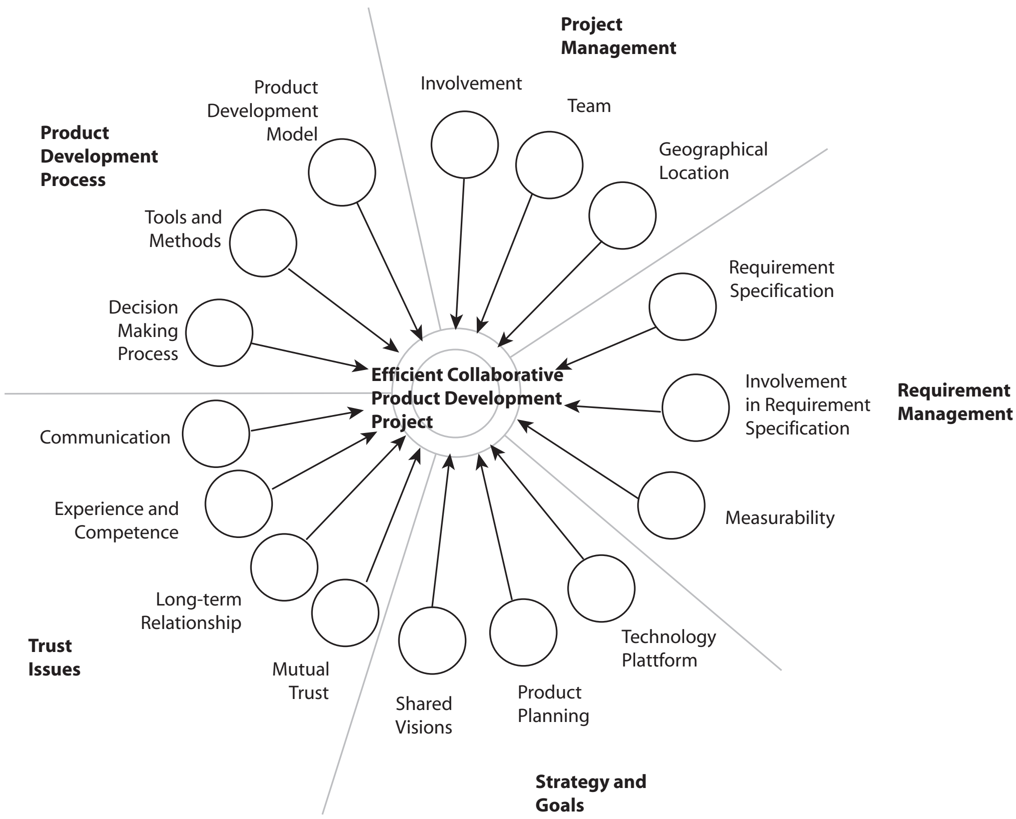

Figure 36 • The proposed model of relationships between efficient collaborative product development projects (project performance) and key factors found in case studies and literature.

Contextual Variables

During the first part of the research project, the focus was upon managing collaborative product development in small companies. Issues concerning small companies in particular were tracked down and compared to larger companies' conditions. Findings from the case studies show that the main purpose for small companies to join or start collaboration is the lack of the appropriate resources. The findings correspond well with theory (for instance see Quinn 2000; Hoffmann and Schlosser 2001; Carlson-Skalak 2002).

When the appropriate resources are available, the small company often has a flexible organisation that, in an efficient way, can develop products. Small companies do have great competencies, but maybe not in all areas needed. As a result, many of these companies need to collaborate to supplement the resources. Furthermore, the small companies have the need for trust. Many small companies have informal relationships with other companies that are built upon mutual trust and commitment. As Pettersson (1999) argues, the role of trust in small collaborating companies is extensive. The role of durable relationships based upon trust allows small companies to gain information and professional advice, which otherwise could be very expensive.

Further, rather often employees in small companies seem not be used to working with advanced communication tools. Sometimes, their only connection to information systems is via the Internet and e-mail. This does not seem to be problem in medium and large sized companies. Different means of electronic-based communication, e.g., telephone, e-mail, video conferencing, Internet, Intranets, and Extranets[26], are used in the large companies. This implies an increase in the options for collaborative product development, especially when it is distributed and when co-ordinating activities and developing and communicating product information (Sosa et al. 2002).

Collaborative settings

During the case studies, several types of collaborative settings were addressed. The settings represent different interfaces in the product development projects studied. Both internal as well as external interfaces were identified in the case studies.

[26] Park and Favrel (1999) define Extranet as a platform for accessing information, similar to an Intranet. Park, K. H. and Favrel, J. (1999). Virtual enterprise - Information system and networking solution. *Computers & Industrial Engineering*. 37(1-2). pp. 441-444.

Table 5 • Interfaces and types of collaboration in the different case studies.

Case Study	Type of Collaboration	Actors
Case A	Main and Sub-Supplier	*External*: Sub-supplier – Customer (main supplier) *Internal*: Product development – Production
Case B	Network/cluster	*External*: Network – Customer (main supplier) *Internal*: Network members – network members
Case C	Cross-functional	*External*: Main-supplier – Consultants *Internal*: Product development – Production – Purchasing – Marketing
Case D	Partnership/Alliance	*External*: Competitor – Competitor *Internal*: Product development – Production

Examples include the internal interfaces between design and production, and design and marketing (Case A and C), external interfaces like the one between main and sub-supplier (Case A), between two competitors (Case D), or between suppliers in a network (Case B) (see Table 5). The interfaces represented in the different cases are not unique. They are confirmed by theory and may be seen as traditional, often addressed in product development literature (see for instance Goldman and Preiss 1995; Souder et al. 1997; Campbell and Cooper 1999; Wynstra et al. 2001).

From case study C, five different types of collaborative settings were identified and formalised into a model for collaborative settings. They are: (1) *Internal product development*, in-house projects in R&D department, internal collaboration with e.g. production and marketing, (2) *Internal industrialisation*, in-house projects like the customisation of a product, collaboration with customer, (3) *Integrated product development*, cross-functional with the external involvement of suppliers, (4) *Distributed product development*, cross-functional with external collaboration with a supplier or other actor, and (5) *External product development*, external projects where a supplier or a partner takes full responsibility. In *Paper D*, these were further explored and applied on three additional cases. The results from the additional test are presented in Table 6, and may be compared to the collaborative settings presented above.

Table 6 • Applying the model for collaborative settings on additional cases.

Case	Categorisation of Cases	Setting
A	External development where the case company had full responsibility for the development of the customer's product.	5
B	External development where small groups within the network had the responsibility of parts of the development towards one customer. A cluster-engine co-ordinated the projects.	3-4
C	Internal development with organisationally dispersed departments. Project demanded high degree of integration of production department.	1-2
D	External development where one close partner had responsibility for the development of the product.	4-5
Additional Case 1	Internal development with appr. 50% of work performed by external actors. Star network, with the main supplier as coordinator.	3
Additional Case 2	Internal development with appr. 60% of the work performed by external actors (i.e. sub-suppliers, consultants and research institute). Two parallel star networks, with the main supplier as coordinator.	4
Additional Case 3	Internal Research project. The main supplier did appr. 30% of the total work. Star network, with the main supplier as coordinator. Sub-tasks solved in small groups with a more ring-formed network approach.	3-4

Further, important factors were searched for in all four case studies. Depending on the collaborative setting in each case, factors were identified and related to these settings. Four types of collaboration were studied (later categorised into different collaborative settings): main and sub-supplier, network/cluster, cross-functional, and partnership (see Table 7).

Table 7 • Summary of key factors related to type of collaboration.

Case Study	Type of Collaboration	Important factors
Case A	Main and Sub-Supplier	Requirement management, product development process, trust, competence/knowledge, decision-making
Case B	Network/cluster	Communication (tools), trust, mutual strategy, few physical meetings, geographically dispersed, no common product development model or process
Case C	Cross-functional	Geographical location, communication, requirement management, common goals, product development process, mutual strategy, co-ordination, integration, trust
Case D	Partnership/Alliance	Geographical location, trust, communication, complex organizations, integration

Survey: Testing the Model

A questionnaire survey was conducted to test and verify the theories and the findings from the case studies. The proposed factors and relationships, derived from the case study and the theory, are presented in Table 8. The purpose of a survey is to collect information and data that may be analysed in-order to discover patterns and compare those patterns. The survey aimed to address mainly three questions:

1. Which key factors correlate strongly with project performance in CPD settings?
2. Which key factors have the strongest impact on or a unique contribution to project performance in CPD settings?
3. How does the impact from key factors vary depending on the type of collaborative setting?

Forty-three questionnaires were sent to respondent, thirty-four questionnaires were returned, which represents a response rate of 79%. Thus, the unit nonresponse (when the observation is missing), was 21% (9 nonresponses). Nonresponse may have different causes, but there are some common factors affecting the nonresponse rate, e.g., survey content, methods of data collection, and respondent characteristics (Lohr 1999). Some of the nonresponses in this survey were project managers at small companies that did not feel they had the time to complete the questionnaire. One of the nonresponses did not get the web-based questionnaire, because of problems with an e-mail server. Further, when the contact with intended respondents was through a second-hand contact, with no possibility to further discuss or present the survey, it was difficult to get the respondents to answer the questionnaire in time.

The web-based questionnaire[27] was answered between September and December 2006. Respondents' details are provided in Table 9. For more details, see *Appendix – Survey*.

[27] The web-based questionnaire was provided by www.createsurvey.com

Table 8 • A proposed framework of important parameters and key factors to manage in collaborative product development projects.

Parameters and Factors
Product development process
Product development model (consistency in applied model)
Tools and methods (access to and use of)
Decision making process (consistency and clarity in process)
Project management (Organisation)
Involvement (early involvement of actors)
Team (culture)
Geographical location (co-location of team members and actors)
Strategy and goals (Common objectives)
Technology platform (access to and use of)
Product planning (product cohere to)
Shared visions (among team members and actors)
Requirement management
Requirement specification (mutual understanding of)
Involvement in requirement management (integrating actors)
Measurability (manageable)
Trust
Communication (access to and efficient use of tools)
Competence (relevance)
Experience (reuse of)
Long-term relationships (among team members and actors)

Table 9 • Company and respondent details.

Characteristics	**Number of responses**	**Percent of responses**
Business		
Electronic and optical products	7	20.6
Transportation vehicles	4	11.8
Manufacturers of machines and tools	13	38.2
Chemistry and pharmaceutical equipment	2	5.9
System development	8	23.5
Size of company		
Small (1-49)	8	23.5
Medium (50-249)	5	14.7
Large (250-)	21	61.8
Turnover		
Under € 7.5 million	8	23.5
€ 7.5 million - € 80.99 million	8	23.5
€ 81 million - € 260.99 million	8	23.5
€ 261 million plus	8	23.5
Missing value	2	6.0
Type of project		
Internal product development	12	35.3
Internal industrialisation	1	2.9
Integrated product development	11	32.4
Distributed product development (external collaboration)	9	26.5
External product development (partner takes full responsibility)	1	2.9

Actors and Interfaces

During the survey, the respondents were asked to identify the different actors[28] involved in the addressed product development project. This query aimed to identify interfaces not commonly addressed in literature. A mixture of different actors was involved in the projects investigated. All projects were cross-functional to some degree, and a considerable part of those projects developed the product together with external partners. The findings from the survey revealed a wide range of different actors active in the collaborative product development projects. Consequently, there are also many interfaces.

Fifteen different actors were identified in the survey as participants in product development projects (see Table 10 and compare to the ones identified in case studies). Ninety-four percent of the projects included the design department, 71% involved production and marketing, 56% involved the customer, and 35% of the projects involved suppliers and external partners. Fifteen percent involved quality, 9% purchasing and 6% specialists and academia. In only 3% of the cases were maintenance, logistics and industrial design involved in the project. The projects seldom involve only two actors.

Several different functions and external actors were usually present. In one of the projects studied seven different functions and actors were involved: design, production, marketing, customer, partner companies, quality control and maintenance.

Table 10 • Actors represented in the collaborative product development projects addressed in the survey.

Internal Actors	External Actors
Design	Customer
Production	Supplier
Marketing	External partners
Quality	Specialists
Purchasing	Academia/research institutes
Logistics	Consultants
Maintenance	
Ergonomics	
Industrial design	
Owner/board	

[28] The identified actors differ from the concept of stakeholders, referred to in project management literature, e.g., Maylor (2003). An actor is active in the project as a member, representing a function or external partner in the project team.

Investigating the Key Factors' Correlation with Project Performance

The preliminary analysis (with non-parametric tests) revealed three factors that strongly correlated with project performance in collaborative product development projects (i.e. $r = .50$ to 1.0, or $r = -.5$ to -1.0 according to Cohen 1988). These factors stand out from the others: decision-making process ($r = .58$), shared visions and goals ($r = .61$), and measurability ($r = .64$). All three are highly positively correlated with project performance ($p<.01$). The use of tools and methods in the projects were correlated with project performance on a medium level ($r = .36$, $p<.005$) (see Table 11). These findings are the results of a non-parametric test, which is argued to be less sensitive and may fail to detect differences between groups. A non-parametric test does not make assumptions about the underlying population distribution. Non-parametric tests may also be used when the sample is very small (see Pallant 2001). The sample in this survey is on the verge of being small (N=34), exceeding, however the recommended sample size, N=30. Thus, parametric tests were also used to further analyse the data.

First, a factor analysis was conducted in order to test the framework developed from the case studies. The result from the factor analysis contributed to a revision of several factors. In sum, the 16 original factors were first reduced to 14 during the Spearman's Rank Order Correlation and further reduced to 12 during the factors analysis. It became quite clear that some factors were sensitive to address, and thus difficult to ask about in a questionnaire. Trust was one of those. The items and questions in the survey regarding trust were adopted from other studies on trust and commitment (see Lindh 2006). Still, it was difficult to get a valid result out of these questions.

The factor analysis excluded measurability, team, involvement and geographical location as single factors. After further analysis and revision of the factors in Table 8, these were indeed excluded. Instead, three new factors were formed based on the involvement of consultants, customers, and production.

Table 11 • Preliminary results using Spearman's Rank Order Correlation without revising the factors.

Independent Variables (factors)	Correlation with Project Performance
Product development model	.27
Tools and methods	.36*
Decision-making process	.58**
Involvement	.13
Team	.38*
Geographical location	.19
Technology platform	.05
Shared visions and goals	.61**
Requirement specification	.43*
Involvement in requirement management	.20
Measurability	.64**
Communication	.22
Competence/Experience	.27
Long-term relationships	.18

Spearman's Rank Order Correlation
*. Correlation is significant at the .05 level (2-tailed)
**. Correlation is significant at the .01 level (2-tailed)

Further, a multiple regression analysis was conducted in order to address the three research questions, i.e., find correlations, variance, and unique contribution to project performance. Table 12 shows the results from a multiple regression analysis (subsequent of the factor analysis).

The analysis showed that six factors correlate significantly with project performance: shared vision and goals (r=.659), decision-making process (r=.569), requirement management (r=.536), consultant involvement (r=.471), tools and methods (r=.447), and production involvement (r=.332). This implies that when these factors were managed properly in the collaborative product development projects studied, project performance was perceived as high (satisfactory fulfilment of time, cost and quality). Moreover, the revised framework in Table 12 can be said to constitute a model of factors that explain project performance[29].

[29] The model used when doing statistical analysis, not a systems model.

Table 12 • The revised framework of key factors.

Key Factors	Explanation of Revised Factors	Correlation
Product development model	Consistency in applied model	.286
Tools and methods	Access to and use of	.447**
Decision-making process	Consistency and clarity in process	.569**
Requirement management	Complexity in requirements	.536**
Documentation	Availability and usability of information and documents	.256
Technology platform	Access to and use of	.088
Shared vision and goals	Among team members/actors on strategies and goals	.659**
Co-operation	Communication and trust	.155
Competence/Experience	Project manager reuse of	.275
Consultant involvement	Involvement and integration	.471**
Customer involvement	Involvement and integration	.029
Production involvement	Involvement and producibility	.332*

Pearson Correlation
*. Correlation is significant at the .05 level (2-tailed)
**. Correlation is significant at the .01 level (2-tailed)

The model (the different factors together) turns out to explain 66.7% of the variance in project performance (adjusted R square=.667). Of the factors included in the model (variables), shared vision and goals makes the largest unique contribution to explaining project performance (beta=.514). Decision-making process (beta=.468) and requirement management (beta=.322) also make statistically significant contributions to project performance. However, the contribution is less. The figures on Beta may be seen in Table 13.

Table 13 • Key factors' unique contribution to project performance.

Key Factors	Beta
Product development model	-.115
Tools and methods	.246
Decision-making process	.468*
Requirement management	.322*
Documentation	-.157
Technology platform	-.104
Shared visions and goals	.514**
Co-operation	-.156
Competence/Experience	-.014
Consultant interface	.136
Customer interface	.073
Production interface	-.118

Beta=Unique contribution to Project Performance
Multiple Regression
*. Correlation is significant at the .05 level (2-tailed)
**. Correlation is significant at the .01 level (2-tailed)

One condition for including different factors (variables) in a model when using multiple regression is that there may not be too high a correlation between the independent variables ($r < .70$) (Cohen 1988). Thus, this was checked for in the analysis. None of the factors had a correlation coefficient exceeding .70. Thus, all factors were kept in the model (according to Table 12). However, in six cases there were correlations exceeding .50, which may be considered relatively strong. The documentation factor exceeded .50 in three cases: decision-making ($r=.529$), competence/experience ($r=.661$), and production involvement ($r=.555$). Moreover, co-operation including communication and trust had a correlation coefficient higher than .50 in two cases: consultants involvement ($r=.518$) and competence/experience ($r=.570$). The correlation between decision-making and competence/experience was .535. Further, a visualisation of the strength of the relationships between the different key factors is presented in Table 14.

As the factors had been revised since the correlation matrix was presented in *Paper B*, it is difficult to make any fruitful comparisons. However, the relationship between decision-making and competence/experience is highlighted based on the case studies in *Paper B* and than confirmed in the survey.

Consequently, six different factors were found to have medium strong or strong relationships to project performance (question 1):

- Shared vision and goals
- Decision-making process
- Requirement management
- Consultant involvement
- Tools and methods
- Production involvement

Table 14 • Relationships between different key factors.

	Project Performance	Consultant involvement	Customer involvement	Production involvement	Shared vision and goals	Requirement management	Documentation	Co-operation	Product development model	Tools and methods	Decision-making process	Technology platform	Competence/ Experience
Project Performance	-												
Consultant involvement	◖	-											
Customer involvement			-										
Production involvement	◖	◖		-									
Shared vision and goals	●	◖		◖	-								
Requirement management	●	◖	○	○	○	-							
Documentation	○	◖		●	◖		-						
Co-operation	○	●		○	◖		◖	-					
Product development model	○	○		○	○		○		-				
Tools and methods	◖		○	○	○	○	◖		○	-			
Decision-making process	●	◖		◖	◖		◖	◖	◖	◖	-		
Technology platform				○	○			○	○	○	○	-	
Competence/Experience	○	◖	○	◖	◖		●	●	◖	○	●	◖	-

The strength of Correlation (Pearson) (Cohen 1988):
Small = ○ r=.10 to .29 or r=-.10 to -.29
Medium = ◖ r=.30 to .49 or r=-.30 to -.49
Large = ● r=.50 to 1.0 or r=-.50 to -1.0

Thus, depending on how well these factors are managed and how well activities related to those are executed, it will affect time, cost and quality (project performance) in a CPD project. For instance, if the decision-making process is executed as planned, knowing who makes the decisions, what decisions to be made and when, decision-making contributes to increased efficiency in a project. However, the level of shared view of the strategy and common goals within a CPD project may be concluded as the best predictor for project performance (question 2). Decision-making is thus the second best predictor for project performance.

No considerations regarding the innovativeness of or the novelty of the product have been taken. And the conclusion has to be viewed in relation to the relatively small sample in the survey (N=34), and treated as more of a guideline than the final truth.

Focus on Decision-Making

In the questionnaire, the respondents were asked whether it was clear who should make decisions and when the decision should be made. Seventy percent of the respondents argued that it was clear (the upper half of the Likert-scale) who should make the decisions during the project. Fifty percent found it clear when the decisions ought to be made, while approximately 30% did not (the remaining 20% were recovered in the middle of the scale). A follow-up question was asked, whether the decisions actually were made at the right moments during the project. Here, 65 % of the respondents thought so. An opportunity to comment on this was given in the questionnaire. Decision-making is an area that affect people. Almost all the respondents took the opportunity to discuss decision-making further. Some of the respondents' answers are cited next:

> Decisions should be made fast by competent peoples. This presupposes valid and accessible data as input for the decision.
>
> All decisions must be founded on informed conclusions. A pro-active strategic management needs to prepare for future operative decisions through research, studies and surveys. A rather small, operative and central team should make strategic decisions.
>
> Clear and distinct goals enable correct decisions at the appropriate time.
>
> In making decisions, the entire team should be together, focused on having open discussions where everybody may express oneself and their opinions clearly and simply.
>
> Efficient decision-making is fast decisions optimised for time, cost and quality
>
> A wrong decision is preferable to no decision at all!

Consequently, there are many views on what decision-making is and how it should be executed.

Investigating Contextual Variables

In the survey, 34 projects were studied relying upon questionnaires. Small companies owned eight of those projects (see Table 9). Comparing the three company sizes represented in the survey did not reveal any large distinction between those in terms of average for project performance (T, C, Q). The small companies reported a slightly better result considering project performance than the medium and large companies. The medium sized companies did well in terms of reaching quality goals, slightly better than both small and large companies. However, the medium sized companies did less good in terms of time-to-market, compared to the small and large companies.

During the survey, respondents were asked about their experience as project managers. The experience stretched from one year to over 30 years of project management experience. Comparing the outcome of the projects and the experience of the project managers revealed that projects lead by an experienced manager came out better in terms of overall project performance. Further, Littler et al. (1995) argue that more experienced managers (in terms of a CPD project) address different key factors for CPD success than less experienced project managers. Thus, the experience of the project manager, both in terms of years of experience and experience of CPD projects (variables dependent upon each other) can be considered important for how key factors are perceived in CPD projects, and, thus, the outcome of the CPD project.

The respondents were also asked to categorise the projects according to the model for collaborative settings developed from case study C. The main parts of the projects were categorised into three of the five collaborative settings: setting (1) 35%, (2) 3%, (3) 32%, (4) 27% and (5) 3%. This may be due to difficulties in determining the setting of the project, or that the proposed settings are not adequate. The possibility of relationships between the factors found to correlate significantly with project performance and the different collaborative settings was investigated using Spearman's Rank Order Correlation (due to the relatively small sample, see Table 9).

The analysis provided results on three of the collaborative settings (1) internal product development, (3) integrated product development, and (4) distributed product development. Within distributed product development, there was a strong, positive and statistically significant correlation between several of the factors and project performance. This was true of shared vision and goals ($r=.908$, $p=.001$), decision-making process ($r=.897$, $p=.001$), tools and methods ($r=.738$, $p=.023$), and requirement management ($r=.711$, $p=.048$). For Internal product development, shared vision and goals correlated significantly with project performance ($r=.632$, $p=.037$). Lastly, of 34 project managers participating in the survey, six of them were women (about 18%).

Focus and Summaries of Appended Papers

Five papers are included in *Part 4 Appended Papers* of this thesis. A summary and a short description of how the papers relate to the research questions follow below.

Paper A - "Understanding Complexity of Product Development in Small Companies"

First and foremost, paper A (Elfving 2004) presents and discusses the first part of case study A (see *Appendix – Case A*) in relation to research question 2. This paper also contributes to research question 1. The paper results in a first draft of a framework of key factors, partly from theory, partly from the empirics gathered in case study A. The paper is summarised further.

Small industrial companies in Sweden have difficulties growing and stay competitive, often due to the lack of resources. This prevents the companies from performing in product development. Thus, this paper aims to examine and identify key factors that influence the success of product development in a small Swedish company. Case study research forms the base for the results. The case study shows that the product development process in the case company is complex and is influenced primarily by two key factors: requirement specification and technical competence.

Paper B - "A Model for Evaluating and Improving Collaborative Product Development"

Paper B (Elfving and Jackson 2005) constitutes a summary of the results presented in the licentiate thesis in 2004 (Elfving 2004). Thus, it constitutes a summary of the results from four earlier papers (not appended in this thesis, see Andersson and Elfving 2003; Elfving and Jackson 2003; Andersson and Elfving 2004; Elfving and Hägg 2004). The results from the licentiate thesis are complemented with results from case study C. The results are discussed and a first draft of a model presenting key factors and relationships between them is developed. The paper addresses all four research questions, with special emphasis on key factors and the development of a model. The paper is summarised further.

A conclusion from the prevalent outsourcing trend is that companies need to analyse how and why collaboration is important for the organisation and for product development, and investigate which key factors influence such collaborative situations. Thus, the objective of this paper has been to present a model that could serve as a tool for companies when evaluating and improving their collaborative product development. A model built on previous research, literature review, and a case study is presented. The model evaluates five parameters: organisation, strategy and goals, requirements, development process, and trust. Trust is found to be crucial for successful collaborative product development. In spite of well-informed organisations there are difficulties improving and building trust.

Paper C - "Enabling Knowledge Transfer in Product Development and Production: Methods and Techniques from Artificial Intelligence"

Paper C (Elfving and Funk 2006) addresses mainly the fourth research question, the applicability to industry and knowledge transfer. The paper is a result of the ExAct-project[30], which focuses on experience reuse in industry by using intelligent systems. The ExAct-project enables research results to be transferred into industry, using AI-techniques and tools. The paper discusses several problem areas in industry identified during case studies and how transfer of knowledge in different ways could manage these problems. The paper discusses the theory of knowledge transfer and how this research project could benefit from it in terms of applicability to industry. The paper is summarised further.

The trend to move production abroad to low-wage countries implies loss of important production knowledge in organisations. Effectiveness of developing and producing products is reliant upon such production knowledge. Thus, how may knowledge transfer between production and product development be enabled? The paper concludes that a company may increase its efficiency by enabling knowledge transfer within and between the product development and production department using Artificial Intelligence (AI) methods and techniques. Thus, the paper discusses how the AI methods and techniques could facilitate knowledge transfer in product development and production. Three cases illustrate current needs of AI methods and techniques within manufacturing industry. Problem areas are information overload, past project experience and tacit knowledge. These could be facilitated by case-based reasoning, ontology and intelligent agent technology.

[30] ExAct - Intelligent Experience Reuse in Production, founded through the ProViking program and The Swedish Foundation for Strategic Research.

Paper D - "Efficient Collaborative Product Development: Critical Aspects and Parameters Influencing the Outcome of Collaboration"

Paper D (Elfving and Fagerström 2006) is a synthesis of the results from the four case studies conducted during this research project and three case studies conducted between 2001 and 2003 by Fagerström (see Fagerström 2004). The results are compared and discussed in relation to each other, and then a synthesis is made. The paper addresses all four research questions, with a focus on key factors and the relationship between those factors and different types of collaborative settings. The paper is summarised further.

Few studies have taken a holistic approach in order to analyse the execution of the product development process in a collaborative and distributed context. Therefore, this paper investigates how different parameters influence the outcome of CPD projects. The outcome of seven different cases are presnted and combined with existing theory and further used to set up a framework for analysing, setting up and running CPD projects. The framework consists of five groups of parameters, and describes its' influence on the execution of projects. Knowledge and trust are two parameters that have extensive impact on CPD projects, especially in the collaborative setting with high level of external collaboration. A five-step procedure for better usability of the framework is also presented.

Paper E - "Important Factors for Project Performance in Collaborative Product Development: A Survey Investigating Contextual Settings"

The fifth paper, paper E, mainly presents the findings from the survey, based on the theoretical framework and the previous results of this project. It has the purpose of adding another dimension to the discussion of the results, where the relationship between factors, project performance and different collaborative settings can be discussed in a more profound manner than if only based on findings from case studies. The paper addressed all four research questions, with an emphasis on interfaces, key factors and relationships. The development of the model is included in the result part of this thesis. The paper is summarised further.

Much research has focused on cross-functionality in product development, few studies focus on the contextual setting of the collaborative product development project. This paper presents the results from the concluding survey aiming to identify the relationships between project performance and different factors when the contextual setting varies. Mainly three collaborative settings were explored, including internal product development, integrated product development and distributed product development. Six factors were found to have strong correlation with project performance. Measurability of requirements, shared visions and goals for the project team, and the decision-making process were highly correlated with project performance. Several of the factors correlated strongly with the project performance in distributed product development.

Chapter 7

Managing Collaborative Product Development Settings

Chapter 7 is comprised of a synthesis of the research results and the development of a model for managing collaborative product development. First, actors, interfaces and collaborative settings are discussed. Further, a model and a checklist for key factors are presented. The model for identifying key factors in CPD projects concludes the chapter together with a discussion of experience reuse and knowledge transfer between projects.

Managing Interfaces

The first section mainly addresses the first research question, RQ 1 How may relevant interfaces be managed in CPD settings in order to support successful CPD projects? Thus, research question 1 addresses the need for a holistic view of the CPD setting. To answer this research question, relevant interfaces within a CPD setting have to be identified. In doing so, the actors between whom the interfaces exist have to be identified as well. Contextual variables affecting the interfaces and how those should be managed need to be discussed. As described in *Chapter 6*, a variety of actors and interfaces between those actors have been identified through theory, case studies and the survey.

Managing is the act of management, and is often referred to as planning, organising, staffing, leading, and controlling in general management (Project Management Institute 2004). Here, management is referred to as how, an organisation, a part of an organisation, or a set of activities, are carried out, by whom, and when.

Actors and Interfaces

The focus of this research can be identified among the interfaces Fagerström (2004, p. 77) describes in the interface model for main and sub-supplier collaboration (see *Chapter 4*). Interface five (5), though, the interface between different organisational functions, internal as well as external, is the most appropriate interface related to this research project: the context of collaborative product development settings.

Thus, interfaces between different internal organisational functions and external actors have been searched for. Theory, case studies and the survey have contributed to the identification and understanding of such interfaces. Several types of interfaces have been identified through theory besides those presented above, related to main and sub-suppliers. In Integrated Product Development (Andreasen and Hein 1987), the focus is on internal interfaces between marketing, design and production. In those interfaces, interplay exists between the functions that add problem areas (e.g., poor interplay between those functions (ibid.)). Lundin et al. (2006) champion design-manufacturing interface (DM-interface) as an important one to manage. Andersson (2007) argues that the interface between logistics and product development is important. In literature, interfaces between the main supplier and the customer, the consultants and competitors are also addressed (e.g., Campbell and Cooper 1999; Wynstra et al. 2001).

In Figure 37, a model has been developed so as to obtain a more comprehensive and holistic picture of the identified interfaces and the context they exist in. The model is intended to be used together with the other parts of the concluding model. The purpose of the actors-and-interface model is to highlight the different actors within a CPD project. As such, the model should be different for each project. Although all interfaces in the model are not unique, the model addresses interfaces not commonly addressed in literature. For instance, the interface between design and maintenance and between design and logistics are moderately addressed in literature (for maintenance, see Markeset and Kumar (2001); for logistics, see Johansson (2006) and Andersson (2007)).

If necessary, the model could include other actors than those presented in Figure 37. The model might be applied using the following procedure:

1. *Represent*. Represent the real project in the model in terms of the organisation,
2. *Identify*. Identify and include internal as well as external actors, and
3. *Define*. Define the different interfaces between actors.

The model is further used when addressing the collaborative product development system.

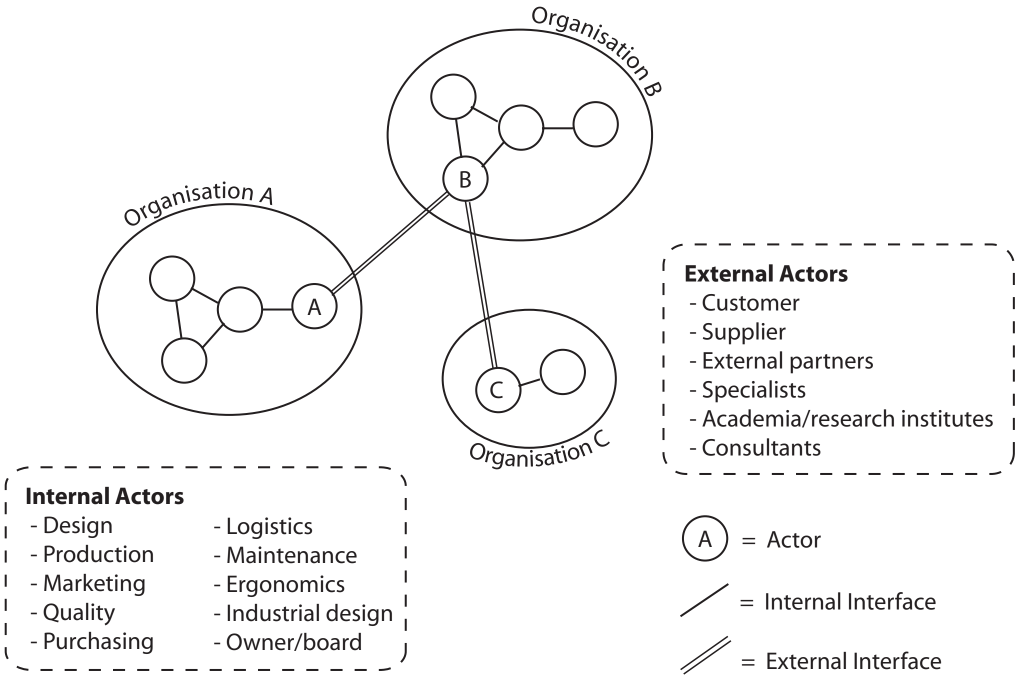

Figure 37 • Actors-and-interface model. Here, the collaborative setting in a product development project consists of three organisations linked together with external interfaces. If organisation A is the owner of the project, actors B and C becomes external actors.

Collaborative Complexity

Based on literature and the empirical findings, a model for categorising projects types in terms of collaborative setting was presented in *Paper B*. The model was further explored in *Paper D*, where it was applied to three additional cases (cases earlier presented in Fagerström 2004) and in the survey regarding 34 projects. When applying the model on earlier cases, som problems with the categorisation revealed themselves. Some cases were straightforward. Others were much more difficult to categorise, lying at the crossing point between two settings. This may depend on that the collaborative setting is dependent upon several aspects: the number of actors involved in the project, the types of actors involved (internal/external), thus the type of collaboration, and the level of integration of the actors, thus, difficult to address. The different aspect mainly refer to organisational complexity, however, according to Maylor (2003) all aspects are influenced by the technical complexity in the project.

However, five collaborative settings have been identified and are applied more thoroughly. The collaborative settings should be treated as examples, not precise definitions. Thus, collaborative settings are:

1. *Internal product development.* In-house projects in the R&D department, high level of internal collaboration, e.g. between design, production and marketing.
2. *Internal industrialisation.* In-house projects, e.g. customisation of a product, collaboration with customer. Some level of external involvement.
3. *Integrated product development.* Cross-functional projects with external involvement of suppliers, for example. The level of internal and external involvement is rather even.
4. *Distributed product development.* Cross-functional projects with external collaboration and integration of supplier or other actor. Higher level of external involvement
5. *External product development.* External projects where a supplier or a partner takes full responsibility of development. The external responsibility is high.

The boundaries between the different types are somewhat fuzzy. However, it is people that categorise a project, having subjective ideas and understanding of the different settings. Altogether, this implies that the use of the model for categorising projects is neither precise nor considered the final. Thus, to bypass difficulties by precisely categorising a project or a phase during a project, the model leaves room for imprecise categorisations. Consequently, the model ought to be approached from different aspects related to the complexity of a project.

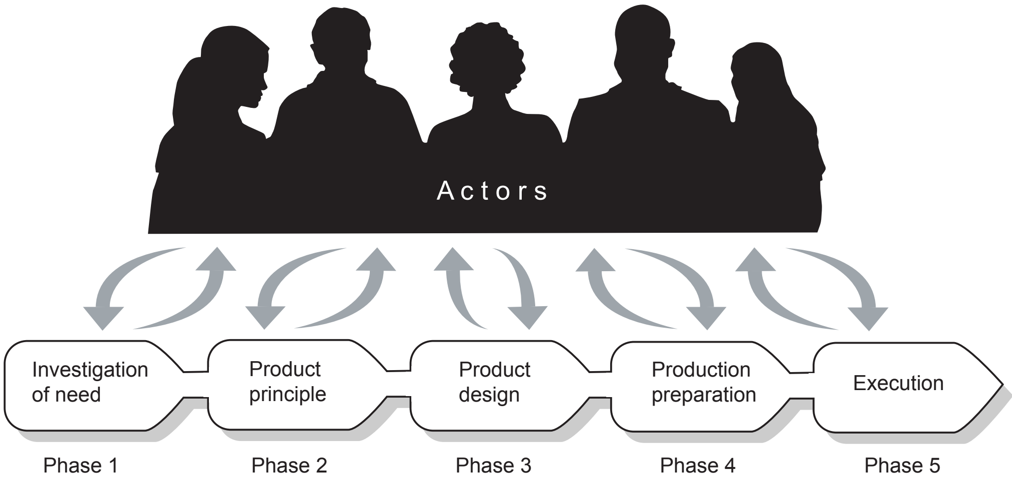

Figure 38 • Actors moving in and out of the product development process (Illustration by S. Jonasson and H. Nerlund).

During a collaborative product development project, the number of actors will vary, all actors will not attend at the same time or all the time. The need for integrating different functions or external actors varies during the different product development phases. Figure 38 visualises the variation of actors during the product development process. The number of actors will also vary depending on the phase, and the picture will change from project to project (see Figure 39). Ottosson (2006) champions a similar approach.

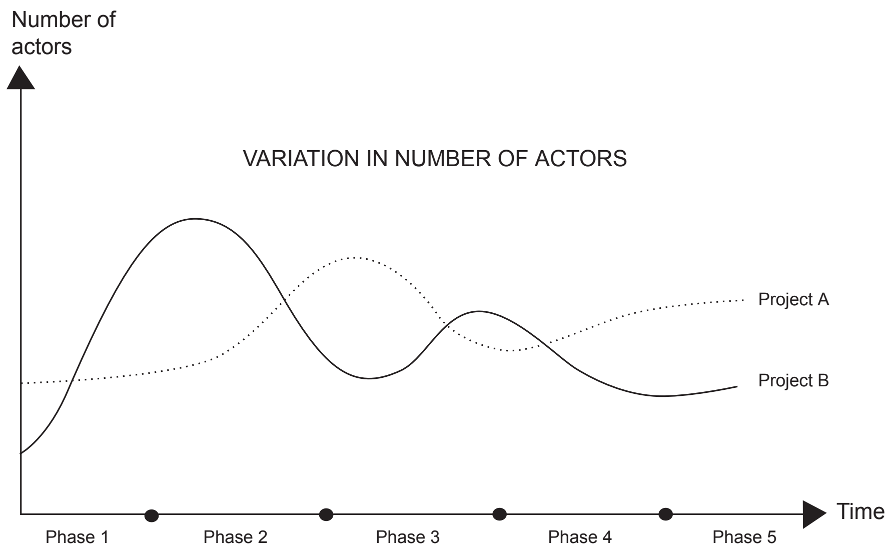

Figure 39 • Number of actors. The number of actors may vary during a CPD project depending on the phase, and each project will differ (Illustration by S. Jonasson and H. Nerlund).

The different phases will also vary depending on the company applying the model. A small company's phases during the product development process will not likely agree with a large company's phases. For instance, the dynamic product development process is concluded to be appropriate for small companies, while larger companies apply concurrent engineering, integrated product development, and recently lean product development. Differences between industries (e.g., pharmaceutical and electronics) are also to be expected.

Further, both internal and external actors will go in and out of the process. An example of how the involvement of internal and external actors may vary during the different phases in a CPD project is illustrated in Figure 40. The complexity of integration will thus vary. It is most likely that some actors will be more active at the beginning of the project, some at the end and some will have a higher level of integration depending on the phase (see Figure 41).

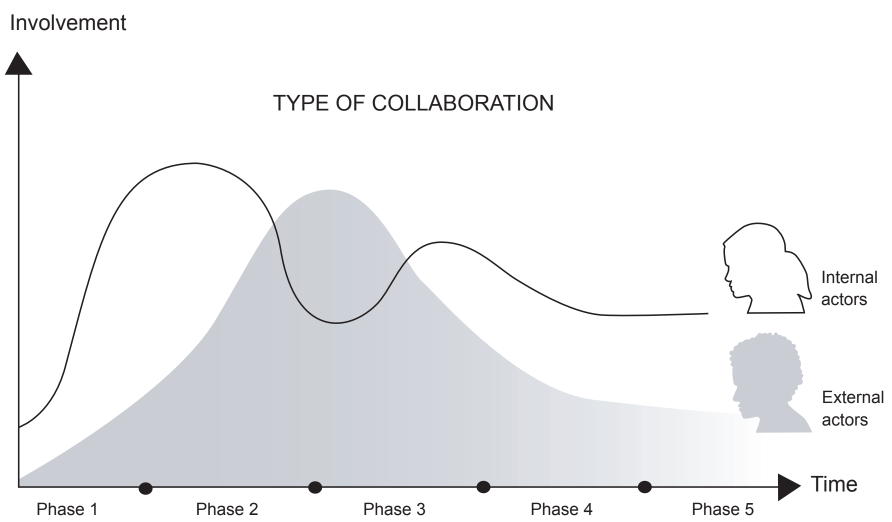

Figure 40 • Type of collaboration. The involvement of internal and external actors may vary during a CPD project depending on its phases. This is an example (Illustration by S. Jonasson and H. Nerlund).

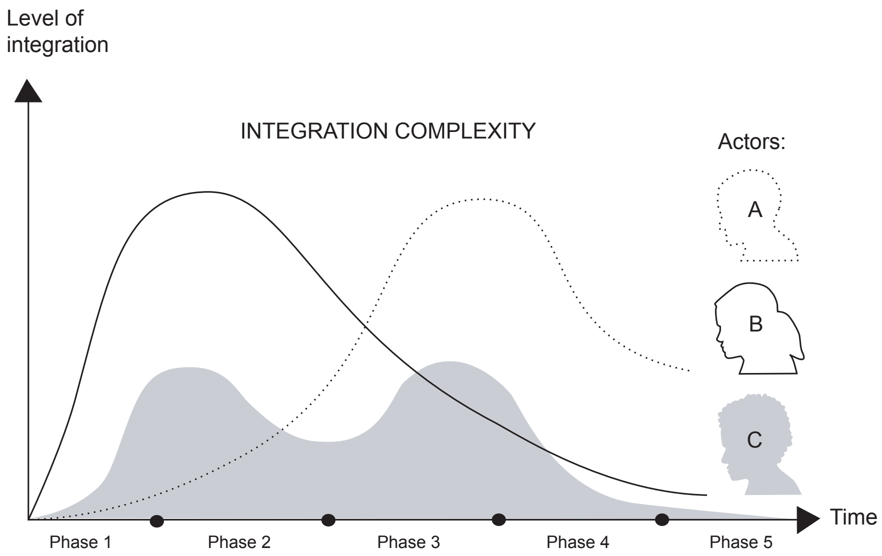

Figure 41 • Integration complexity. The level of integration of different actors during different product development phases will vary (Illustration by S. Jonasson and H. Nerlund).

For instance, much of the literature argues for early supplier involvement (e.g., see 1996; Wynstra et al. 2001; Fagerström and Jackson 2002). Supplier involvement was found to be a key factor for project performance in our survey and, in several cases, a factor hard to manage in CPD projects. Petersen et al. (2005) argue for five possible supplier integration points in the NPD process, given the level of technical complexity. Thus, if the suppliers are integrated during early phases of a product development project, resource complexity will increase.

Further, early involvement of production, logistics, customers, etc., will maximise the complexity in the early phases. However, as argued, the involvement of each actor varies during the process, and so, as a result, the total level of complexity. The project as a system will differ between different phases. In addition, the actors will vary, and as a result, the relationships among those and the connecting interfaces will differ. In theory, it would be possible to render a new system for each phase, involving actors, interfaces, and key factors affecting this particular system. In Figure 42, an example of how systems may vary is presented.

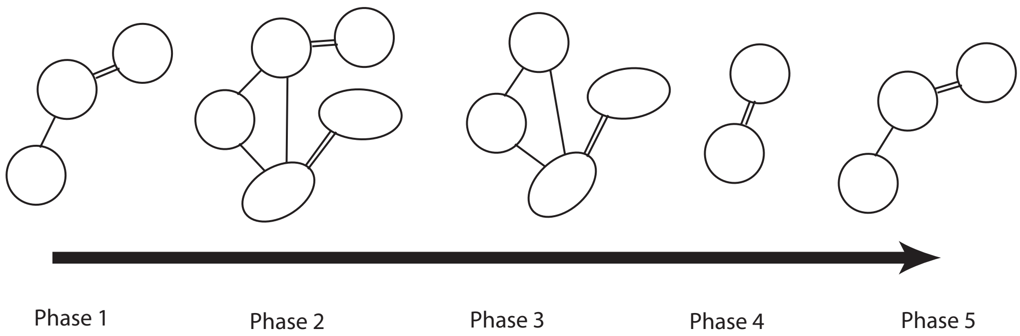

Figure 42 • An example of how the collaborative setting may vary during different product development phases.

However, this may be difficult in the reality. To agree upon an average based on the three aspects of complexity for the project is a more realistic procedure, for instance "…the project largely corresponds to the collaborative setting (4) distributed product development". The total collaborative complexity will vary over time in the CPD project, and is mainly influenced by the integration complexity, the type of collaboration (internal/external), and the number of actors involved in the project.

Thus, managing a CPD setting is a matter of managing three dimensions of complexity. However, depending on the collaborative setting (and thus the complexity of the project), the key factors will differ in importance. Consequently, it is important to identify: who to involve (resource complexity), how many to involve (organisational complexity), how to involve (the level of integration-technology complexity), and when to involve whom (in which phase).

Thus, three dimensions of complexity are accounted for: the level of integration as described by Fagerström (2004) which relates to the technological complexity of the product and how well different actors are integrated in the development process. Further, the number of actors in a project, and last the type of collaboration, both related to organisational complexity. A three dimensional model is presented in Figure 43. The model should be seen as guide when categorising a project and when analysing its conditions and surrounding environment. By identifying the preconditions for the project (the different levels of complexity), it is possible to understand which factors influence the project and what interfaces have to be managed and accounted for.

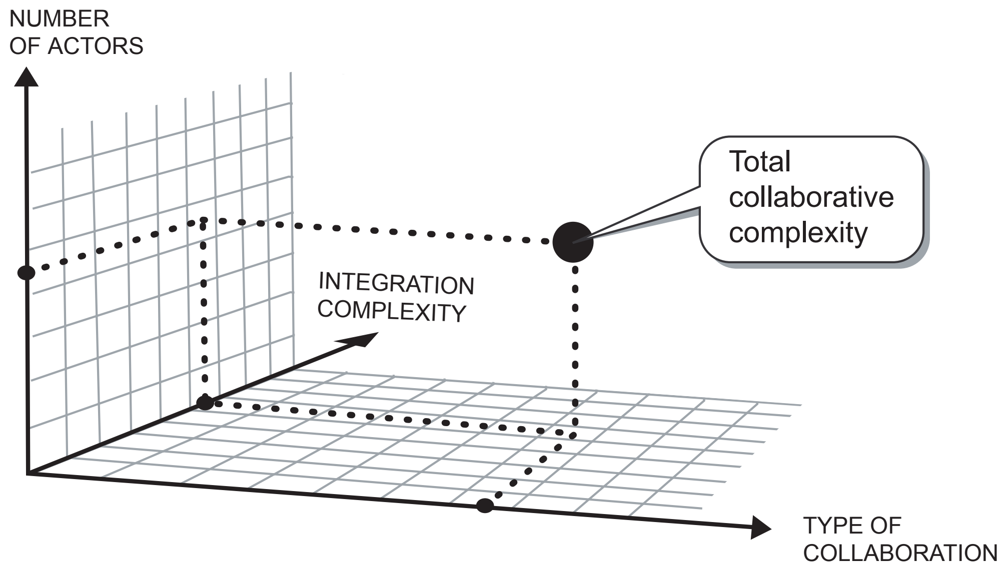

Figure 43 • Total-collaborative-complexity model. A three dimensional model to determine the complexity of the collaborative product development project (Illustration by S. Jonasson and H. Nerlund).

Consequently, a CPD project should be categorised in three dimensions. Based on the result from using the actor and interface model, one should determine the internal and external actors, how many they are and when their activities are integrated in the product development process. Based on, for example, the complexity of the product, one should then determine the level of integration needed for each actor. This procedure implies that appropriate suppliers for the project are already decided upon.

Managing Key Factors

In each and every product development project, it is important to create the proper conditions for success. Each project displays numerous aspects that have to be considered and taken into account on different levels and in different fields. Examples of this include the type of product developed (see Cooper 2001), the complexity of the organisation, resources and technology, as previously discussed (see Maylor 2003), and key factors related to those aspects. To control all conditions and aspects in a project is unrealistic. Some of the problems appearing in projects are initiated much earlier and on other levels in the organisation. The effect of such problems may not be evident until a project is executed, and then they may have a severe impact. The aim should be that the effect of a decision should be known earlier, thus easier to act upon if not correct.

However, there are aspects that are possible for a project manager to respond to in the initial phase of a product development project. The conditions for a product development project can be addressed in terms of factors for success. To establish the right conditions for a project, the factors to apply have to be analysed. If they are considered as barriers, or if some factor does not contribute to the right conditions, they have to be acted upon. The theory of product development and collaboration addresses a large number of such factors. Some of the factors are managed outside the scope of a project. As a result, it is not possible for the project manager to influence the initial phase of a project. A factor may not be easily measured nor grasped, making it difficult to act upon. This, for instance, is the case with trust and commitment (see Morgan and Hunt 1994), which also may be considered as a specific knowledge or tacit knowledge. As the project manager has limited time and resources, she/he may not act upon all factors in a project. Rather, the factors considered as key have to be identified and then acted upon.

Key factors for the efficient execution of collaborative product development projects were presented and discussed in *Chapter 6*. Sixteen of the factors were tested during a survey and reduced to twelve. Together with the synthesis of the theory, the list ends in 22 key factors summarised in six categories. The key factors and the categories are presented in a key-factors' model in Figure 44. Some of the categories and factors are subordinated to other categories and factors, thus approached on different levels and in different phases of a project. E.g., according to the literature, mutual trust is dependent on well functioning communication. Further, cooperation in general is dependent on mutual trust.

Each category can be said to include different types of factors that effect people in a project. Some examples of such factors include organisational arrangements, social factors, physical setting, and technology (see Porras and Robertsson 1992). The first three categories - product development process, requirement management, and information system - mainly include factors related to technology. Strategy and goals and project management relate to organisational arrangements, while trust issues primarily relate to social factors. The key factors are presented within each category in Figure 36.

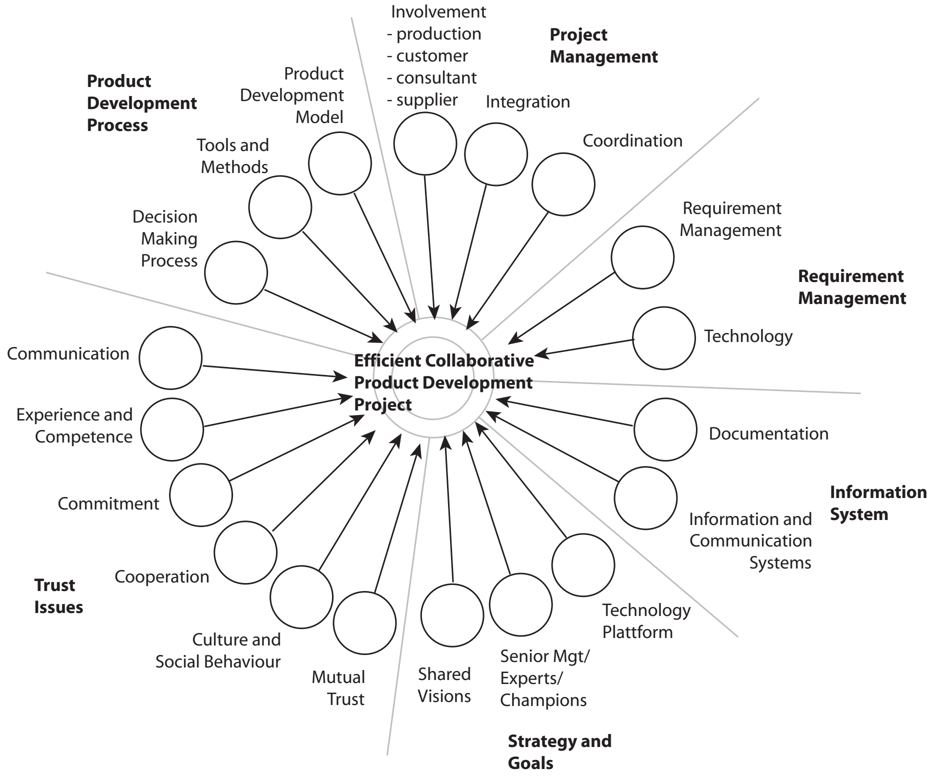

Figure 44 • A key-factors' model. A model for identifying relationships between efficient collaborative product development projects (project performance) and key factors. In the model 'involvement' is summarised in one factor.

If the model should be seen from the analytical approach and if one of the factors is excluded from the model, the effect will still be the same and the other factors will not be affected by the change. However, seen from the systems approach, if one of the factors is excluded from the model, the entire system will change, thus affecting both the other factors (indicators) and the outcome of the project (the effect). As presented in Table 14, each factor relates more or less to the other factors. Thus, acting upon key factors considered as barriers or enablers in a CPD project will affect the entire project. Thus, to predict the effect of an action, it is important to know why a factor is being acted upon, how that act influencing the rest of the system and the outcome of the project.

Moreover, some of the key factors have a larger impact on the project outcome depending on the collaborative setting, this has been indicated for in the survey. The key factors are presented again in Table 15, now as a checklist including the relationships between the key factors and three collaborative settings (internal, integrated and distributed product development). The checklist includes all the factors identified as key for CPD. If the factor is also considered key for product development, this is too highlighted. Further, the strength of the correlation between each factor and project performance in different collaborative settings is also indicated. The context of collaborative product development includes cross-functional teams, supplier collaboration in NPD, concurrent engineering, integrated product development and distributed product development.

Table 15 • Checklist of key factors including relationships to project performance in different contexts (T=found in theory, ○= found in case studies and survey)

Key Factors	**PD**	**Collaborative Product Development**			
		CPD	**Internal**	**Integrated**	**Distributed**
Product Development Process					
Product development model	T	○			
Tools and methods		●	◖		●
Decision-making process	T	●	◖	○	●
Requirement Management					
Requirement management	T	●	◖	○	●
Technology	T	T			
Information System					
Information and Communication Systems		T○			
Documentation		○			
Strategy and Goals					
Technology platform		○			
Shared vision and goals	T	T●	●	○	●
Senior Management/ Experts/Champions	T	T			
Trust Issues					
Co-operation		○			
Competence/Experience	T	○			
Trust	T	T○			
Communication		T○			
Commitment	T	T			
Culture and Social Behaviour	T	T			
Project Management					
Integration	T	T			
Production involvement		◖	◖	○	◖
Customer involvement		○			
Consultant involvement		●	◖	◖	◖
Supplier involvement		T			
Co-ordination		T			

○=correlation, ◖=medium correlation, ●=strong correlation

Despite the lack of strong correlations between trust issues and project performance in the survey, trust is important in CPD (see Barczak and McDonough 2003; Chu and Fang 2006 and case study results). However, trust is found to be both a barrier and an enabler when integrating actors in product development projects. The difficulties involved in establishing trust put high pressure on the companies integrating actors. One example of this is when choosing suppliers based on long-term trustful relationships. Petersen et al. (2003, pp. 295-296) argue:

> The results suggest that customer/supplier integration on an NPD project requires a detailed formal evaluation and selection of potential suppliers prior to consideration for involvement. Only trusted suppliers with a proven track record should be approached (at least initially) to participate. Some of the important criteria to consider include the supplier's relative level of experience and capability in new product development as well as their relative level of expertise with a given technology.

If one of the main criteria when integrating suppliers into product development is trust, e.g. "trusted supplier", then the evaluation of how well the supplier or the actor is trusted becomes increasingly important. Still, it is difficult to measure trust, so how do the companies accomplish this? Which criteria define a trustful relationship? Is it the number of earlier involvements in NPD, the informal relationships within the company or long-term relationships? There are issues still to be addressed.

Further, mutual strategy, common goals, and shared values and visions are closely related to the decisions executed in a project (Cooper and Kleinschmidt 1996; Connell et al. 2001; Gibson and Cohen 2003). Decision-making may be considered as explicit knowledge, while mutual strategy, common goals, shared values, norms, and so on are closely related to tacit knowledge. Thus, several key factors depending on tacit knowledge influence the efficiency and effectiveness of decision-making during CPD projects. Further, decision-making is according to the findings in the survey, not surprisingly, closely linked to the competence and experience of the project manager. The strength of the relationships between the different key factors studied in the survey is presented in the *Appendix – The Survey*.

Fagerström's model for the level of integration (Fagerström 2004) may be used to determine the need for the level of integration (and thus how to involve actors). The actors-and-interface model is a proper means for categorising the project in terms of type of collaboration, i.e. internal/external actors involved. A third dimension of complexity has been added to those two dimensions. It is the number of actors involved, supplementing the first two, creating a three dimensional model (presented in Figure 43). The output from the model for total collaborative complexity (the three dimensions of complexity) may be used to relate product development phases to the collaborative setting, thus identifying key factors important to act upon in each and every phase.

Figure 45 illustrates an example where phase 2 in a product development project is characterised by the 'distributed product development' setting. Using the checklist four key factors may be identified as especially important to consider during this phase, namely tools and methods, decision-making process, shared visions and goals, and requirement management. As the process of determine the total collaborative complexity in each phase is rather complex and subjective a mean (collaborative setting) for the entire project could be more appropriate to apply.

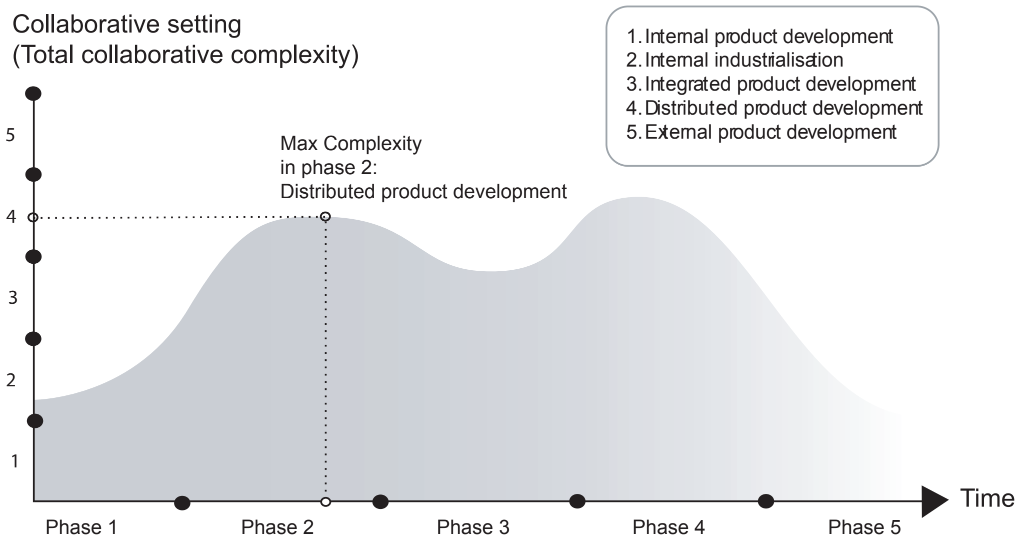

Figure 45 • An example on how the complexity, thus the collaborative setting may vary in different phases during a CPD project (Illustration by S. Jonasson and H. Nerlund).

A Model for Identifying Key Factors in Collaborative Product Development Projects

The discussion presented in this part relates to the objective and research questions presented in *Chapter 1*. The process when developing the models has been iterative, consisting of several versions of the results. This part summarises and synthesises the models presented above into a concluding model. The wish is to bring the model one step closer to applicability in industry.

The Proposed Model

The different results presented in the form of models and a checklist of key factors constitutes a framework of which purpose is to support the set-up of a collaborative product development project. The framework includes an actors-and-interface model, a total-collaborative-complexity model, a key-factors' model, and a checklist of key factors (see the framework in Figure 46).

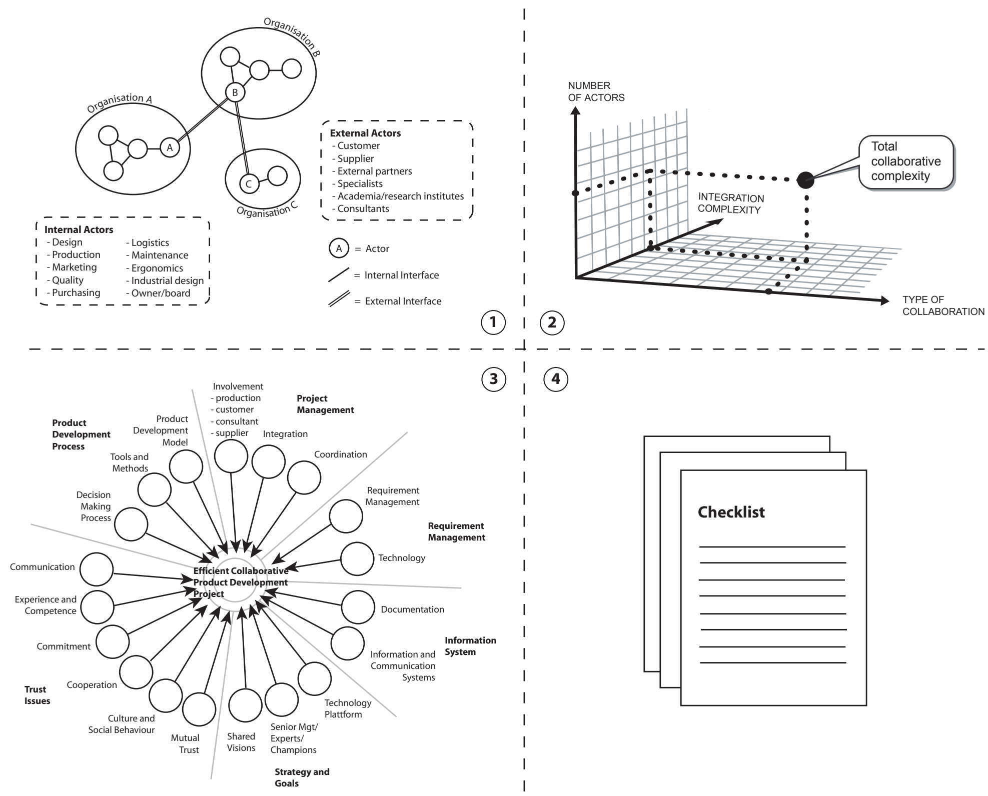

Figure 46 • Tools for managing CPD settings make the foundation to the model for identifying key factors in CPD projects. (1) the actors-and-interface model, (2) the total-collaborative-complexity model, (3) the key-factors' model, and (4) the checklist.

These four parts are synthesised into a model for identifying key factors in collaborative product development projects presented in Figure 47. The outcome of using the different parts generates input to the concluding model, which enables a holistic approach towards the CPD project and its components. The comprehensiveness of barriers, enablers, action points, etc., increases, which facilitates the efficient execution of the CPD project.

A collaborative product development project is comprised of several components. The interfaces constituted one type of component. In the systems model presented in Figure 47, the interfaces between actors are addressed. However, there may exist several other interfaces depending on the viewpoint (Fagerström 2004). The different actors in the system, internal as well as external, are also components. The interfaces between the actors, or the relationships, are influenced by different factors (in this specific system, the factors presented in the checklist). The project is considered as the actual system, and is influenced by external factors impossible to manage from inside the system. These factors could be environmental. Actors also bring their own organisational culture and social behaviour into the project, contributing to the complexity in the system. The system, here the project, operates within a specific contextual setting influencing the system.

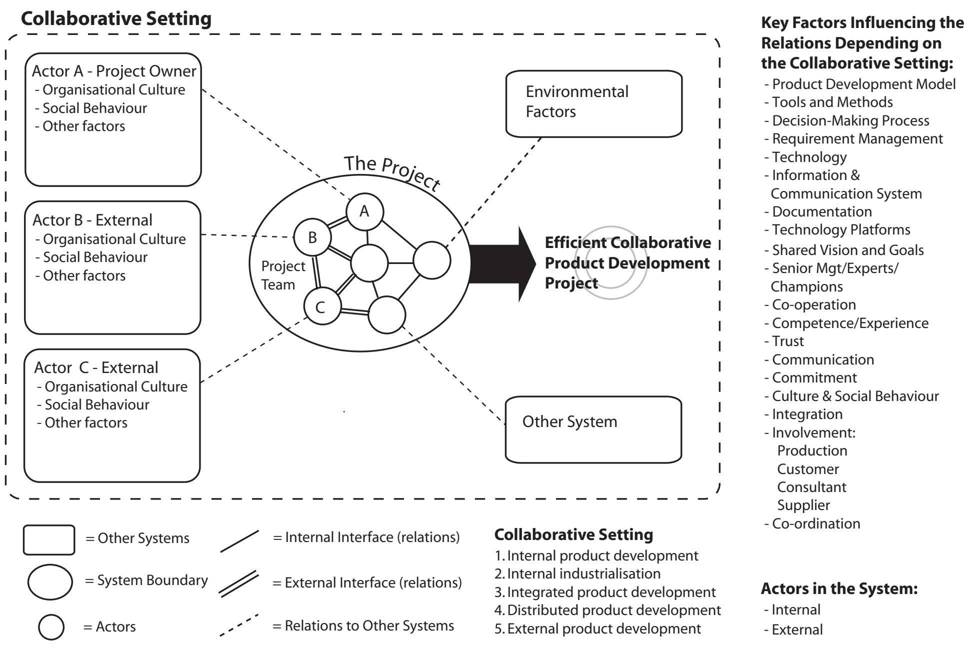

Figure 47 • A systems model for identifying key factors in collaborative product development projects.

The framework of key factors presented previously is here put into a wider context to be made useful. The factors found in the case studies and in the survey are valid for the systems they were found in. Thus, to describe that system and relate the different settings and factors to that system is important. The systems model describing the collaborative product development setting studied in this research is one way to describe reality. Other alternatives for its description also exist.

A Process for Managing CPD Settings

Management in general includes planning, organising, leading and controlling. This thesis mainly addresses the planning and organisation phases of managing CPD settings. In *Paper D* (Elfving and Fagerström 2006), a general procedure was presented for managing CPD projects. The procedure included five steps: identify, analyse, action, execute, and evaluate.

The procedure has further been developed into a five-step process which is proposed next. The purpose of the process is to function as a support when analysing and setting up a collaborative product development project. Some generic phases have to be included in the process. There exist many different 'procedures' for coping with quality assurance and improvements of projects in industry. One example is Six Sigma, a methodology used for implementing a measurement-based strategy that focuses on process and product improvement and variation reduction. Six Sigma mainly adopts two processes for improvement: DMAIC (define, measure, analyse, improve, and control) and DMADV (define, measure, analyse, design, and verify). DMAIC is used for incremental process improvements, while DMADV is used for more radical improvements or re-designs of products and processes (see Magnusson et al. 2003). However, the process sought for in this research may be compared to the DMAIC process.

Further, the process sought for is intended for the tactical level of an organisation, here the management of projects. To determine the level of an organisations collaborative and integrative maturity, which might be seen as strategic questions, the maturity model developed by Hammer (2007) or the collaboration framework by Fraser et al. (Fraser et al. 2003) might be applied.

The focus of this thesis is on the identifying and analysing key factors. Parts of the process could be broken down into sub-parts including important questions to ask and answer. These are described in more detail in the process presented below:

Process for Managing Collaborative Product Development Settings

1. **Identify**

   Focus: Identify actors, interfaces and key factors.

   Questions: What actors will be involved? How many? During which phases are they involved? What interfaces exist between the actors? What problems may occur? What factors are considered key for this project?

   Tools: Actors-and-interface model, Total-collaborative-complexity model, Key-factors' model, Checklist

2. **Analyse**

   Focus: Analyse key factors, actors and complexity. Evaluate the project against best practice or internal goals or measures. Analyse the identified key factors against the valuation of the project. Decide on preventive actions, consider alternative set-ups or a no go decision.

   Questions: Is the factor a barrier or an enabler? What preconditions exist for this factor in the project? Should we act upon it? How should we act upon it? Which key factors are related to each other? Which key factors are related to which phase? Level of integration? Type of collaboration? Number of actors? Relationship between the complexity and product development phases?

   Tools: Actors-and-interface model, Total-collaborative-complexity model, Key-factors' model, Checklist.

3. **Action/Improve**

   Focus: Take actions to improve critical problem areas or key factors not satisfactorily fulfilling the goals. Highlight other factors considered important. Decide if the preventive actions are considered to be enough, consider alternative set-ups or a no go decision.

4. **Execute**

   Focus: Execute the project according to the project plan including revisions and actions taken. Consider re-evaluation if conditions change considerably.

   Tools: Appropriate means of communication.

5. **Evaluate**

   Focus: Evaluate problem areas and key factors using a before-after assessment. Evaluate the project according to the organisation's effect analysis or by key measures. Feedback to the project organisation and other projects, to enable improvements. Feedback for improving the model and this process.

   Tools: Appropriate means of communication.

The process presented above has the aim to improve the chance for successful outcomes of collaborative product development projects. Further, it aims to report back (provide feedback) to an overall project organisation, which in turn develops and improves the business processes. Figure 48 presents the systems model for identifying key factors in collaborative product development projects related to the different tools and the process present above. The process for managing CPD settings may be introduced in the late stages of the 'define the process' phase presented by Maylor (2003).

Further, it should be seen as a complementary and parallel process to the decision-making process. Thus, the process for managing CPD settings aims to provide the decision-making process with appropriate information. Harbison and Pekar (1995) champion a relationship coordinator that should be responsible for coordinating relationships in an organisation or within project. This coordinator could be a mean for introducing a holistic view of the CPD setting. Experience reuse and knowledge transfer between projects and between projects and the project organisation is further discussed.

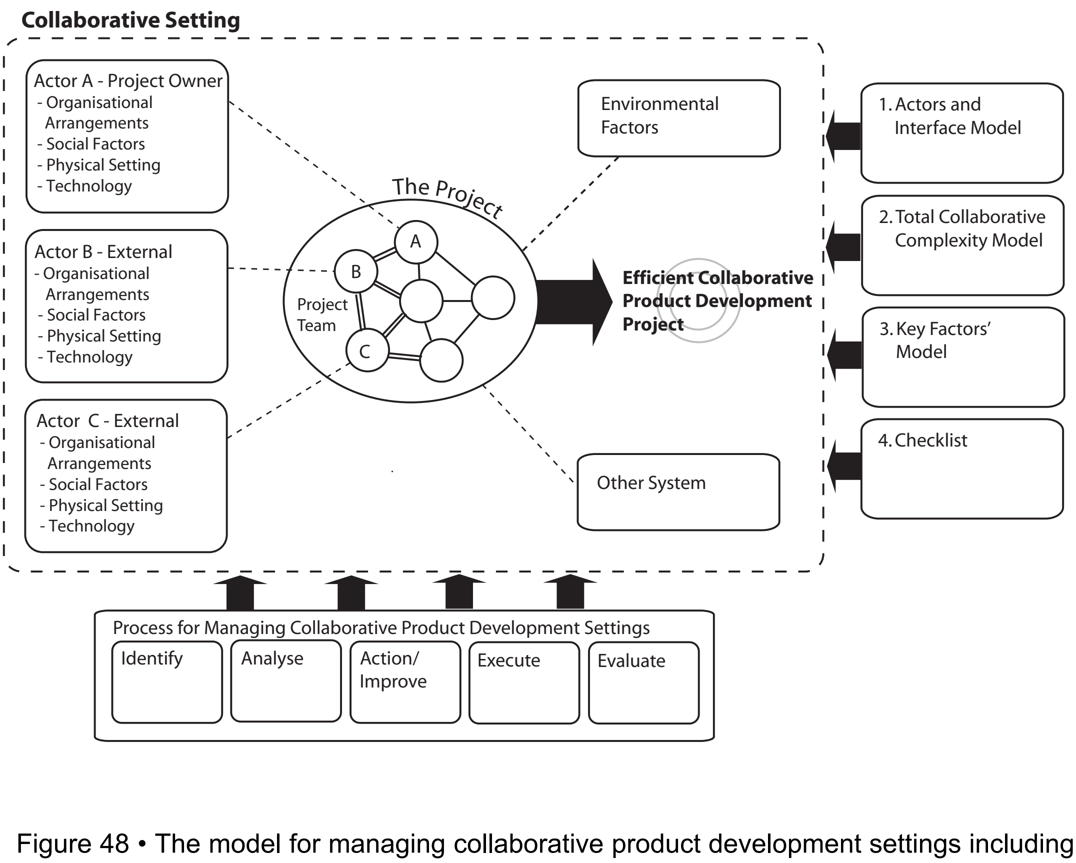

Figure 48 • The model for managing collaborative product development settings including the process for applying the model and input from the tools.

Experience Reuse and Knowledge Transfer between CPD Projects

The process and the use of the model are today not connected to any information system or AI techniques. However, the data and information gathered during the five steps could be an object for knowledge transfer and experience reuse using AI techniques. One way of doing as much would be to focus on the problem area of 'past project experience', presented in *Paper C*. Past project experience could be easily collected and found by using both ontology and Case Based Reasoning (CBR). Ontology makes the search for the right "experience" easier, and CBR may compare past projects, present optional solutions and later store this new case. Problems related to tacit knowledge, if such arises during the process, cannot be transferred between humans with these kinds of methods and techniques. However, CBR, for instance, could reduce the dependence of a designer, operator or other, holding that particular tacit knowledge. In this way, the system is more independent of noise.

During collaborative product development data, information and knowledge is not only transferred between team members and actors, but also between projects and the project organisation. It is therefore a learning organisation that develops (see Argyris 1990; Senge 1990). No means of communication is capable of distributing large amounts of information immediately in a satisfying way (McDonough et al. 1999). The means of communication as presented in the context of *Chapter 4* intended for the collaboration within the team. Nonetheless, all of the means are used for other purposes, too. However, when large amounts of information and knowledge are to be transferred between projects, this puts pressure on the means of communication used.

When enabling the transfer of knowledge between projects and between projects and the project organisation, an overall aim is to continually improve the process of developing products. When applying parallel product development (e.g., IPD, CE or Lean PD), the objective should also be to transfer experience and knowledge in parallel between projects. Figure 49 visualises such transfers of knowledge. As Nonaka and Takeuchi (1995) describe in their model of knowledge transfer, different means of communication are used for different purposes when transferring different types of knowledge. Thus, different means of communications ought to be used depending on the type of knowledge to be transferred between the CPD projects and between a CPD project and the company's overall project organisation. For instance, if product data are to be transferred to the next or a parallel project exchange of documents and reports may be used, a PDM-system could host these information sets.

However, when project experience not easily written down and made explicit ought to be transferred, face-to-face meetings (see Nonaka and Takeuchi 1995) or some form of more advance information system are required (for instance, an expert system founded on AI technology) (see *Paper C*). The access and use of tools and methods in CPD projects are important for project performance. Thus, it will also be important to decide upon appropriate tools and methods for experience reuse and knowledge transfer between the CPD projects (in addition to the project settings).

Each time the model for managing collaborative product development settings is applied, irrespective of phase (see Figure 38), the experience developed has to be reused and the new knowledge attained has to be transferred to the concerned parts of the organisation. If the organisation is mature enough to use a more advanced information system, an expert system could be applied. However, as addressed in the case studies, many small manufacturing companies do not have the appropriate knowledge or experience to use advanced means of communication. Therefore, applying such a system during or after a CPD project involving small companies as actors is a matter of discretion. In the network presented in case B, it just did not work.

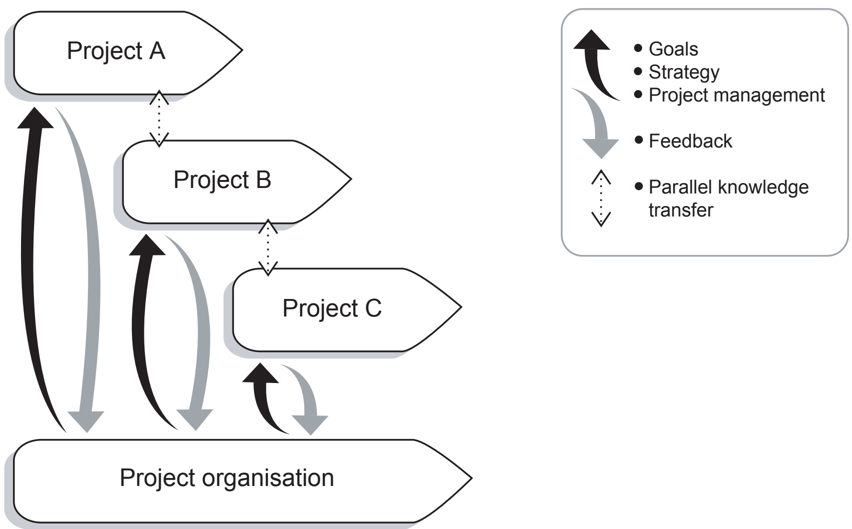

Figure 49 • Experience reuse and knowledge transfer between projects and between projects and the project organisation (Illustration by S. Jonasson and H. Nerlund).

Chapter 8

Discussion and Conclusions

The purpose of chapter 8 is to discuss the findings, relate them to the purpose and research questions, estimate the quality of the results, and to reflect upon and conclude the conducted research. Finally, thoughts on future research are presented.

Objective and Research Questions

As stated at the beginning of this thesis, collaborative product development brings many opportunities. However, it takes time and is costly. The efficient execution of CPD projects requires a holistic view of the product development process as well as the efficient use of supporting tools. Early awareness of barriers and enablers, facilitating preventive actions, increases the probability of success. A model for setting up and evaluating those barriers and enablers in terms of key factors in the initial phase of a CPD project has been developed. So how does the result correspond to the overall purpose, the objective and the research questions? The objective for this research has been:

> The objective of this research is to provide a supporting model for analysing and setting up projects in CPD settings, focusing on key factors, enabling successful product development in terms of lowering costs, increase perceived quality of the product, and time-to-market.

The research objective mainly covers five areas within product development. These are:

- The interfaces between actors in collaborative product development settings.
- Key factors important for the execution and success of collaborative product development.
- The relationship between key factors and project performance.

- Support for collaborative product development in manufacturing industry.
- Experience reuse and knowledge transfer within and between collaborative product development projects.

Four research questions have been posed during the research. Each and every question had sub-questions that were addressed in the case studies and in the survey. The research questions are:

RQ 1. How may relevant interfaces be managed in CPD settings in order to support successful collaborative product development projects?

RQ 2. What key factors may be identified and related to the efficient execution of CPD projects?

RQ 3. How may identified and relevant key factors relate to project performance in CPD projects?

RQ 4. How may CPD projects be managed with the support of the tools and models developed during the research?

The next part will discuss the fulfilment of the research questions and the objective.

Managing Interfaces

Research question 1 addresses the need for a holistic view of the CPD setting. To be able to answer this research question, different actors and interfaces within CPD settings have been identified through case studies, a survey, and literature studies. This question has primarily been addressed by studying the case companies' environmental and organisational interfaces. To a large extent, literature has contributed to answering the question.

An interface is here defined as the intersection between two actors (for example, between two organisational functions such as design and production, or between a main and a sub-supplier). The management of interfaces may be performed in the context of using the model for managing the collaborative product development setting. Identifying and highlighting existing actors and interfaces in a project may be considered as a precondition for the efficient management of collaborative product development projects. In addition, defining each actor's role within the project may be seen as crucial. Further, the interfaces may be addressed with the support of relevant and appropriate means of communication. Nevertheless, the use of technology does not solve interface related issues.

Further, sixteen different actors were identified as present in collaborative product development projects. The actors could be categorised as internal or external, with interfaces stretching outside an organisation or between functions within an organisation. Some interesting findings were revealed concerning how different actors were involved and functions integrated into product development projects. For instance, the low level of integration of maintenance and logistics functions into product development projects is especially interesting. Since many resources are devoted to maintenance activities each year in the Swedish industry, there ought to be a large potential for cost savings in this area. This would provide an incentive for integrating maintenance in product development. However, maintenance is many times neglected during the design phase, and is not involved until the design is completed (Fabrycky 2006). Applying for example Design for Maintenance (DfMaint) could be one way to integrate maintenance activities during product development (DfMaint is addressed by, e.g., Markeset and Kumar 2001). Moreover, in the light of an increased awareness of environmental issues and the escalating cost for transporting goods all over the world (both in terms of destroyed environment and actual costs), incentives for integrating logistics into the early phases of product development should be prevalent and increase the willingness to do so.

All the interfaces found in the different collaborative settings contribute to the understanding of the project as a system. Thus, when it comes to interfaces between actors in a collaborative product development project, all should be considered as part of the collaborative setting. However, that does not tell whether any two interfaces are equally important. The actors and interfaces between them that constitute a collaborative setting are presented in the actors and interface model in *Chapter 7*. The collaborative setting depends not only on the pre-requisites for the project, but also on the active decision to involve specific actors. Integration and fruitful collaboration have to be enabled between those involved in the projects.

Key Factors

Research questions 2 and 3 are closely related. As such, the two will be discussed together. The aim has been to identify barriers and enablers in terms of key factors for the efficient execution of a collaborative product development project, and how these key factors relate to each other, in order to project performance and to different contextual settings.

Research question 2 has been addressed during all studies, literature studies as well as case studies and survey. As the views of respondents and the interpretation of those are subjective, the case studies contributed to this question in terms of indications and possible movements. The contribution from the survey, conducted during the end of the project (thus having another theoretical and empirical foundation to rely upon), was more precise and specific. A preliminary list of key factors was presented in *Chapter 6* and worked as input when presenting the findings from case studies and the survey. The key factors from theory are not only connected to product development, but also to organisational and collaboration issues, areas being part of collaborative product development. A synthesis was made based on the theory and the empirics gathered in the different studies, resulting in a model describing key factors for collaborative product development projects.

Further, a checklist of 22 factors was developed to be used together with the other tools in the model for identifying key factors in CPD projects. Six of these key factors were found to have a strong significant relationship to project performance. Some of the factors relate more or less to other factors, thus providing important knowledge concerning how a factor may be influenced or managed by a project manager in the set-up of a project. A preliminary indication of possible relationships was made in *Paper B*, based on the case studies. The different relationships were further investigated in the survey. The findings in the survey should be treated as indications, and not established relationships. However, it indicates how project managers in this sample perceive important factors in collaborative product development projects.

The factors that had a considerably strong relationship to project performance in collaborative product development in general were also tested regarding their relationships to the collaborative settings. Three settings were possible to test. Of those, the distributed product development setting stood out from the others, with several significantly correlating key factors. A larger sample of product development projects would be needed to test all settings. However, this was not possible to attain during this research project.

Several interesting relationships were found. In addition, some predicted to be found were not (e.g., the strong correlation between trust and project performance failed to appear). This could have several causes. However, it was perceived as very difficult to address trust issues in a questionnaire, compared to during interviews. This problem was discussed in a session of the International Conference on Engineering Design in Melbourne 2005, Australia. The conference participants were divided into two main camps: one felt it possible to measure trust, the other not. No consensus was reached, but those of us at the conference agreed on the complexity of the problem. We also recognised that trust is an important issue to deal with in product development.

The context in which product development projects are conducted is constantly changing. Consequently, the key factors will change over time as well. Trust is a factor considered in several cases to be key for collaborative product development. However, it is less addressed as key within the theory of product development specifically. The focus among project managers seems to have shifted from a technology focus to a more behaviour-oriented focus.

Applying the Findings

The fourth and last research question addresses how to make the attained knowledge accessible and available as a supporting model when managing collaborative product development projects.

During the project, both theoretical and empirical findings have been arranged in terms of models in order to obtain a better understanding of their meanings. The models have been proposed and discussed during research conferences and workshops. As a result, a model for managing collaborative product development settings has been developed. The model includes several tools to be used in the initial phases during product development projects. The tools constitute an actors-and-interface model, a total-collaborative-complexity model, a key-factors' model, and a checklist of key factors including relationships. A process for applying the model and managing a project is proposed. The process and the output of the tools are related to the model. This is one possible way to describe and present the findings.

In order to create new knowledge, the model has to be accessible and available for industry. However, a model like the one provided here is not easily used straight ahead. As with every method, process, or tool, it has to be adapted to the specific conditions of a company or part of a company: the model has to be tailored for the organisation it is intended for. Moreover, when experience and new knowledge are attained during the application of the model, the model itself will develop and change, the model thus being refined.

Some readers may find it appropriate to integrate the framework with an information system and make it online as an IT-tool. Others may not. Some different AI techniques are proposed for how to transfer knowledge and experience reuse. These have not been fully tested in a collaborative product development setting yet. However, other researchers are continuing the development of such techniques.

Correspondence to Purpose and Research Area

The responses to the research questions presented above have contributed to the fulfilment of the purpose for this research. It is argued that the purpose of the research is fulfilled on several levels. As stated in *Chapter 1*, the purpose of this research project has been:

> The overall purpose of this thesis is to facilitate the efficient execution of collaborative product development projects in the manufacturing industry by focusing on key factors and how they are related to different CPD settings.

A checklist of key factors is presented. The checklist includes not only different factors, but also how they relate to different collaborative settings and to project performance. The checklist adds some new factors not addressed specifically in relation to collaborative product development in earlier theory. These are key factors that have not been extensively addressed previously, known at the time of the writing of the thesis. One example is the decision-making process in relation to product development. To be able to use the checklist and understand what collaborative settings the factors influence, a model for estimating the total collaborative complexity is presented. The model is a combination of earlier research conducted by Fagerström (2004) and the results from this research project. A third dimension of integration is introduced and added to the model, the number of actors.

Further, to understand a collaborative product development project and its prerequisites, there has to be an understanding of the surrounding context and actors involved in such a project. For this purpose an actors-and-interface model is presented. A process for applying the model is proposed. Together these tools give input to the model for identifying key factors in collaborative product development projects, which constitutes the main result. The use of the model and the accompanying process may possibly enable the efficient execution of CPD projects. To further determine the impact and effects within an organisation's product development process, the model should be implemented and tested in its natural context.

Davenport and Prusak (1997) argue that knowledge is valuable information from the human mind that includes reflection, synthesis, and context. Thus, to fully understand how the model would contribute in a company, there is a need for testing it further. However, implementation and full tests lie outside the scope of this project. If you apply a systems approach, implementation corresponds to a full system construction based on the system analysis and model presented in *Chapter 7*, and then applying the proposed model to the real system, a collaborative product development project.

Novelty of Results

The new knowledge created by conducting this research project is mainly general knowledge (knowledge about theories and models). However, the case studies and the survey contribute to the understanding of different contexts and behaviour patterns in those contexts. Thus, specific knowledge has also been created (described by Gummesson 2000). To further address the novelty of the conducted research, a summary of the results is presented below, including short remarks about the level of novelty.

- A synthesis of important research on the subject of key factors in collaborative product development settings has been performed. In combination with recently conducted case studies and a survey, this field has been further extended, as has the area of application (in the domain of product development) to which this research is applicable.
- An key-factors' model and a checklist have been developed in order to structure, compare and make use of the different findings concerning key factors and relationships. The indication of strength in the relationships between key factors and project performance related to collaborative settings contributes to a better understanding and increased knowledge of the phenomenon.
- The knowledge of actors and the interfaces between them has been further developed in an actors-and-interface model. The model aims to function as a support when analysing the real system, the collaborative

product development project. The content of the model is not innovative. Still, its form and the use of the knowledge in a structured way contribute to novelty.

- A total-collaborative-complexity model for categorising projects in terms of collaborative complexity has been developed. The model consists of results from earlier research and new knowledge attained from case studies and the survey. This model facilitates the categorisation of projects and relating key factors to different phases in the product development process.
- A process for applying the results in industry is presented. It is founded on previous research and management literature. The process together with the rest of the tools and checklist constitutes a systems model to be used during project set-ups.

Estimating the Quality of the Research Results

This section corresponds to the last part of *Chapter 2,* in which ways of estimating research quality are discussed. That part will now be related to the results from this research project and the methodology used during the research process. As described in *Chapter 2*, when one deals with qualitative data for purposes of understanding concealed and deeper phenomenon, and as the result from research adopting the systems approach mainly is unique and/or typical cases, and is modelled as systems structures, using concepts like generalisation, validity and reliability is not fully suitable in its traditional meaning.

Both qualitative and quantitative data have been gathered during the research. The quantitative data and the quality of it have been judged separately, employing methods and tests commonly used when analysing statistical material. A detailed description of that procedure is presented in *Appendix – Survey*. Details regarding each method used in the case studies are also available in the *Appendix* section. Further, this discussion will focus on the quality related to the main results from this research, the model for managing collaborative product development settings. First, the role of the researcher and how that role may have affected the outcome of the research will be discussed.

Role of the Researcher

A PhD candidate with placement at an academic department finds her/himself quite distanced from the research object, certainly in this project. Thus, the collaboration with industry and the access to objects have been crucial. Four different cases have been addressed, two in which the ability to access people and information was deeper (case studies A and C). As a researcher, I have not participated in the day-to-day work at the studied objects. I have had a rather distanced role, where interviews, observations and documentations have played an important part when gathering data. In three of the case studies, product development projects and activities from the past (within a reasonable time frame) have been studied.

In one case, the study was focused on the present and how the day-to-day work proceeded (Case study B). In two of the case companies, additional studies have been conducted, involving both respondents from earlier studies and new respondents (Case study A in 2002 and 2006 and case study C in 2002 and 2004). By collaborating with the case companies during the entire research project, access to the companies has been simplified. During the survey, several more cases were addressed (34 projects). As the study was conducted using a questionnaire, the influence on the objects was limited. However, by asking questions with only a limited possibility to explain or discuss the meaning and importance of them, the distance also becomes a limitation for the overall understanding of the phenomena.

Dependability

Dependability may be seen as parallel to the concept of reliability (e.g., that two or more researchers studying the same phenomenon with similar purposes should reach similar results). Moreover, that data is stable over time, and may be approached again in the same way.

Part 1 of the model, the model for estimating the total collaborative complexity, is founded on results from two separate research projects. The part of the model that supports the type of collaboration (internal-external) is based on multiple sources, both from theory and empirics. The theory of different types of projects and product development processes are considered stable. Just the same, it will develop over time. The case studies and the projects studied in those are by definition non-repeatable, projects with a limited timeframe, budget and specific context. However, collaboration as a phenomenon in product development projects will certainly remain. This goes for the actors and interface model as well. The content and the components of the different systems are possible to identify all over again. However, the result from a systems analysis is dependent upon the interpreter of the real system. It is always coloured by the knowledge creator's pre-understanding. Thus, it will never be entirely objective (on systems approach, see, e.g., Senge 1990; Arbnor and Bjerke 1997; Checkland and Scholes 1999).

The case studies revealed similar findings compared to theory concerning the key factors (the key factor model and checklist). However, the checklist could profit from additional data, preferably interviews with experienced engineers or project managers.

Confirmability

Confirmability can be seen as parallel to the concept of objectivity, and is related to how other researchers comprehend the research results. It has similarities with dependability when considering the reproducibility of the results.

As explained earlier, my role has been fairly distanced compared to what it would have been if, for example, an action research approach had been applied. The survey backed up the results from the case studies and contributed to the objectivity of the models and tools included in the main model. The process, on the other hand, is rather subjective, and will remain so. Each organisation or manager using such a process has to tailor and adapt it to the prevailing conditions. All case studies have been conducted and analysed together with other researchers or post-graduates. The survey design was done together with several researchers and specialists (statisticians, behaviour scientists, engineers, etc.). Several project managers for product development projects tested the questionnaire further. Further, experienced researchers have confirmed results.

Credibility

The criteria for credibility are parallel with internal validity (for example, how the results correlate to reality and the credibility of the results).

The collaborative setting may be divided in two parts regarding credibility. The first part, settings 1, 3 and 4, is backed up both from case studies and the survey. Conversely, the second part, settings 2 and 5, is not backed up by the survey. Thus, maintaining and increasing the credibility of the model for collaborative settings could profit from additional tests on projects in industry. The entire model for total collaborative complexity, including the part on integration and organisation complexity, would profit from such a test. This is because the model has not yet been tested as a whole. The credibility of the actors and interface model lies in the eyes of the beholder and the real system studied for the moment. The model and checklist of key factors is supported by case studies and the interviews carried. The results from the survey also support it.

However, the understanding of the respondents' answers and what has influenced their views are always lacking when using questionnaires. The survey results and the checklist could profit from a deeper, more profound discussion with the respondents. However, an informal workshop with 20 people from companies developing products and experts from academia was held to address some of these issues further and to provide industry with research results. In the case studies, the respondents examined the material from the interviews afterwards.

Transferability

Transferability in turn may be seen as parallel to external validity, generalisation and the domain the results are applicable within (see Guba and Lincoln 1989; Yin 1994; Alvesson and Sköldberg 2006).

This research takes on a systems approach, which limits the ability to generalise findings. Instead, it is possible to talk about the domains in which the results are applicable or the transferability to similar systems. The checklist of key factors is quite well established in the literature and by case studies and the survey. The checklist describes in which settings some of the factors are more or less important. However, a difference between different types of industries has not been searched for or tested statistically in the survey. Nonetheless, the different industries have been accounted for. The domain can be said to be product development in general. However, the models will not be transferable to all cases within that domain. Thus, the proper area of application has to be judged by the ones (researchers or project managers) who wish to use the model. That is the reason for the checklist. The findings are at the very least valid for those cases that have been studied and similar ones. To increase the transferability, more cases have to be included.

Concluding the Research

The main results of this research project were presented in *Chapters 6 and 7*. The results have been further discussed in terms of the fulfilment of the thesis objective and the correspondence to the thesis purpose in this chapter. Here, relevant conclusions are summarised and presented organised in three areas.

Managing Interfaces between Actors

During the case studies, five types of collaborative settings in the product development projects were addressed:

1. Internal product development
2. Internal industrialisation
3. Integrated product development
4. Distributed product development
5. External product development

Different settings relate to different sets of actors involved in projects. Thus, the different interfaces, external as well as internal, will differ. During the survey, studied projects were to some degree cross-functional. In addition, a considerable part of those projects developed the product together with external partners. The findings from the survey revealed a wide range of different actors active in the collaborative product development projects. Consequently, there are many actors and, in turn, interfaces to manage. It can be concluded that the integration of functions like maintenance and logistics is rather low in product development projects.

In collaborative product development projects, there is a need to identify which actors will be involved and how they will relate to each other (the interfaces between them). An actor-and-interface model was developed to support the identification of both actor and interfaces. In order to determine the total collaborative complexity of collaborative product development projects, an additional model was developed. The model addresses three dimensions: the type of collaboration in terms of the degree of the internal-external project, the level of integration of collaborating actors in the project, irrespective of being internal or external, and the number of actors involved.

Identifying and Analysing Key Factors in Project Set-ups

There exist a large number of key factors when it comes to increasing the efficiency in product development projects. Key factors from the areas of product development (NPD, CPD, IPD, CE), organisational theory, collaboration and network theory, supply chain management, and virtual and cross-functional teams were addressed. In total, some 22 key factors for collaborative product development are presented in the result section of this thesis. Fifteen of those were addressed during the case studies and the survey, while the others were found in the theory. A list including key factors from both theory and empirics was developed to be used as a checklist. A summary of the factors is presented in Table 16.

Table 16 • Key factors for collaborative product development.

Key Factors	
Product development model	Trust
Tools and methods	Communication
Decision-making process	Commitment
Requirement management	Senior Manag./Experts/Champ.
Documentation	Co-ordination
Technology platform	Info. and Communication Systems
Shared visions and goals	Technology
Co-operation	Culture and Social Behaviour
Competence/Experience	Consultant involvement
Production involvement	Supplier involvement
Customer involvement	Integration

Relationships were indicated during the case studies. They included those between some factors and project performance, among factors, and between factors and type of collaborative setting. These kinds of relationships were searched for during the survey. It can be concluded that several of the key factors have a strong impact on project performance in the collaborative product development projects studied in the survey. Six of the key factors are especially important for project performance. The factors that had the largest unique impact and the strongest relationships to project performance are presented in Figure 50.

The key factors effect on the project performance was significant during the collaborative setting; distributed product development (shared vision and goals, decision-making process, requirement management, and tools and methods). Thus, shared vision and goals, decision-making process, requirement management, consultant involvement, tools and methods, and production involvement in collaborative product development projects positively influence project performance.

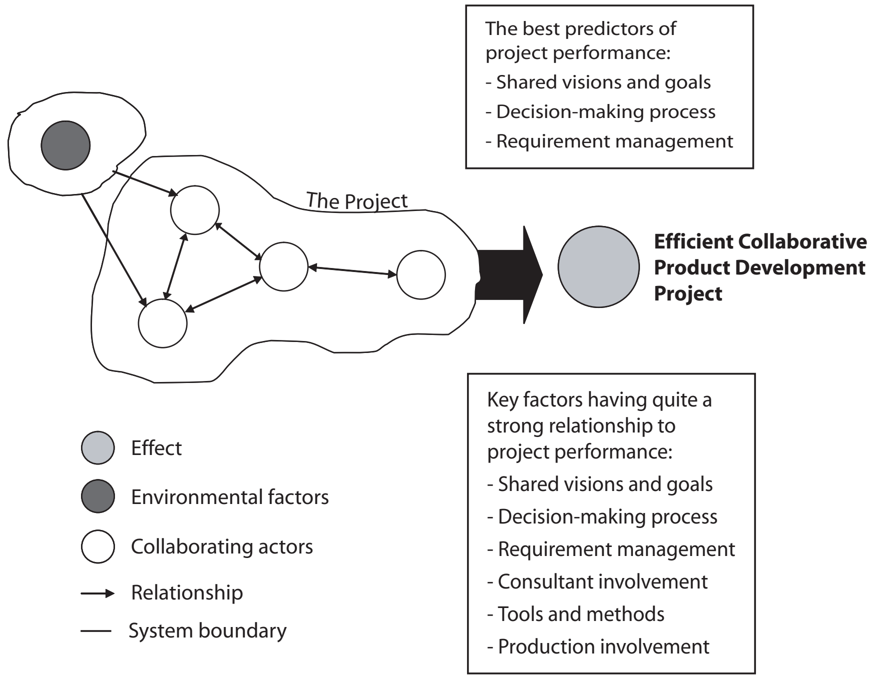

Figure 50 • A systems model presenting key factors for a collaborative product development project.

Some of the key factors' are dependent of each other. It is important to realise that if one factor is changed it will have consequences for other factors. Thus, when making changes considering, e.g., documentation concerning product content and the accessibility or readability of it, it may have repercussions for the decision-making process, the competence/experience of the project manager, and production involvement. Further, co-operation (including areas such as communication and trust) is found to be linked to the consultant involvement and competence/experience of the project manager in a collaborative product development project. However, it is still unclear which factors are independent or dependent variables in this case.

Managing Collaborative Product Development Settings

To be able to manage a collaborative product development setting, a model was developed describing what a collaborative product development setting might look like and what means there are for analysing it. The model includes and is influenced by several components, its context, environmental factors, and other systems. The boundary of the project is the system boundary. The components consist of, for example, the actors, the interfaces between the actors, and the key factors influencing the model.

Further, in order to make use of the model and the tools included, it was supplemented with a process for analysing CPD projects. The process consists of five steps:

1. Identify
2. Analyse
3. Action/Improve
4. Execute
5. Evaluate

Contributions

The conclusions and the contributions may be summarised in two parts. The scientific contribution will be considered first, followed by the contribution to industry.

- The main scientific contribution is the increased knowledge of the key factors for collaborative product development settings, especially to what degree those factors affect project performance in three different collaborative settings (the relationships), and linking internal and external collaboration in the context of product development.
- The main contribution to industry is the model, including the model for determining the level of complexity, the actors and interface model, the key factor model and checklist, and, further, the process for using the model (i.e., analysing CPD projects).

Reflections

Several authors have defined the concept of collaborative product development. In this thesis, a wider perspective has been applied. I believe that adopting a wider perspective on collaborative product development, including both internal and external collaboration in product development, allows for new approaches and insights. The area has been addressed from many perspectives before, each arguing for the importance of one or another function or phenomenon. A holistic perspective is needed, although the area implicates complexity and other difficulties. Consequently, the research process has not been straightforward. The process is described in *Chapter 2*, somewhat edited.

I have experienced the process as iterative and somewhat difficult to manage. However, that is how we learn; that is how my knowledge has grown during this project. My personal intensions and goals for the project have more or less the same. However, the actual research purpose and objective have shifted slightly as knowledge about the area and phenomenon has accumulated. Five years ago, I was a novice within research and, so to say, in the area of collaborative product development. This fact made the road a bit bumpy. As this thesis is a composite thesis, the bumps are still with me. If I had known what I know today, I would certainly have done the project in a different way. I would have insisted more and struggled harder to gain more in-depth access to some of the studied companies. A longitudinal study would have contributed to usable empirics and paved the way for more tests, a thorough system construction and an implementation of a new proposal on a real system. Thus, it would have been part of a change process.

One difficulty I have perceived is to concretise and document the new knowledge attained. The increased understanding of people's behaviour in a collaborative product development setting can be quite tricky to express and transfer, independent of medium used. Further, the research area itself is complex. Theory shows that it is not fully agreed upon by researchers, e.g., if both internal and external collaboration should be included in the concept of CPD. Further, collaboration and product development, two large and complex areas, are approached within different disciplines having different focuses. Consequently, more researchers have to bridge the gap between the two disciplines and link them together. As with the aim of this project, a holistic approach towards CPD might be a way to overcome the inconsistency. The holistic approach should include rather than exclude different collaborative settings. As the external collaboration in a firm is dependent upon how well the internal collaboration is managed (Hillebrand and Biemans 2004), it should be natural to link the two in a product development context to a greater extent.

To break down and analyse problems in such a context has not been a trivial task, and I still wonder how it might be done in the most appropriate way. Blessing, Chakrabarti and Wallace (1998) provide important input into the process of developing such a research area by proposing a methodology for it.

Future Research

The different results obtained during this research have also served as an incentive for future projects. Thus, research within the area of collaborative product development is far from finished. Several additional roads are possible to pursue and investigate further on the basis of the model presented here. Some of those possible roads will be addressed next.

First and foremost, the proposed model has to be further analysed and tested on real systems. This could possibly be done through the continuation of the research project. It can also be done by providing industry with the appropriate means for testing, analysing and developing the model.

Substantial amounts of research have been conducted within the area of key factors for product development (e.g., Link 1987; Johne and Snelson 1988; Littler et al. 1995; Cooper and Kleinschmidt 1996; Balachandra and Friar 1997; McDonough 2000; Connell et al. 2001; Nellore and Balachandra 2001; Sosa et al. 2002). However, few authors address the key factors in such a way that the factors' relative importance for project performance becomes obvious and possible to act upon for industry. The research presented in this thesis takes a clear step in that direction. Nonetheless, there are still great amounts of work to be done in the field. To determine the collaborative setting is concluded to play an important role considering what factors influence the outcome of a project, and how.

Distributed product development as a collaborative setting is especially highlighted in the findings here. Factors such as shared vision and goals, decision-making process, requirement management, and tools and methods are factors standing out from the rest. The decision-making process has been underscored as "…the heart of administration" by Simon (1947). However, with a few exceptions (see Krishnan and Ulrich 2001; Ullman 2006), relatively little has been written about the decision-making process from a product development perspective. Further, the survey indicated a profound interest in the subject. Thus, it is an area in need of more research in a product development context.

As concluded and discussed in *Chapter 7*, some may find it appropriate to integrate the research results with an information system and make it available online as an IT-tool. Different AI techniques for this have been presented.

However, these have not been fully tested in a collaborative product development setting yet. The process and the use of the model are today not connected to any information system or AI technique. This may be one possible direction of future research.

Further, during the latter part of the research on collaborative product development, an increased interest in women's roles in design activities, product development and production in Europe today has emerged. During the case studies and the survey, the number of women in the project teams (as project managers and so on) has been documented. The conclusion is that few women can be found in the engineering design area. This issue has also been addressed in a publication presented at the 5th International Seminar and Workshop on Engineering Design in Integrated Product Development, Zielona-Gora, Poland in 2006. The publication was not appended to this thesis (Elfving and Hellström 2006). The paper addresses women and their role in the engineering design educational programmes at the Department of Innovation, Design, and Product Development at Mälardalen University. The paper concludes (see Elfving and Hellström 2006, p. 4):

> Women are needed in industry and academia to force new ideas and thoughts into the area of engineering design. Today it is evident that industry needs women's way of thinking. Few argue against it. However, how many are really taking actions and putting effort in a change? What counterproductive forces are still present, since the progress is so slow? This is an important area to address further, not only on undergraduate and graduate level, but also on staff level.

Thus, as described above, future research could branch out in several directions: further research on the proposed model, the importance of decision-making in distributed product development, the development of information systems using AI techniques and tools for the transfer of design specific knowledge and information, and, finally, research into women's roles in product development or adopting a gender perspective in engineering design research.

The Next Step

This research project started out as a pre-study in a higher course in Integrated Product Development with 20 students finishing their master's degrees. I was one of the students. I dug deeper into the area of main and sub supplier collaboration and product development by finishing my master's thesis at a small innovative company. Since then, I have been committed to it, wanting to find out more. Today I have a much better understanding of what influences product development in a collaborative context and why it does so, both regarding large and small companies. Now, I am eager to apply my knowledge and the developed model in a more profound way within industry.


MANAGING COLLABORATIVE
PRODUCT DEVELOPMENT SETTINGS

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PART 4

Appended Papers

Paper A Understanding Complexity of Product Development in Small Companies – a Case Study

Paper B A Model for Evaluating and Improving Collaborative Product Development

Paper C Enabling Knowledge Transfer in Product Development and Production: Methods and Techniques From Artificial Intelligence

Paper D Efficient Collaborative Product Development: Critical Aspects and Parameters Influencing the Outcome of Collaboration

Paper E Important Factors for Project Performance in Collaborative Product Development: A Survey Investigating Contextual Settings

Paper A

Understanding Complexity of Product Development in Small Companies: a Case Study

Sofi Elfving

4TH INTERNATIONAL SEMINAR AND WORKSHOP ON ENGINEERING DESIGN IN INTEGRATED PRODUCT DEVELOPMENT. EDIPROD2004. OCTOBER 7-9, 2004. ZIELONA GÓRA: POLAND.

Paper B

A Model for Evaluating and Improving Collaborative Product Development

Sofi Elfving and Mats Jackson

INTERNATIONAL CONFERENCE ON ENGINEERING DESIGN. ICED'05.
AUGUST 15-18, 2005. MELBOURNE: AUSTRALIA.

Paper C

Enabling Knowledge Transfer in Product Development and Production: Methods and Techniques From Artificial Intelligence

Sofi Elfving and Peter Funk

1ST NORDIC CONFERENCE ON PRODUCT LIFECYCLE MANAGEMENT.
NORDPLM'06. JANUARY 25-26, 2006. GOTHENBURG: SWEDEN.

Paper D

Efficient Collaborative Product Development: Critical Aspects and Parameters Influencing the Outcome of Collaboration

Sofi Elfving and Björn Fagerström

INTERNATIONAL CONFERENCE ON PROJECT MANAGEMENT.
SEPTEMBER 27-29, 2006. SYDNEY: AUSTRALIA.

Paper E

Important Factors for Project Performance in Collaborative Product Development: A Survey Investigating Contextual Settings

Sofi Elfving

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PART 5

Appendices

Appendix A

Case Study A

This part describes case study A in more detail. The background of the case is presented, including information about the case company, the context of the case study, a proposed system description, etc. Further, the procedure when gathering data and when analysing it is presented. Finally, the results are summarised, and the questions used during interviews are presented. The results from case study A are partly presented in Paper A, Elfving (2004).

The Case Company

The first part of this case study was conducted in a small Swedish company in 2002. The aim of the case study was to identify and map critical success factors within the product development process in a small company. The main contribution of the study was to answer research questions RQ 1 and RQ 2.

In 2002, the company in which the case study was carried out was situated in a mid-sized city in Sweden. At that point, the company had 25 employees, but was expected to grow. The core competency was within electronic technology development. The company consisted of a project organization, with top management, quality assurance team and project teams. The quality assurance team consisted of senior engineers. In addition to leading the company, the top management was also involved in the product development process. The company mainly had customer oriented product development, meaning that the customers came up with the idea and the company realized it. The requirement specifications varied from customer to customer, more or less throughout. In 2006, the company had grown from 25 to 38 employees. The company is still situated in the same accommodation, but now they suffer from a lack of space. The company is still expected to grow, and during the last year several recruitments have been made. The company's organisation is still the same. That is also the case with their core competency and customers.

The Study

In 2002, eight product development projects were studied. Each project meant the development of a product in close cooperation with the customer. Throughout, the customers were large companies outsourcing parts of their product development. In 2006, the study was comprised of interviews with people on different levels of the organisation. No specific projects were studied.

Selection of Case and Projects

The selection of this specific case was primarily based upon research question 2. The choice to study product development projects was made in co-operation with the management of the company, based on several criteria: the studied projects should consider new development of a product, the product should be a success to the customer but unsuccessful for the company due to an overdraft of the budget or an inability to keep to the time schedule and, finally, the project closure should not have been later than three years ago. The reason why these criteria were chosen was due to the complexity of the study. There can be various reasons why projects are successful or unsuccessful. When narrowing the conditions and delimitating the study, some tracks may be eliminated, thus facilitating the analysis of the data. Therefore, the result can only be considered to be valid for projects with conditions that are similar to those studied.

Data-gathering

Interviews as a data collection method was tested in the beginning of the research project during a pilot study[1]. The purpose with the study was to investigate the phenomenon of inter-organizational relationships between main and sub suppliers in product development. During the pilot study, interviews were held with management people and design engineers on several industrial companies, both large and small, who had close collaboration with suppliers in the R&D process. The result from the pilot study showed that interviews could serve as a suitable method when investigating the outcome of product development projects and inter-organizational relationships. Seen from this, interviews were prepared and held according to obtained

[1] The pilot study was conducted during a higher course with the participation of 30 master students (See Olsson, E. (2002). *Produktutveckling i samverkan*. Department of Innovation, Design and Product Development. Mälardalen University. Sweden.

knowledge. The interviews were held with the assistance of a questionnaire with areas of questioning defined in advance (see Westlander 2000). The analysis of the interviews was performed according to Kvale's (1997) so called sentence concentration[2]. The most essential parts of the interviews were summarized and interpreted according to this method of analysis.

The data collection was made through open-ended interviews, half-structured interviews, and an overview of project documentation. A literature review was conducted, mainly within the field of product development in small companies, to simplify the identification of interview areas and critical factors in the case study. The interviews were made in two parts. First, interviews were held with people from the board, the managing director and vice managing director, to further identify interview areas and to complement the data gathered from the project leaders. During these initial interviews, six key areas could be identified. These were the ones that presumably would include factors that influence the outcome of the product development projects most. The theoretical framework was partly used when developing the interview questions. However, the aim has been to study the companies in an unbiased manner in terms of key or important factors in their product development process. From the interview material factors were identified and later analysed and discussed together with findings from literature.

Thereafter, five project leaders were interviewed regarding eight different product development projects. The half-structured interviews were prepared by sending an open-ended questionnaire, dealing with the key areas, to the respondents in advance. In that way, the respondents had the time and ability to comprehend the questions that were to be asked, and there was an opportunity to clear out question marks and misinterpretations before the actual interview. During the interviews, the respondent had the opportunity to freely discuss the questions asked. If they wished, both the respondent and the interviewer could follow the prepared questionnaire, and in that way make the interview more structured. Questions were asked on six key areas: requirement specification, customer relationship, technical competence and resources, project closure, project management, and quality assurance. The questions were asked in Swedish. These can be obtained in Swedish from the author upon request. In total, 12 interviews were conducted.

[2] Sentence concentration implies a reduction of material through the concentration of sentences and that the most important information is kept (See Kvale, S. (1997). *Den kvalitativa forskningsintervjun*. Lund: Studentlitteratur.

The documentary information has been important during the case study. The collection of data has considered administrative documentation as: management documentation, project plans, etc. With the help of the documentary information, a background to the case has been created and an understanding of the system reached.

Analysis

The analysis of data was carried out twice: after the initial interviews and the reviewing of documentation, and after the in-depth interviews. During the first analysis, six interview areas were identified based upon how frequently and to what magnitude a particular phenomenon appeared in the data. The six areas were: *product requirement specification, customer relations, technical competence and resources, project closure, project management, and quality assurance.* None of the areas were compared or weighted in relationship to each other in this first analysis.

The second analysis was performed after the more profound interviews. The analysis was carried out with the support of a matrix where every project was analysed by key area (See Table 1). A total of 48 analyses were made, six in each project. For every project, a synthesis was formulated based upon the analyses. When an overall view of each project had been achieved, syntheses were created for each key area. These twelve syntheses were the basis for the identification of the key factors influencing the product development projects. In the case where a key area had great influence on the outcome of each project, or a majority of them, this area was concluded to be a key factor. Two key factors were identified from the key areas.

Table 1 • Each project analysed by key area.

	Projects								
Key areas	1	2	3	4	5	6	7	8	*Analysis*
Requirement specification	Y	N	N	Y	Y	Y	Y	N	**Y**
Customer relation	Y	N	N	Y	N	Y	N	Y/N	N
Technical competence	N	Y	Y	N	Y	Y	Y	N	**Y**
Resources	Y	N	N	N	N	N	Y	Y	N
Project closure	N	N	Y	Y	N	N	Y	N	N
Project management	N	N	Y	N	Y	N	Y	Y	Y/N
Quality assurance	N	N	N	N	N	N	N	N	N

Y (Yes) Indicates that the key area had considerable influence on the project outcome
N (No) Indicates that no strong correlation between key area and project outcome could be found

Results

This part summarises the results from the case study. It also ends in reflection upon the case study, and parallels are drawn to the developed model presented in *Chapter 7*.

The System – Contextual Setting, Actors, and Interfaces

The unit of analysis during this case study may be divided into two levels: the overall project organisation (business level) and each specific project (project level). On the business level, the product development process and project management were studied. On the project level, requirement specification, customer relation, technical competence, resources, project closure, and quality assurance were studied. During the first part of the case study, in 2002, the overall project organisation constituted the owners and steering board, having a large influence on the projects and the set-up of them. One project manager managed each project.

The managers had expressed dissatisfaction with time and cost fulfilment in the projects, and wished to explore why many of the projects turned up like this. In the company there were no professional project managers. The engineer free at the time or seen as most suitable was appointed project manager. The projects conducted can be considered as quite short, ranging from 2-12 months. The core team consisted of one to two people. The production department was involved occasionally, as was the customer. In some projects, the customer was considered as "a source of problem". The main feeling one is struck by when visiting the company is a feeling of energy and that a multitude of activities are going on at the same time. People seem to work closely together and communicate easily. The coffee room is a place where things happen and important decisions are made.

Important Factors

The analysis showed that *product requirement specification*, the design of *test specification,* and *technical competence* are the factors that affect the rapidity in the product development process the most. Product requirement specifications and technical competence have a dramatic influence on development time. However, both management steering and customer relationships are critical as well. The scheduling of resources and time in the projects is one phase that can be seen as critical. It seems at this point that the problem with product development time is initiated. That would imply that there is nothing wrong with the company's product development model, but rather that it is a question of the establishment of the project plan and time schedule. The planned development time should instead be based upon earlier successful projects with corresponding plans. The study also shows that small projects have small margins and, therefore, they are sensitive to changes. Changes in a small project can thus bring problems and effect the development time. Small margins make the project vulnerable and thus demand fast decisions. To eliminate possible problems in the termination of projects, a number of criteria that have to be fulfilled in the termination process have been defined: (1) all tests must have been finished and approved by the customer; (2) a complete production documentation must exist; (3) the product must have been delivered; and (4) the customer should be satisfied.

In 2006, the case company had various problems: too much dependency on requirement specification, development teams based on similar characters within the same area of expertise, top-down managed teams (lack of trust), lack of a joint view of the project between inefficient meetings, exceeded project time and budget, and engineers' time spread across multiple projects.

Contribution

The contribution of this case study to this research has mainly been of an introductory sort to the project. It has been a first glance at the small development company context, which has demonstrated the complexity of product development. A first comparison of the theory and empirics has been made, and some critical factors have been sorted out. Some reflections upon the study include the following: the company has recurrent problems allocating enough and the proper resources to their projects, and there is little or no collaboration between the company and their customers in the projects. They also have few close partners. The company is surprisingly independent. Nonetheless, it is confronted with, according to literature, common small company problems (e.g. limited resources, engineers' time spread across multiple projects, and little documentation of designs and of lessons learned).

Due to the fact that the case study was conducted within one company and a limited amount of projects were studied (8 projects), the result cannot be generalised to fit product development projects in small companies in general. However, the qualitative methodology used in this case study aims to seek structure and circumstances. This is quite important when studying processes, and is what makes such a case useful and interesting. In this research, the "construct validity" has been secured by using multiple sources of evidence (that is to say, interviews and documentation). During the compiling phase of the case study, the respondents have reviewed drafts of the interviews. A manager and a project leader in the involved company reviewed the final report to eliminate confusion and misinterpretation.

Reflections

Having completed the main part of this research project and having developed a framework for managing collaborative product development projects, I became curious about testing the parts of the framework on the case study. In Figure 1, the systems model describing case company A's collaborative product development setting is presented.

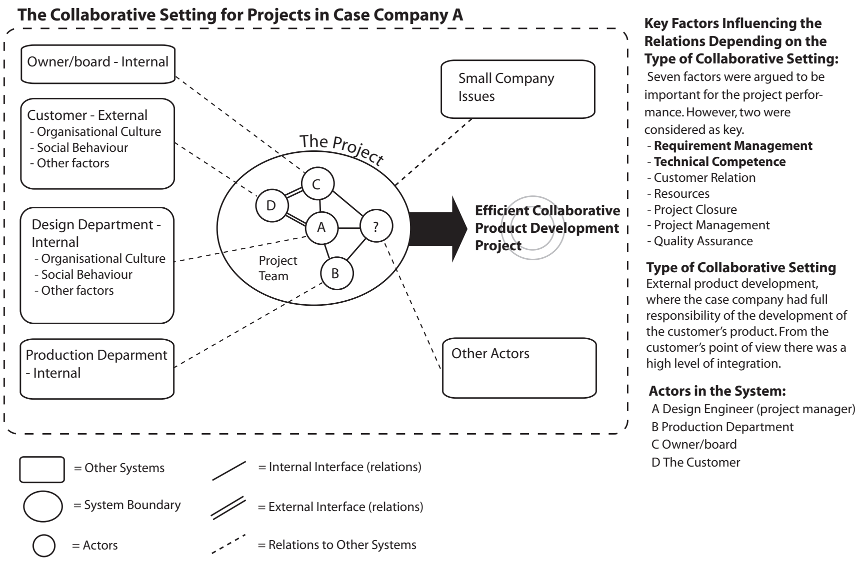

Figure 1 • A systems model describing the collaborative setting for projects in case company A.

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Appendix B

Case Study B

This part describes case study B in more detail. The background of the case is presented, including information about the case company, the context of the case study, etc. Further, the procedure when gathering data and when analysing it is presented. Finally, the results are summarised and the questions used during interviews are presented. In addition to being presented in this thesis, the results from case study B are presented in two papers not included in this thesis, Andersson and Elfving (2003) and Andersson and Elfving (2004).

The Virtual Network

The case study was conducted in a network of Scandinavian companies in 2003. The aim of the case study was to examine the collaboration among the network members during product development, as well as their use of virtual project place as a means of communication. The case study mainly addresses research questions 1, and 2.

The case study was conducted at virtual industrial network during the year 2003. In 1996, an inquiry on the subject of founding a network was sent out to companies within the plastic (polymer) and tools industry in Sweden. In 1998, a web-based cluster/network was created. The network has about 70 member companies in Sweden, Denmark and Norway. The network is web-based and covers five different business areas: apparatus; machinery; tools; development, and, components. The network develops and produces products or parts of products for larger customers. The network has no employees; the meaning of the network is to only have companies as members. The network has a so-called "business centre" in Stockholm, Sweden. Here, members can get together and discuss and create businesses during frequent meetings. In the network, the physical and virtual meetings are of great importance for co-operation since the companies within the network are located at remote places. One of the network's goals is to have a functioning virtual factory that can be used by members and customers frequently during the product development process.

During the case study, we studied how the companies in network were collaborating in the product development process via the virtual workspace, "the virtual factory". We then believed that the design of the virtual workspace influenced the product development processes negatively and therefore made the work within the network inefficient.

The Study

The manager of the network and representatives from five different member companies were interviewed and studied. The interviews and observations were made on a business level, addressing issues concerning the process of developing and producing products in general within the network. The virtual workspace was analysed and tested.

Selection of Member Companies

When analysing the target group (the network), seven companies were selected with significant experience in product development, representing five different fields within the cluster: apparatus, machinery, tools, development, and components. Two of the companies left the group, and the remaining five companies remained in the interview study. The respondents were the ones that had the major responsibility of the network membership. Thus, the companies had different business focuses: mechanical equipment and prototypes, electronics and software development, plastics and prototype development, electronics development and integrated systems, and integrated development in polymer technology. Finally, the companies differed in size (the number of employees ranged from 9 to 600) and geographical location.

Data-gathering

In this study, three sources (documentation, interviews and direct observations) were used as sources of evidence. These sources complement each other and therefore provide a comprehensive image of the companies' relationship within the network.

Documentary information is important for nearly every project. The collection of data may consider administrative documentation, letters, and communiqués. The power of documentation is that data is precise and can be reviewed over and over again. A main problem when collecting this kind of evidence is that there may be difficulties in accessing the documentation. To map the idea of the network and to analysis the target group[1] of the network, we have taken part of documents considering the network activities, e.g. contracts, business strategy and information. We have also visited the business centre, the network's physical meeting place, interviewed the "cluster engine" and taken part in the network meetings being held there. The contact with the "cluster engine" has been continued and, in total, two deep interviews have been conducted for the purpose of receiving genuine information regarding the network history, problem areas and expectations for the future. Further, five managers in member companies were interviewed. The questions were half-structured, formed to receive detailed answers and explanations from the respondent (Häger 2001, p. 61). The interviews were documented both on paper and tape. The power of interviews is that they focus on the case study topics, with the opportunity to guide the respondent into the right area. The resulting weakness is that the respondent could give the answer she/he believes the interviewer wants to hear, or the interviewer leads the respondent to a specific answer. The questions during interviews could also be poorly formulated so the respondent cannot give a proper answer due to a misunderstanding or the interpretation of the interviewer (Lantz 1993). Five groups of questions were asked, e.g. on behalf of the background of the network, the product development process, the communication process, and the means of communication used. The questions were asked in Swedish. These can be obtained from the author upon request.

The third source of evidence (direct observation) has the advantage of covering events and their context in real time. However, direct observations are both time-consuming and expensive. It is also very selective (Yin 1994). During the direct observation, a task analysis was performed in the workspace[2] used by the network. A task analysis provides fast answers concerning eventual misinterpretations of the product. The method's weakness is that the results are in the hands of the person performing the "test" (Jordan 2002, pp. 73-75). In a task analysis, the researcher observes her/his behaviour as a user within a specific context.

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[1] The network members
[2] The virtual factory

Analysis

The units of analysis for this research project during this case study were: networks, external collaboration in product development, communication, tools and methods, and strategy and goals. As the case study was conducted in co-operation with an information design researcher, there were several more aspects considered than those. A task analysis was performed to explore the communication tool (the virtual workspace) used in the network. In this study, we, as researchers, walked through the virtual workspace, tried out links, read texts, uploaded files, etc. Every step was instantly registered and documented with the help of screen dumps[3]. Observation and perceived experiences were instantly written down. The screen dumps and the written comments were brought together in a 40-page Word document. If an experienced designer uses this method, her/his own previous knowledge of design can influence the results. The direct documentation (the screen dumps and the written comments) helped us set our biases aside and objectively observe the choices and actions we made in the virtual workspace. A summary of the analysis is presented in Table 1.

Results

This part summarises the results from the case study, and ends in reflection upon the case study.

The System – Contextual Setting, Actors, and Interfaces

In the network, there were mainly three types of actors, the "cluster engine" (the coordinator of the network), the member companies, and the customer. During gatherings of the network, it became evident that each member company brought their own organisational culture and social behaviours into the network, with little willingness to adapt to the contextual setting of the network. A "virtual factory", or a virtual workspace, was the means of communication that would make the network function. In reality, this was not the case. The different actors and the relationships between them are presented in Figure 1.

Several member companies expressed dissatisfaction concerning the use of the communication tool. Studying Figure 1, the "cluster engine" is an

[3] A screen dump is like as a photo being taken of the screen.

information provider. There is a flow of information directly between the companies and the customer or via the virtual factory. There is also an internal flow of information and technical communication within their companies. Further, the respondents expressed a lack of trust within the network. One reason why users of a virtual workspace can lose trust in the organisation is that they do not experience that they have a natural bond to the system. This can result in a lack of motivation, and the organisation and project may lose its trustworthiness. The virtual workspace can then be perceived as a fictive place and the projects as unreal and unreliable.

Findings

The answer to the question of what was the major reason for joining the network appears to be: lack of resources (capacity), a need of direct contact with the customer (to discuss, for example, development issues), and to communicate products to the market.

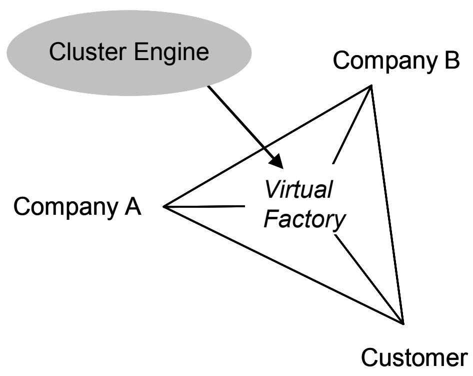

Figure 1 • The components of the network and the relationships between them.

None of the companies used the virtual factory as a tool in collaborative product development. This was primarily because of a lack of contemporary projects in the network, along with the difficulty to handle and comprehend information in the workspace. The respondents found no use of a virtual factory if only one or two actors were involved in a project. In those occasions, they used e-mail and telephone. Some of the respondents argued that extra manpower was needed if the workspace were to be used as a means of communication. Some companies do not have any operational experience with virtual workspaces since they exist in a context that does not support such IT-tools (e.g. lack of technical support or IT-tradition). Finally, the respondents think that the present workspace does not fulfil its purpose (See Table 1).

If the means of communication is based on principles of information design, the cluster can obtain more efficient product development processes. This can lead to new opportunities in developing products and result in more satisfied customers. If the available means of communication is not satisfactory to the users, companies collaborating at remote places, supported by a virtual factory, will not lead to efficient product development. Information design influences product development both positively and negatively depending on how well defined the design of information is in the media of use.

Reflections

This case study was completed in 2003. Today, in 2007, the network is still active, although with fewer members. The feeling one was struck with in 2003 when meeting the member companies and the coordinator for the network was a feeling of competition, not collaboration. There were few physical meetings. During those few meetings, company presentations were quite frequent and it sometimes felt like a sales meeting. The slogan for the network is similar to "Partnership for product development and production". In 2003 the feeling was that little is happening in the product development part and that the collaboration did not really work. However, there was a willingness to make it work, and evidently many companies were willing to put time and effort into the network.

Table 1 • A comparison between task analysis and interviews and the conclusions therewith.

	Analysis	Interviews	Conclusions
The workspace, generally	It had a reading value, but no readability or legibility. It had low usability. The workspace had a reading value, since the users intent to co-operate.	The workspace was too difficult to handle and comprehend. It was time consuming and requires education before using.	Both analysis and interviews pointed out the lack of well-designed information in the workspace. Consequently, the workspace was not being used.
Information and trustworthiness	Parts of the information were incorrect. It may result in a lack of trustworthiness in the published information.	The respondents did not experience trustworthiness in the workspace since, for example, information was out of date and there was no activity among the companies in the workspace.	If the workspace is disorganised and is not consistently designed it can reflect negatively upon the cluster. The workspace did not express the values of the network.
Tools for communication	The workspace had no clear purpose. It did not function as a means of communication within the product development process.	All the respondents found communication in the product development a necessity. At the time the companies communicate via phone, e-mail or fax.	Because the provided means of communication did not function, it may be a barrier for communication and the product development process.

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Appendix C
Case Study C

This part describes case study C in more detail. The background of the case is presented, including information about the case company, the context of the case study, etc. Further, the procedure when gathering data and when analysing it is presented. Finally, the results are summarised and the questions used during interviews are presented. The results from this case study are partly presented in Elfving and Jackson (2003) and in Paper B, Elfving and Jackson (2005).

The Case Company

Two studies were conducted at this case company, the first in 2002 and the second in 2004. The first study aimed to explore the role of the production department in a product development project. The second study aimed to more deeply study one product development project, the actors involved in the project, and what influenced the success of the project. Case study C addressed all four research questions.

Case study C involved a large company within the mechanical and mechatronic industry. The company has about 600 employees within the internal marketing/sales, design and production departments. Most of development and production is situated in Sweden. However, in recent years, there has been an increased interest in the Asian market, and a production facility is under development in Shanghai. The case company is a part of a larger group. The company has a high degree of interaction between the different functions, but has some difficulties managing the collaboration. Despite physically separated production and design departments, the development of products has been carried out in a collaborative manner with especially improved early involvement of the production organisation. The production department has taken most of the initiatives for the studies, as a step towards better integration of production into product development projects. The production department has not been satisfied with the commitment to the product development projects. They have also had problems getting their demands connected to production met with sympathy. The production department has put effort into educating and improving the competency and understanding about product development among personnel. A new way of working with production issues has been initiated in the last two large development projects.

The Study

In 2002, two different product development projects were studied. Each project meant the development of a product in cooperation with the production department. In 2004, the study was comprised of deeper interviews with people on different levels of the organisation, working with production related issues in product development projects.

Selection of Case and Projects

The company was a good case due to its ongoing efforts to cope with collaborative product development, with an emphasis on internal collaboration between the production and design departments. A trustful relationship had already been established with the case company; thus, in-depth knowledge and information was rather easy to access. People seemed to have a positive attitude towards the studies, and therefore appeared opened minded. During the first part of the case study, people involved in the two projects were chosen for interviews. In total, eight interviews were conducted in 2002. In 2004, nine interviews were conducted with people from production, design, and marketing.

Data-gathering

In 2002, the study was based on interviews involving management people in the steering boards, engineering manager, project leaders, subproject leaders from production, process owner for product development, and people in close connection with the projects, such as planning and purchase engineers. During the interviews, a picture of the work and the results of the two projects as well as the relationships between people during work evolved. Three main questions were asked and discussed during the interviews in the case study:

- How has production department formulated and put their requirements on the product development projects?
- Will the products be easier to produce and with better productivity in the process compared to earlier products?
- How can the cooperation between the product and process departments be improved during the development process?

The interviews were semi-structured. This was to keep them within the main question area while still retaining the possibility of getting the interviewees' own ideas and feelings. The interviews in the study conducted in 2004 were much more open than interviews conducted in the other case studies. A question form with areas specified in advance and main questions were used as guidance. Each area was further addressed with follow-up questions. The areas were: type of project, organisation, strategy, goals and requirements, product development process, tools and methods, and trust issues. The questions were asked in Swedish. The questions can be obtained from the author upon request.

In 2004, the case study was also based on semi-structured interviews involving managers (from production, design, and marketing), project leaders, project participators, and internal evaluators. Questions were asked and freely discussed in areas prepared in advance. The areas were the first draft of a model for managing collaborative product development projects. The areas were discussed in relation to different types of collaborative settings. The discussion also dealt with how and why to improve addressed areas and factors in different situations. In this way, a profound understanding of the different factors' impact on projects in a collaborative context, and what can be done to improve the possibility for success in product development, was created. The interviews were summarized through sentence reduction and interpreted and analysed.

Analysis

In 2002, the data gathered during the interviews were summarised and analysed by two researchers. The analysis considered six different areas: the product development process, the formulation of production requirements, product development vs. technology development, purchasing issues, key measures for development projects, and strategies and principles. In 2004, the analysis of data was conducted using the areas defined in advance and success factors addressed in earlier case studies and in theory. The main areas addressed were: organisation, strategy, requirements and goals, product development process, and methods and tools. The proposed model and areas have earlier been presented in Elfving and Jackson (2005). Further, a matrix was used to analyse each interview. The matrix included the factors proposed in advance. The interviews were analysed in two turns by two different people, and the findings were further discussed to obtain consensus.

Results

This part summarises the results from the case study, and ends in reflection upon the case study.

The System – Contextual Setting, Actors, and Interfaces

The units of analysis during the second part of the case study were mainly collaborative product development projects, organisation, trust, strategy, product development process, and goals and requirements.

Several different actors were involved in the development projects. However, the main focus was on the design department, the production department, and the interface between those. There was a willingness to involve logistics, but this aim was not fulfilled at the time for the case study. The company has made a great effort to rationalise and improve the production facility. Thus, the production department seems to have a rather strong position within the company. However, the collaboration between design and production is still not satisfactory. The two departments are located in different buildings, but in the same city. There is a short distance between them, but still there are problems related to communication and trust between the departments. The development projects have improved over time when it comes to openness and dialogue, which contributes to the overall commitment from the organisation.

Contribution

It was quite obvious that the production organisation had succeeded in improving the formulation of their requirements and getting them accepted in the project organisation in relation to earlier projects. The engineering department noticed dramatic changes in what kinds of demands that were formulated and the way they were handled in the projects. Both general and specific *production requirements* were formulated in the projects. Typical general production requirements were reductions in throughput times, assembly man-hours, numbers of articles, and numbers of variants. Examples of more specific production requirements in the projects were efficient material handling through modularisation, late customer-order point, performed DFAA-analysis (Design For Automatic Assembly), and customisation in only one module. Further, the *producibility* has been in focus throughout the development of the new products. Examples of this are, for example, several DFA-analysis performed (Design for Assembly), several investigations made in relation to the automation of the assembly process, reduction of articles (in one of the projects by 50% in relation to earlier generation), modularisation and development of modularised work-shops, standardised modules with fewer variants, late customer order-point, reduction of the number of components (in one case from 36 variants in earlier generation to 7 in the new product), and no customised material bought from suppliers. All of these were customisations performed in-house.

The *cooperation* between people from different departments has been improved in the two projects in relation to earlier projects. Our explanations for this are that the requirements were well and clearly formulated and communicated. Resources were reserved, and people worked in close cooperation with the design engineers to fulfil the production requirements. In this way, a much better climate of communication was created between departments and people in the organisation. It was stated that cooperation in the two projects had been successful, or more successful than earlier projects, due to the development of strategies and the formulation of requirements. The organisation knew what they wanted to achieve in the projects.

Further, several factors were identified during the second part of the case study. Five overall dimensions were defined based on the interviews: project management, strategy and goals, requirements, development process, and trust. Five different types of projects were also identified, namely internal development projects, industrialisation projects, and development projects with involved suppliers, development projects with integrated suppliers, and development projects with full going partnerships. A summary of the factors and the types of projects may be seen in Figure 1.

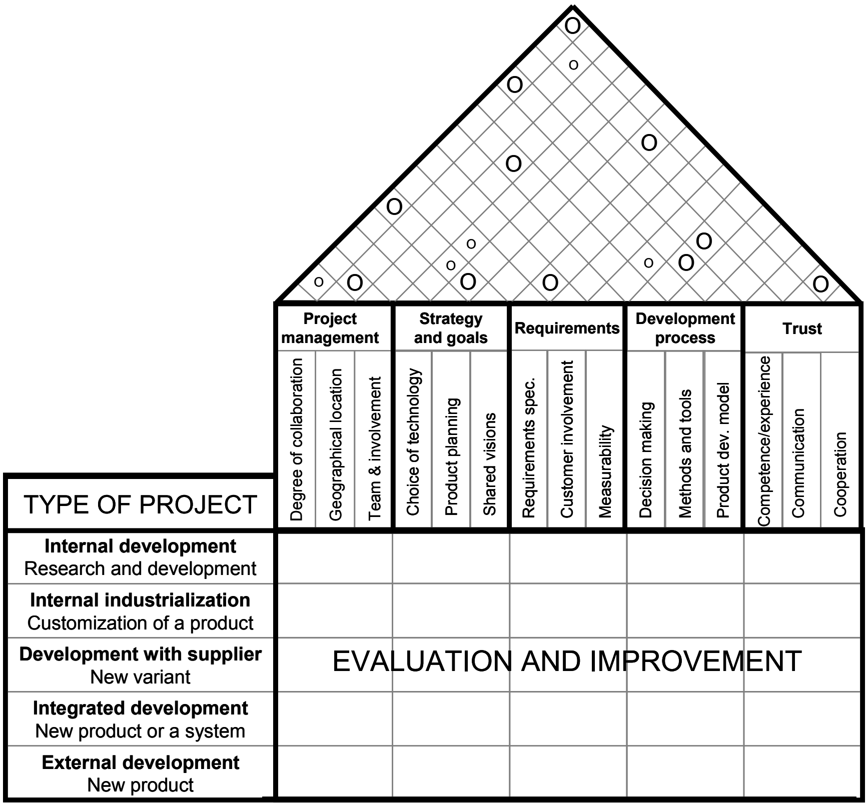

Figure 1 • An early draft of a model for managing collaborative product development projects.

Reflections

Two professors in product development and innovative production conducted the main part of the first study (in 2002). Due to certain circumstances, one of them was not able to complete the study, and that is where I took over. Thus, this first part of the study contributes less to the overall goal for this research project. The second part of the study (in 2004) was more directed towards this research project, thus contributing more.

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Appendix D
Case Study D

This part describes case study D in more detail. The background of the case is presented, including information about the case company, the context of the case study, etc. Further, the procedure when gathering data and when analysing it is presented. Finally, the results are summarised and the questions used during interviews are presented. The results from this case study are also presented in Elfving and Hägg (2004).

The Case Company

This case study was conducted in 2003. The aim of the case study was to identify critical parameters involved in the decision to join an industrial alliance for product development. The case study mainly contributed to addressing research questions 1 and 2.

The case study was conducted at Volvo Construction Equipment Components AB in Sweden. The purpose of the case study was to study the alliance between Volvo and a competitor. The competitor developed, among other products, transmissions in this case to articulated haulers. Volvo had the global responsibility for developing and manufacturing drive train components. The head office was located in Eskilstuna, where they also manufactured axles and transmission for wheel loaders and articulated haulers. At the time of the case study, Volvo CE Components had approximately 950 employees. The competitor was an Austrian company that developed systems for, among other things, agricultural machines, and had about 630 employees. In the year of 2000, the competitor was purchased by ZF, a German company. ZF had about 55,000 employees all over the world, and develops drive train components for cars, boats, and other commercial vehicles.

For a long time, Volvo developed and produced the product in-house. But when the customers demanded a simpler variant of the product, Volvo had to consider whether to make or buy. This was due to a lack of capacity and resources. Volvo wanted to reduce the costs, but had the requirement that no competitive priorities should be affected negatively. The competitor, who already had an approximately ten-year relationship with Volvo, showed interest in developing the product. On the basis of the belief that the competitor could cut the prices more than its competitors and the already close relationship with Volvo, Volvo chose them as a partner. During July 1996, Volvo and the partner conducted a pre-study of the new product, and that was the beginning of the new partnership, the alliance.

The Study

This case study contributed to two separate research projects, collaborative product development and sourcing decisions. Though separate, the two projects exist within the range of the same areas. To get a broader view of these two concepts, the projects were put together, and two different kinds of knowledge areas were combined. This involved asking questions from two different points of views, and also analysing the data thereafter.

Selection of Case and Projects

The case study was chosen to be conducted at Volvo. It is a large company with experience from alliances and co-operation with several external suppliers. Further, contacts were already established. It was rather uncomplicated to gain access to people and documentation. At Volvo, two different projects could be chosen as the focus of studies: (1) an alliance with an external supplier (known by the Volvo cooperation), and (2) co-operation with a competitor within product development. The alliance with the supplier (1) had started at 1996, and the developed products have already been manufactured for some years. The relationship with the competitor (2) was a relatively new project in its pre-study phase; information about the project was therefore rather sensitive for Volvo to expose to people outside of the organisation. The authors therefore decided to study the alliance (1), since that project had finished and Volvo had already reflected upon the results.

Three semi-structured interviews were conducted at the Volvo plant with three different respondents. One interview was conducted with a project manager who had an overall view of the alliance, another with the responsible buyer involved in the alliance and the last one with the R&D - manufacturing coordinator. Unfortunately, no respondent could be attained from the partner company, which is a shortcoming of the case study.

Data-gathering

The data collected from the case study mainly addressed three questions:

- What reasons do companies have for joining industrial alliances?
- Which factors influence the decision to join an industrial alliance or not?
- Is the decision to join an industrial alliance strategic?

Three sources of evidence have been used during the case study. Our opinion is that these sources, interviews, documentations and direct observation are highly complementary and, therefore, give a comprehensive picture of the companies' relationship and the outcome of the alliance. Most of the data was collected through semi-structured interviews. The choice of semi-structured interviews instead of, for example, questionnaires was made since there are only a few employees at Volvo that are considered to be well initiated in the alliance with the partner company. These employees can therefore give a more detailed picture during a personal interview.

Personal interviews can also provide the possibility to ask complementary questions to obtain a higher level of understanding. The questions, which were open, were sent to the respondents in advance. The interviews were not recorded due to the wishes of the respondents. Rather, careful notes were taken. A question form with areas specified in advance and main questions were used as guidance. Each area was further addressed with follow-up questions. The areas were: the product, history and background, product and sourcing strategy, process, outcome, and the future. The questions were asked in Swedish. The questions can be obtained from the author upon request.

The direct observation was conducted at the Volvo plant by the authors. Through observation of the daily work, an understanding of the context could be created. The most valuable data that came out of the observations was information about the product specification and in which context the product fitted in. Some interesting observation about how the information flows within Volvo was captured. A major weakness in this proceeding was that there could not be any direct observation of the work within the partner company in Germany. Instead, the study of the alliance was made from Volvo's perspective. The documentation provided discussed, general information about the two companies. As one of the researchers worked part time at the main case company, the environment and contextual setting could be observed and more thorough knowledge about the collaboration obtained.

Analysis

The three main questions were used when analysing the data gathered: reasons for joining industrial alliances, factors that influences the decision to join an industrial alliance, and strategic decisions. The notes taken during the interviews were compared and analysed to make sure that nothing important was neglected or differed from the real interviews. The summarised information and analysis was then studied by the respondents to make sure that nothing was misunderstood and that, for the benefit of the company, no non-sensitive information was exposed. The analysis was then compared with findings from literature within the area of sourcing, alliances and decision-making.

Results

This part summarises the results and ends in reflection upon the case study.

The System – Contextual Setting, Actors, and Interfaces

The units of analysis during this case study were collaborative product development projects, partnerships/alliances, strategy, and sourcing. The project included both internal and external actors from Volvo's point of view. Within the Volvo design department, the production and purchasing departments were involved. ZF may be seen as an external actor. ZF also had different functions involved in the development of the product. The collaboration was controlled and managed through three different contracts. Both companies seemed to have great experience involving how to manage these kinds of co-operations.

Findings

The alliance between Volvo and the partner consists of a trustful partnership with good communications between the two organisations. A great deal of effort was put in the beginning of the project into building trust and securing each organisation's rights. The complex project organisation demanded that the communication must function between the functions and people. The alliance was built on the fact that the product is outsourced due to Volvo's lack of resources. Volvo did go through different options, whether to make and develop the product themselves or buy it from an external supplier.

The decision was a long-term one, and it has been reconsidered over the years. Volvo's main reason for the buy decision was a lack of resources and capacity. There was also an economic reason: the expense to make the product was higher than to buy it. Volvo did make the decision on the premises that it would increase their degree of competing advantages. But they did not base the decision on parameters like long-term survival, logistics or impure flow. The results from the interviews were compared to theory. A summary of that analysis may be seen in Table 1.

Reflections

This case study was the least extensive one, only including three interviews and observations. However, it provided fairly good insight into the alliance and how an alliance between two large companies may be managed. The main focus was on collaboration in general, and not on the product development process. As a result, the contribution is limited, but still fruitful.

Table 1 • Key factors influencing industrial alliances. A comparison between theories and the findings in the case study.

Theory	Case study	Conclusions
i. Clash of cultures	Yes, Volvo did feel that there were some problems. Because the companies were from different countries with different language there was some clash of cultures.	Clash of cultures will always be a critical factor when joining alliances, especially when the actors are coming from different countries.
ii. Lack of trust and risk sharing	No, Volvo and the partner already had a trustful partnership with good communication.	No clear conclusion could be drawn, but one cannot forget that Volvo and Steyr had worked together for a long time and developed trust during this time. Trust can still be critical for "new" partners.
iii. Lack of clear goals and objectives	No	No conclusion could be drawn.
iv. Lack of coordination	No, because of the well functioning joint steering group.	No conclusion could be drawn.
v. Differences in operation procedures and attitudes	Yes, the partner did have other ways of communicating product changes than Volvo. The reduced amount of physical meetings also caused some problems.	This factor could be a part of *i. clash of cultures* but with more couplings to organisation theories. Still it seems to be a critical factor.
vi. Relational risk	No, both companies are large.	No conclusion could be drawn.
vii. Future local or global competitor	No, when the partner was bought by ZF, competitors to Volvo, none of the actors saw that as a problem.	No real conclusion could be drawn, but this could be an effect of the already established trustful relationship.

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Appendix E
The Survey

This part presents the survey in more detail. The background of the survey is presented, and further, the survey design. The analysis and the results are presented next. Last, the questionnaire is presented. Further information on the survey, data sheets, and code keys may be obtained from the author upon request.

Background

A questionnaire survey was conducted to test and verify the theories and model developed according to the research process in *Chapter 2*. The proposed factors and relationships, derived from the case study and the theory, may be seen in Table 2.

The purpose of a survey is to collect information and data that may be analysed in-order to discover patterns and compare those patterns. The survey aimed to address and examine possible relationships between factors affecting efficient collaborative product development using a web-based questionnaire. The survey also addresses possible differences between types of projects, in respect to level of collaboration. The study is a part of research into distributed and collaborative product development in the Swedish manufacturing industry.

Survey Design

A qualitative research approach has been used for the first part of this research, i.e., the case studies. Thus, an analytical approach was sought to more deeply examine the relationships between the identified factors (without losing the understanding of the big picture). Therefore, the endeavour was to find respondents with specific important knowledge and experience. This resulted in a quite small sample (N=34), but still useful for the purpose. This type of sampling is called purposeful sampling (Maxwell 2005), and is not a fully randomised sample.

The companies that agreed to participate in the study were from diverse businesses: manufactures of machines, electronic and optical products, transportation vehicles, equipment for process industry, equipment/products for sports and leisure, and pharmaceutical equipment.

The companies had to develop their own product; alternatively, they had to develop a product together with a partner or a customer. The sample of companies was a purposeful sample chosen on behalf of the business, the size of the company and the type of product developed (see Table 1). As the survey aimed to examine conditions at project level, it was important to find suitable product development projects and respondents.

The respondents were chosen on behalf of the criteria: the respondent should be a project leader and someone who has managed a project that fulfilled four aspects: the project should have implied the development of a new product, alternatively a major re-design or revision of an existing product, i.e. a new functionality or performance; the project should have implied a team of at least five (5) different actors, of which at least one (1) was an external actor (e.g., customer, supplier, partner) or from the production department; the project should at least have stretched from six months and on, and the project must be finished and handed over when participating in the survey. To reach suitable respondents, recommendations from product development managers in each company were searched for. Each manager was contacted in person and was asked to identify projects and respondents meeting the criteria.

Twenty-seven of the companies contacted had suitable respondents and projects to complete a web-based questionnaire. The most important criterion for the projects to fulfil was that the project should have a high degree of collaboration. It was also this criterion companies in some cases failed to fulfil, thus excluding them from the study. The method to find the sample ensured that all the respondents would have been involved in a collaborative product development project. However, the degree of collaboration in each project, and the project leaders experience differed.

The survey items were developed from literature and the case studies. The survey was tested and modified in several rounds before it reached the respondents. When the identification of the sample was completed, a copy of the web-based questionnaire was sent to 43 respondents. Thirty-four questionnaires were returned, which represents a response rate of 79%. Thus, the unit nonresponse (when the observation is missing), was 21% (9 nonresponses). Nonresponse may have different causes, but there are some common factors affecting the nonresponse rate, e.g., survey content, methods of data collection, and respondent characteristics (Lohr 1999). Some of the nonresponses in this survey were project managers at small companies that did not feel they had the time to complete the questionnaire. One of the nonresponses did not get the web-based questionnaire, because of problems with an e-mail server. Further, when the contact with intended respondents was through a second-hand contact, with no possibility to further discuss or present the survey, it was difficult to get the respondents to answer the questionnaire in time.

The project leaders (respondents) were asked to approximate the outcome of the project in terms of fulfilment of time plan, cost and quality. Their opinion of the overall efficiency and collaboration success was also asked for. Further, five blocks of items were asked about. Each item was measured by asking the respondents to rate a statement on a seven point Likert-scale, where 1 = strongly disagree and 7 = strongly agree. Thirty-four questionnaires were returned, a response rate of 79%. The web-based questionnaire[1] was answered between September and December 2006. Further, the questionnaire was conducted in Swedish and constituted several pages. The questions were grouped in terms of the parameters: product development process, project management, strategy and goals, requirement management, and trust. The actual questionnaire is not possible to present as it was web-based and designed thereafter. However, the questions asked in the questionnaire can be obtained in Swedish from the author upon request.

Analysis

The analysis of the quantitative data gathered in the survey was primarily done statistically using software called SPSS. The data was analysed in terms of item and factor reliability using Cronbach's alpha tests. The data was tested and analysed in several ways: (1) using Spearman's Rank Order Correlation, which is a non-parametric test, comparable to Pearson Product-Moment Correlation (parametric technique); (2) using standard multiple regression; and (3) using

[1] The web-based questionnaire was provided by www.createsurvey.com

factor analysis (see *Paper E*). The results from these test was then used as guidance and indications of direction for the continuation of developing a systems model. On factor analysis, see Hair (2006). Details of the sample are found in Table 1.

Table 1 • Company and respondent details.

Characteristics	Number of responses	Percent of responses
Business		
Electronic and optical products	7	20.6
Transportation vehicles	4	11.8
Manufactures of machines and tools	13	38.2
Chemistry and pharmaceutical equipment	2	5.9
System development	8	23.5
Size of company		
Small (1-49)	8	23.5
Medium (50-249)	5	14.7
Large (250-)	21	61.8
Turnover		
Under € 7.5 million	8	23.5
€ 7.5 million - € 80.99 million	8	23.5
€ 81 million - € 260.99 million	8	23.5
€ 261 million plus	8	23.5
Missing values	2	6.0
Type of project		
Internal product development	12	35.3
Internal industrialization	1	2.9
Integrated product development	11	32.4
Distributed product development (external collaboration)	9	26.5
External product development (partner takes full responsibility)	1	2.9

The sample consisted of 23% small companies, 15% medium-sized, and 62% large companies. The average size of the companies in terms of turnover was €474 million. The project performance was measured in terms of fulfilment of time schedule, fulfilment of budget in terms of meeting expected costs, and the quality of the product. The measures are similar to measures used by other researchers who have studied product development on a project level (see McDonough 2000). To explore the reliability of these three items, a reliability analysis was performed. The reliability analysis resulted in a Cronbach's alpha coefficient of .71 for the items included in project performance, which is acceptable. Cronbach's alpha coefficient is quite sensitive to the number of items in the scale; thus, it is quite common to find low Cronbach's alpha (.5) (Pallant 2001).

Data were gathered on the factors presented in Table 2 using two-four items for each factor. A reliability analysis was also performed on these items, which resulted in the exclusion of some items not correlating satisfactorily.

The relationship between project performance and each factor was investigated using both Spearman's Rank Order Correlation, which is a non-parametric test, and the Pearson Product-Moment Correlation (parametric technique).

Table 2 • A framework of important parameters and factors to manage in collaborative product development projects.

Parameters and factors
Product development process
Product development model (consistency in applied model)
Tools and methods (access to and use of)
Decision making process (consistency and clarity in process)
Project management (Organization)
Involvement (early involvement of actors)
Team (culture)
Geographical location (co-location of team members and actors)
Strategy and goals (Common objectives)
Technology platform (access to and use of)
Product planning (product coherence to)
Shared visions (among team members and actors)
Requirement management
Requirement specification (mutual understanding of)
Involvement in requirement management (integrating actors)
Measurability (manageable)
Trust
Communication (access to and efficient use of tools)
Competence (relevance)
Experience (reuse of)
Long-term relationships (among team members and actors)

Results

The first analysis (with non-parametric tests) revealed three factors in which correlation (r) with project performance in collaborative product development projects was very strong ($r = .50$ to 1.0, or $r = -.5$ to -1.0 according to Cohen 1988). These factors stand out from the others: decision-making process ($r = .58$), shared visions and goals ($r = .61$), and measurability ($r = .64$). All three are highly positively correlated with project performance ($p<.01$). The use of tools and methods in the projects correlated with project performance on a medium level ($r = .36$, $p<.005$) (see Table 3). These findings are the results of a non-parametric test, which is argued to be less sensitive and may fail to detect differences between groups. A non-parametric test does not make assumptions about the underlying population distribution. Non-parametric tests are also used when the sample is very small (see Pallant 2001). The sample in this survey is on the verge of not being a small sample ($N=34$). As such, parametric tests are also used to further analyse the data.

Table 3 • Preliminary results using Spearman's Rank Order Correlation without revising the factors.

Independent Variables (factors)	Correlation with project Performance
Product development model	.27
Tools and methods	.36*
Decision-making process	.58**
Involvement	.13
Team	.38*
Geographical location	.19
Technology platform	.05
Shared visions and goals	.61**
Requirement specification	.43*
Involvement in requirement management	.20
Measurability	.64**
Communication	.22
Competence/Experience	.27
Long-term relationships	.18

Spearman's Rank Order Correlation
*. Correlation is significant at the .05 level (2-tailed)
**. Correlation is significant at the .01 level (2-tailed)

Investigating the Factors' Correlation with Project Performance

The results from the factor analysis contributed to a revision of several factors. In sum, the 16 original factors were reduced to 12. It became quite clear that some factors were sensitive to address, and were thus difficult to ask about in a questionnaire. Trust was one of those. The items and questions in the survey regarding trust were adopted from other studies on trust and commitment (see Lindh 2006). Still, it was difficult to get a valid result out of these questions.

The factor analysis excluded measurability and team as single factors. Involvement and geographical location were also excluded after further analysis and revision of the factors in Table 3. Instead, three new factors were formed based on the involvement of consultants, customers, and production. Table 4 shows the results from the multiple regression analysis (subsequent to the factor analysis). The analysis showed that six factors correlate significantly with project performance: shared vision and goals (r=.659), decision-making process (r=.569), requirement management (r=.536), consultant involvement (r=.471), tools and methods (r=.447), and production involvement (r=.332). This implies that when these factors were managed properly in the collaborative product development projects studied, the project performance was perceived as high (satisfactory fulfilment of time, cost and quality).

Table 4 • The revised framework of key factors (correlation with project performance).

Key Factors	Explanation of revised factors	Correlation
Product development model	Consistency in applied model	.286
Tools and methods	Access to and use of	.447**
Decision-making process	Consistency and clarity in process	.569**
Requirement management	Complexity in requirements	.536**
Documentation	Availability and usability of information and documents	.256
Technology platform	Access to and use of	.088
Shared vision and goals	Among team members/actors on strategies and goals	.659**
Co-operation	Communication and trust	.155
Competence/Experience	Project manager reuse of	.275
Consultant involvement	Involvement and integration	.471**
Customer involvement	Involvement and integration	.029
Production involvement	Involvement and producibility	.332*

Pearson Correlation
*. Correlation is significant at the .05 level (2-tailed)
**. Correlation is significant at the .01 level (2-tailed)

Moreover, the revised framework in Table 4 can be said to constitute a model of factors that explain project performance (the model used when doing statistical analysis, not a systems model). Thus, the model was tested using multiple regression. The model (the different factors together) is assumed to explain 66.7% of the variance in project performance (adjusted R square=.667). Of the factors included in the model (variables), shared vision makes the largest unique contribution to explaining project performance (beta=.514). Decision-making process (beta=.468) and requirement management (beta=.322) also make statistically significant though smaller contributions to project performance. Thus, the level of shared view of the strategy and common goals within the project may be concluded as the best predictor for project performance in the sample. No considerations regarding the innovativeness of or the novelty of the product have been taken. And the conclusion has to be viewed in relation to the relatively small sample in the survey (N=34), and treated as more of a guideline than the truth. These figures on Beta may be seen in Table 5.

Investigating the Relationships among Factors

One condition for including different factors (variables) in a model when using multiple regression is that there must not be too high a correlation between the independent variables ($r < .70$). Thus, this was checked for in the analysis. None of the factors had a correlation coefficient exceeding .70. As a result, all factors were kept in the model. However, in six cases there were correlations exceeding .50, which may be considered as relatively strong. The documentation factor exceeded .50 in three cases: decision-making (r=.529), competence/experience (r=.661), and production involvement (r=.555). Moreover, co-operation including communication and trust had a correlation coefficient higher than .50 in two cases: consultants' involvement (r=.518) and competence/experience (r=.570). Finally, the correlation between decision-making and competence/experience was .535.

Investigating the Contextual Settings

In the survey, the respondents were asked to categorize the projects according to the model for contextual settings. The same problem seemed to appear here, as in the test with the additional cases. The main parts of the projects were categorised into three of the five contextual settings: setting (1) 35%, (2) 3%, (3) 32%, (4) 27% and (5) 3%. This may be due to difficulties in determining the setting of the project, or that the proposed settings are not fully sufficient. Possible relationships between the factors found to correlate significantly with project performance and the different contextual settings were investigated using Spearman's Rank Order Correlation (due to the relatively small sample).

The analysis provided results on three of the contextual settings (1) Internal product development, (3) Integrated product development, and (4) Distributed product development. Within Distributed product development, there was a strong, positive and statistically significant correlation between several of the factors and project performance. This was the case with shared vision and goals (r=.908, p=.001), decision-making process (r=.897, p=.001), tools and methods (r=.738, p=.023), and requirement management (r=.711, p=.048). For Internal product development, shared vision and goals correlated significantly with project performance (r=.632, p=.037).

Table 5 • The result from using multiple regression.

Key Factors	Beta
Product development model	-.115
Tools and methods	.246
Decision-making process	.468*
Requirement management	.322*
Documentation	-.157
Technology platform	-.104
Shared visions	.514**
Co-operation	-.156
Competence/Experience	-.014
Consultant interface	.136
Customer interface	.073
Production interface	-.118

Beta=Unique contribution to Project Performance

*. Correlation is significant at the .05 level (2-tailed)

**. Correlation is significant at the .01 level (2-tailed)

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