Exploring the Interplay between Standard Products and Customer Specific Solutions

By
Daniel Hjelmgren
Department of Technology Management and Economics
Chalmers University of Technology

Abstract

This thesis deals with how a company may handle the interplay between the development of standard products and customer specific solutions. There are three aims of the thesis. The first aim concerns how a buyer and a supplier in interaction arrive at a solution involving a mix of standard and customer specific product features. The second aim concerns how the supplier can manage the balance between exploitation of standard products and exploration of new product features during the development of a particular solution. The third aim concerns how the development of specific solutions affects the development of the standard product.

The frame of reference is primarily based on the Industrial Network Approach, and deals with utilization and development of products within networks of interdependent resources. While resource utilisation is seen as dependent on how the resources are embedded into the network, resource development takes place when their features are changed in order to make the resources fit into new combinations.

The thesis is based on a case study focusing on a Swedish ERP-system provider's development of new product features. The main part of the case deals with the company's development of a customer specific solution in interaction with one particular buyer whose requirements could not be met by existing product features. The buyer is a subcontractor on the second tier in the automotive industry and implemented the ERP-system in order to improve the coordination of certain sequentially dependent operations. To understand how the products have developed over time, a series of preceding and subsequent customer interactions and their influence on the use and development of the product features is also part of the case.

The thesis concludes that when developing specific customer solutions the supplier must exploit on existing resource features while adjusting to the customers' particular resource constellations. Likewise, the customer needs to maintain most of its resource constellation while adjusting some parts of it to the new resource. Different strategies that a supplier and a buyer may apply in order to deal with the effects that a certain change may have on other parts of the resource network are suggested. Furthermore, it is concluded that a company, in order to balance between exploration and exploitation, needs to manage three interrelated aspects of resource embeddedness. First, it needs to economise on existing product features when developing customer specific solutions. Second, the company needs to identify similarities among different customer specific solutions when developing the standard product. Third, it needs to deal with a large number of interdependent interfaces, both within the product itself and towards different customer solutions. Finally, it is concluded that separating the issue of efficiently developing customer solutions, and the issue of developing standard product features, into different organisational units may benefit the balancing between exploration and exploitation.

Keywords: interaction, resource, dependence, network, utilization, adaptation, exploitation, product development, exploration, standardisation.

Preface

I would like to express my gratitude to a number of people who have contributed to this thesis.

First of all I would like to thank my supervisor Anna Dubois for her excellent guiding in the empirical fieldwork and in the work to match the empirical world with theory. The bundle of drafts, on which you have made your comments, is surely impressive. Thank you, Anna!

I would also like to thank Lars-Erik Gadde for sharing his extensive experience in the field of research, and Ann-Charlott Pedersen for her constructive comments and good advice. Together with Anna, you both have also constituted important intellectual resources to exploit on. Thank you!

Many thanks also to my other colleagues at Industrial Marketing: Jens Laage-Hellman, Lennart Bångens, Kajsa Hultén, Peter Fredriksson, Frida Lind, Viktoria Sundqvist, Stefan Karlsson, Fredrik Skarp, and Oscar Jellbo. You have not only generously shared your knowledge and experience, but you have also been fun to work with! Extra thanks to Frida Lind for her supportive spirit, and for being a valuable discussion partner and a fine friend. I would also like to thank Yvonne Olausson and her colleagues at Technology and Society (Maria, Kurt, Ilona, Ann-Sofie, Lena, Jan, Bengt, and Erik), who, together with my own colleagues at Industrial Marketing, have created a friendly and helpful work environment. Thanks also to colleagues at other divisions at Chalmers University of Technology for inspiring courses and everyday discussions.

In addition to my colleagues at Chalmers University of Technology, I have also interacted with researchers at other universities. In particular I would like to thank Luis Araujo at Lancaster University for giving constructive and inspiring feedback on my manuscript. Other important contributors to this thesis are: Espen Gressetvold, Elsebeth Holmen, Tim Torvatn, and Magnar Forbord, all at Norwegian University of Science and Technology. In relation to various short visits, courses, conferences, and workshops I have also had the great pleasure to interact with Håkan Håkansson and Debbie Harrison at Norwegian School of Management, Torkel Wedin and Johnny Lind at Stockholm School of Economics, Enrico Baraldi, Alexandra Waluszewski, and Susanne Åberg at Uppsala University, Ivan Snehota at University of Lugano, and Geoff Easton at Lancaster University.

Without the interviewee it had not been be any case, and consequently no thesis. I would therefore most sincerely express my gratitude to all the people who have devoted their time and efforts to my interviews. In particular Anders Berger at IFS, who not only invited me to the empirical world, but who also reviewed my description of this world. I am also grateful to Bo Persson at IFS, who very patiently answered my questions regarding the Constraint Based Scheduling Module.

Also my family has contributed a lot to this thesis. First, I would like to thank my mother and my father (Lise-Lotte and Lennart) for their support and almost foolish believe in me. Thank you for everything! I would also like to thank my elderly brothers (Hans and Magnus) for inspiring me to take challenges like this. Extra thanks to Hans, who also helped me to improve my English. Finally, I would like to thank Maria for showing that there is much more to life than writing on a thesis. I love you!

Thank you all!

Daniel Hjelmgren

Göteborg
Maj 2005

Acknowledgements

I am also grateful for the generous financial support provided by Humanistisk-Samhällsvetenskapliga Forskningsrådet, Torsten och Ragnar Söderbergs Stiftelser, NordForsk, and The Swedish Foundation for Strategic Research, which to a great deal have contributed to the completion of this thesis.

Contents

1 SETTING THE SCENE 1

1.1 THE RELEVANCE OF THE RESEARCH ISSUES 2
1.2 AIMS OF THE THESIS 6
1.3 OUTLINE OF THE THESIS 6

2 FRAME OF REFERENCE AND RESEARCH QUESTIONS 9

2.1 PROBLEM FORMULATION 9
2.2 SUPPLIER-BUYER INTERACTION IN INDUSTRIAL NETWORKS 12
2.2.1 Substance and function of business relationships 17
2.2.2 Adaptation within business relationships 19
2.3 RESOURCE UTILISATION AND DEVELOPMENT 21
2.3.1 Resource heterogeneity 21
2.3.2 Resource flexibility 22
2.3.3 Resource embeddedness 24
2.3.4 Resource features and resource interfaces 28
2.3.5 Organisational units' knowledge about resources 29
2.4 ANALYSING RESOURCE COMBINING, DEVELOPMENT, AND EMBEDDEDNESS 31
2.5 DEFINING FOUR RESEARCH QUESTIONS 34

3 METHOD 41

3.1 THE USE OF A CASE STUDY 41
3.2 THE EMERGENCE OF THE PARTICULAR CASE AND THE THEORETICAL FRAMEWORK 43
3.3 SOURCES OF DATA 50

4 EMPIRICAL BACKGROUND 55

4.1 IFS 55
4.1.1 IFS Application 56
4.1.2 Implementation and development 60
4.1.3 Important issues to deal with 65
4.2 BTAB 66
4.2.1 Production 68
4.2.2 Customers 76
4.2.3 Suppliers and sub contractors 77
4.2.4 Important issues to deal with 78

5 THE IMPLEMENTATION OF IFS APPLICATION AT BTAB 79

5.1 THE CUSTOMER SPECIFIC ERP-SYSTEM 80
5.2 THE CS AND THE SS MODULES – TWO MODULES SENDING AND RECEIVING ORDERS AND PLANS 84
5.3 THE CBS MODULE – A MODULE SUPPORTING COMPLEX PRODUCTION 90
5.4 CONNECTIONS TO EXTERNAL SYSTEMS 94
5.5 MODIFICATIONS AT BTAB 95

6 ANALYSIS OF THE IMPLEMENTATION AT BTAB 97

6.1 ADAPTATIONS OF THREE STANDARD PRODUCTS 98
6.2 THREE CUSTOMER SPECIFIC ADAPTATIONS 101
6.3 ADAPTATIONS OF BTAB'S PRODUCTION FACILITY 103
6.4 THE MIX OF STANDARD AND ADAPTED PRODUCT FEATURES 106

7 PRIOR AND SUCCEDING DEVELOPMENT EFFORTS 109

7.1 DEVELOPMENT OF THE CBS MODULE PRIOR TO THE IFS BTAB PROJECT 109
7.1.1 α-Profiles 110
7.1.2 β-Steel 110
7.1.3 γ-Cement 112
7.1.4 δ-Mining 112
7.1.5 ε-Oil 113
7.1.6 ζ-Bread 113
7.1.7 η-Gearboxes 115
7.1.8 θ-Chemicals 116
7.2 ANALYSIS OF PRIOR DEVELOPMENT OF THE CBS MODULE 116
7.3 DEVELOPMENT OF THE CS MODULE PRIOR TO THE BTAB PROJECT 120
7.3.1 κ-Automobiles 121
7.3.2 λ-Plastics 122
7.4 ANALYSIS OF PRIOR DEVELOPMENT OF THE CS MODULE 122
7.5 SUCCEEDING APPLICATIONS OF THE CS AND THE SS MODULES 124
7.5.1 ϕ-Plastics 124
7.5.2 μ-Hydraulics 125
7.5.3 ν-Packings 126
7.6 ANALYSIS OF SUCCEEDING APPLICATIONS OF THE CS AND THE SS MODULES 127

8 ADAPTATIONS WITHIN A NETWORK OF TECHNICAL RESOURCE UNITS 129

8.1 DEVELOPING A MIX OF STANDARD AND CUSTOMER SPECIFIC PRODUCT FEATURES ... 129
8.2 LIMITING THE CHANGE BOUNDARY OF ADAPTATIONS 135
8.3 NEW PRODUCT FEATURES AND LOCK-IN EFFECTS 141

9 ORGANISING THE INTERPLAY BETWEEN EXPLOITATION AND EXPLORATION 145

9.1 FRAMING THE NETWORK OF CONSIDERED INTERFACES 145
9.2 EXTENDING THE NETWORK CONTEXT AND LEARNING 151
9.3 TECHNICAL IMPRINTS AND COORDINATION 153
9.4 CONCLUDING REMARKS 157

10 REFERENCES 163

APPENDIX 177

List of Figures

Figure 2.1: A dyadic supplier-buyer relationship. 9
Figure 2.2: A focal business relationship embedded into a network of interconnected business relationships. 10
Figure 2.3: The Industrial Network Model (Håkansson, 1987:17). 15
Figure 2.4: Scheme for analysing development effects of business relationships (Håkansson & Snehota 1995:45). 17
Figure 2.5: Four different resource entities in a business network (Håkansson & Waluszewski, 2003). 31
Figure 2.6: The exchanged product and how it is embedded into the supplier's and the buyer's different resource collections. 35
Figure 2.7: Business transactions: four cases (Gadde & Håkansson, 1998:60). 35
Figure 2.8: The exchanged product and how it is embedded into a network of inter-connected products and production facilities extending the boundaries of several companies. 37
Figure 2.9: Schematic picture of how development of specific customer solutions (PF1, PF2) during different supplier-buyer interactions results in new features of the standard product (P), and how it successively develops the standard product. 39

Figure 3.1: A general framework for the analysis of business networks in a contextual time space (Halinen & Törnroos, 2004:1290). 42
Figure 3.2: Systematic combining (Dubois & Gadde, 2002:555). 44

Figure 4.1: IFS Application (2001). 56
Figure 4.2: Picture of a typical master from with an additional detail form. 59
Figure 4.3: Different lead times that needs to be considered. 68
Figure 4.4: In Timmele's first production step different batches of circle knitted fabric are gathered into larger ones. 70
Figure 4.5: In Timmele's second production step the circle knitted fabric is shipped from one side of the plant to the other. 71
Figure 4.6: In Timmele's third production step three trimming machines cut the pile on the surface of the fabric. 71
Figure 4.7: In Timmele's fourth production step all fabric are washed in open or closed washing machines. 72
Figure 4.8: In Timmele's fifth production step all fabric are fixed in a fixation machine. 72
Figure 4.9: In Timmele's sixth production step all tricot and warp knitted fabric are coloured in open or closed washing machines. 73

Figure 4.10: In Timmele's seventh production step fabrics are inspected. 73
Figure 4.11: In Timmele's eight production step some batches of warp knitted fabrics are laminated. 74
Figure 4.12: In Getinge's first production step the fabric is laminated with foam rubber and a plastic film. 74
Figure 4.13: In Getinge's second production step the fabric is cut on the sides. 75
Figure 4.14: In Getinge's third production step fabrics are inspected. 75

Figure 5.1: The flow of data within the customer specific ERP-system. 80
Figure 5.2: The hierarchic structure of a C^{++} program. 91
Figure 5.3: Illustration of how the four objects are related to each other and to the input in terms of orders and the output in terms of a schedule. 92

Figure 6.1: New features were developed at the interface between BTAB's production plants (PF22, PF23, PF24) and the ERP-system (PF21), at the interface between this system and the CS and the SS Modules (P11, P12), and at the interface between these products and two other products (P13, P14). .. 99
Figure 6.2: New features were developed at the interface between BTAB's production plants (PF22, PF23, PF24) and the ERP-system (PF21), at the interface between this system and the CBS Module (P15), and at the interface between this product and two other products (P16, P17). 100
Figure 6.3: New features that were developed at the interface between BTAB's inspection system and the ERP-system, the customer specific module (P18), and the features that were developed at the customer specific module's interfaces towards the Repetitive Production Module and the Inventory Module. 101
Figure 6.4: New features were developed at the interface between BTAB's inspection system (PF26) and the ERP-system (PF21), at the interface between the ERP-system and the Inventory Module (P17), and at the interface between this module and the Repetitive Production Module (P16). An important part of the features that were developed at the interface between the ERP-system and the Inventory Module (P17) were integrated into a customer specific module (P19). 102
Figure 6.5: New features were developed at the interface between BTAB's ERP-system(PF21) and ρ-Software's EDI-converter (P31). 103
Figure 6.6: New features were developed at the interface between the ERP-system (PF21) and BTAB's production plants (PF22, PF23, PF24), and at the interfaces between these plants. 104

Figure 6.7: The implementation of the ERP-system (PF21) affected BTAB's business relationships with π-Curtains and σ-Lamination (BR21, BR22). 105

Figure 7.1: Different standard product features (f1-19) developed in interaction with prior buyers, and the facility features (s1-9) they generated....................... 118
Figure 7.2: Standard product features (f1-10) developed in interaction with prior buyers, and the facility features (s1-5) they generated. 123

Figure 8.1: A network of technical and functional interfaces between different technical resource units. 133

Figure 9.1: The Project Department's (A's) network context for a specific customer solution.. 147
Figure 9.2: The R&D Departments (B's) network context for one of the supplier's standard products. 148
Figure 9.3: The division of a company. Project teams (A_1,…, A_n) focus on the issue of developing specific customer solutions (PF1,…, PFn) whereas development groups (B_1,…, B_m) focus on the issue of developing standard products (P1,…, Pm). 150
Figure 9.4: The overlap of knowledge between organisational unit A and organisational unit B. 153

List of Tables

Table A.1: Overview of interviews... 178

1 SETTING THE SCENE

In 1998 Industrial Financial Systems (IFS) – a provider of Enterprise Resource Planning (ERP) systems - implemented a system at Borgstena Textile AB (BTAB). BTAB is a second tier supplier within the automotive industry and produces fabric mainly used in car seats. As for many others of IFS' customers, BTAB's most important reason behind the implementation of an ERP-system was the company's wish to improve the co-ordination of certain sequentially interdependent operations. With an ERP-system it becomes easier for a company to coordinate various decision-making processes. The system not only stores data, but also determines the appropriate data to store, how to collect and group the data, and how to use the appropriate quantitative analyses to process the data.

IFS's standard system is based on about 60 standard modules. At every new implementation IFS combines a set of these modules into a customer specific solution. In order to make the solution fit with the buyer's operations, most implementations call for some adaptations between the standard modules and the customer's operations. Adaptations can be carried out in two different ways; 1) the customer adapts its operations to the functionality of the standard modules, or 2) IFS makes customer specific modifications of these modules that adapt the system solution to the buyer's operations. Usually the customer specific solution involves a mix of standard modules and customer specific modifications.

This thesis primarily deals with the adaptations that were made by IFS and BTAB during the implementation project at BTAB. The project started with the establishment of a project team including members from both IFS and BTAB. Based on 14 different standard modules, this team developed BTAB's customer specific solution. During the development IFS made some modifications in order to make the solution fit with BTAB's specific use context. An important part of these modifications concerned two modules sending and receiving production plans, a module supporting complex production, and two additional customer specific modules connecting the ERP-system to two other computerised business systems. Conversely, BTAB adapted some of its operations to the features of the solution. From the study of the implementation at BTAB three issues of general interest evolved. The first issue concerns how a supplier and a buyer in interaction jointly arrive at a solution involving a mix of standard and customer specific features.

The two other issues take the supplier's perspective. One of them relates to the implementation at a specific customer. In a particular implementation the supplier's solution normally consists of a combination of standard features and adaptations in relation to the customer's context. Hence, the second research issue deals with mix of existing standard features and the development of new features

When IFS believes that a general need of a product modification exists, the company may integrate these into the standard system. Nearly 75% of the standard system originates from prior customised solutions. Integration into the standard system improves IFS's ability to spread development costs over a large number of different customer applications, and thereby gain through economies of scale. Since it often reduces the need of future customer specific adaptations, and thus the time spent on each implementation, it may also lower IFS's implementation costs. However, it is not always an advantage to integrate a customer specific modification into the standard system. Although it may reduce the need of customer specific adaptations in some future implementations, it may increase this need during other implementations. Moreover, it is three times more expensive to change the standard system than it is to develop a customer specific modification. When IFS is particularly uncertain about the general need for a specific modification, the company always chooses to keep it customer specific. This raises some questions regarding the interrelation between the development of various customer specific solutions and the development of the standard system. A third interesting research issue that can be identified concerns how the development of specific solutions affects the development of the supplier's standard product.

1.1 The relevance of the research issues

This section deals with the general relevance of the three issues identified in the case. As mentioned above, the first research issue concerns how a specific customer solution, including a mix of standardised and customer specific components, is developed. This mix combines two different logics, i.e. the logic of aggregation, and the logic of individualisation (cf. Lampel & Mintzberg, 1996). Through aggregation a supplier may identify common characteristics of different settings, and thus achieve economy of scale by the development of standardised components that can be used in all these settings. Through individualisation, on the other hand, particular characteristics of different settings may be identified, and thus customised solutions that fit into these settings can be developed.

According to Lampel and Mintzberg (1996), the logic of aggregation was the dominant logic during the standardisation movement in the beginning of the twentieth century. This movement emphasised the advantage of economy of scale in every part of the value chain, from development to production to distribution, which promoted academic research focusing on industries in which customers' shared characteristics were easily established. Based on this research *"the standardisation movement contrasted the virtues of aggregation with the vices of individualisation, thereby creating the polarisation that has shaped management thinking ever since"* (ibid:22)

At the end of the twentieth century the great enthusiasm for standardisation was replaced by an almost equally great enthusiasm for customisation. Coates (1995) argues that numerous books and articles have posited that we are witnessing the dawn of a new age of customisation, an age in which new technologies, increased competition, and more assertive customers are leading companies towards customisation of their products. However, according to Lampel & Mintzberg (1996), many of these books and articles have ignored that customisation and standardisation do not define alternative models of strategic action, but rather, pools of a continuum of real-world strategies. These strategies, reaching from pure standardisation to pure customisation, are combining the logic of aggregation with the logic of individualisation in different ways. Consequently, are creating different possibilities for a supplier to spread development costs over several different buyers in order to gain through economy of scale while simultaneously adapting the product to specific buyers' needs.

Anderson & Narus (1999) argue that an important way for a supplier to be able to provide customised solutions at a low cost is to create modular product architectures. One important reason why costs decline is that modular product architectures reduce the need of customer specific components. According to Ulrich (1995), modular product architectures make it possible to develop efficient customisations by only assembling standard components. However, for modular products, such as ERP-systems (cf. Harris, 2000), the supplier may not be able to create an efficient solution without having to add or redesign some components. There are two main reasons for this. Firstly, problems with incomplete or imperfect modularization tend to appear when the modules come together and work poorly as an integrated whole (Baldwin & Clark, 1997). This usually calls for some additional adjustments among the integrated components. Secondly, the extensive variety among different customer contexts may call for some additional customer specific components. Consequently, these solutions usually involve a mix of standard and customer specific product features. How this mix is composed affects a supplier's ability to gain through economy of scale, and simultaneously develop a solution that fits with the specific buyers' use contexts. Consequently, it is important to investigate further how a solution may be customised in order to fit with specific buyers' use contexts and still enable economy of scale. This first research issue concerns how a supplier and a buyer in interaction jointly arrive at a specific solution.

The second research issue concerns how the supplier can develop efficient solutions and simultaneously utilise existing standard modules. This issue is discussed by March (1991) in terms of balancing between exploration and exploitation. His main argument is that companies that engage in exploration of new features to the exclusion of exploitation of existing are likely to suffer the costs of experimentation without gaining many of its benefits. Conversely, companies that engage in exploitation to the exclusion of exploration are likely to find themselves trapped in suboptimal stable equilibrium. *"Maintaining an appropriate balance between exploration and exploitation is therefore a primary factor for a company's survival and prosperity"* (ibid:71). Hence, how suppliers manage the balance between exploitation on standard products and exploration of new product features during the development of customer specific solutions is an important research issue.

According to March, improving the balance between exploration and exploitation is complicated by the fact that the returns from the two options vary not only with respect to their expected values, but also with respect to time and distribution within and beyond the organisation. Griffin & Page (1996) argue that the company's goals of short term efficiency and long term learning determine the relative emphasis placed on exploitation versus exploration. While efficiency primarily concerns getting the most out of available resources, learning refers to development of new resources (Anderson & Narus, 1999). As learning requires time and resources, it may, in the short term perspective, negatively affect the efficiency regarding the utilisation of available resources. When learning is emphasised as an overall goal, it is based upon the belief that new design and/or knowledge will eventually pay significant dividends in increasing the efficiency of development efforts as a whole (ibid.). This brings us to research issue number three, which concerns how the development of specific solutions may affect the development of the supplier's standard product.

In order to learn about customer requirements and preferences, a supplier can develop prototypes, which allow selected customers to experience the functionality of a product and give feedback to the supplier (Anderson & Narus, 1999). As the context of Information System (IS) design is more complex and dynamic than the context of many other product designs, there are usually no clear distinctions between a prototype and a finished product (Bai, 1997). The term “prototype” is in IS research therefore often replaced by “prototyping”, indicating that the product development process rather than the product itself is in focus (Floyd, 1987). Grønbæk (1990) proposes a “co-operative prototyping” approach to support users’ involvement in IS development. In co-operative prototyping both users and designers jointly work with the prototype. This allows their different tacit skills and knowledge to be absorbed and crystallised into the system (Bai, 1997). By being used in different applications, IS-prototypes may then be viewed as learning vehicles absorbing different users’ knowledge about the use context (Floyd, 1984).

In situations as the one referred to above, new product features are developed when project teams try to make customer solutions fit with particular buyers’ use contexts. The customer involvement facilitates exploration of possible gaps between existing features and the customer’s needs. As previously mentioned, these gaps may be over-bridged by additional customer specific features. If these features are integrated into the standard product, they may facilitate fast and efficient development of products ready for implementation. However, this requires that subsequent buyers experience the same need as the one that required the new features. Otherwise the integration may cause development costs that do not reflect improved customer value, and thus reduce the efficiency of the supplier’s development efforts. In order to avoid developing layer upon layer of features to the standard product at costs that do not reflect customer value, a supplier that is uncertain about the general need of a new product feature will probably keep existing standard designs as they are.

In line with this, Floyd (1984) points out that there is a need to investigate further how practical user demonstration may be an important part of the development of information systems. In addition, Anderson & Narus (1999) argue that regardless the type of industry, a way for a company to lower development costs is to collaborate with selected buyers, and thus learn about buyer requirements. Hence, analysing how implementation and development of specific solutions may affect the development of the supplier’s standard product is an important research issue.

1.2 Aims of the thesis

In accordance with the research issues identified above, there are three aims of the thesis. The first aim is to analyse ***how a supplier and a buyer in interaction arrive at a solution involving a mix of standard and customer specific features.***

The second aim is to analyse ***how a supplier manages the balance between the company's exploitation on its standard product and the exploration of new product features during the development of a specific solution.***

The third aim is to analyse ***how the development of specific solutions affects the development of the supplier's standard product.***

While the first aim concerns the interaction between the supplier and the buyer, the other two are analysed from the supplier's point of view. The second aim concerns the development of customer specific solutions, where utilisation of existing standard product features is an important issue. The third aim concerns the development of these standard product features.

1.3 Outline of the thesis

The thesis includes nine chapters. This first chapter introduces the main themes of the thesis; the empirical problems, the relevance of these problems as research issues, and finally the aims of the thesis.

In Chapter 2 the three aims are refined into four research questions. The frame of reference presented primarily involves literature reviews of research conducted by academics within the IMP-group. This review is focused on supplier-buyer interaction, adaptations, and resource utilisation and development.

In Chapter 3 the research process is presented, including descriptions with a focus on how the particular case emerged. The sources of data are also presented.

Chapter 4 presents the two focal companies: IFS and BTAB. Apart from a description of the product, i.e. the standard ERP-system, the presentation of IFS includes an overview of the company's organisation. The presentation of BTAB includes descriptions of the company's production, customers, suppliers, and subcontractors. The presentations provide an empirical background to IFS's implementation project at BTAB which is described in Chapter 5. This chapter primarily involves a description of the adaptations that were carried out, followed by Chapter 6 which is an analysis of the developed mix of standard and adapted product features. Chapter 7 illustrates how the standard versions of two important modules were developed prior to the IFS-BTAB project. Based on this description it is then analysed how previous implementation may affect subsequent development of the standard product, and thus also the development that was made during the implementation project at BTAB. The chapter also describes and analyses how the standard features that were developed during the implementation project at BTAB affected three succeeding implementation projects.

Along with the empirical background presented in Chapter 4, the analyses made in chapter 5 to 7 constitute the foundation for the analyses in Chapter 8 and 9. Chapter 8 deals with the interaction between a supplier and a buyer and how different standard product features are utilised in the development of specific customer solutions. Finally, Chapter 9 discusses development of standard product features, including the implications of the study.

2 FRAME OF REFERENCE AND RESEARCH QUESTIONS

In this chapter the frame of reference and the research questions are presented. Based on a problem formulation presented in Section 2.1, the frame of reference is presented in sections 2.2, 2.3 and 2.4. Together with the three aims of the thesis, this frame of reference, in turn, constitutes the foundation for the definition of the research questions in section 2.5.

2.1 Problem formulation

The first aim that was defined in Chapter 1 concerns how a supplier and a buyer in interaction arrive at a solution involving a mix of standard and customer specific features. Interaction between companies has been identified as a main feature of technical development (cf. Håkansson, 1987; Lundvall, 1988; von Hippel, 1988; Rosenberg, 1994; Wynstra, 1998). A considerable amount of research on technical development that is performed in interaction between companies has focused on the benefits of the supplier. While Lundvall (1988) identifies five important reasons why a producer may benefit from interaction with buyers in general, von Hippel (1988) emphasises the convenience for suppliers' to involve specific buyers in the development of a product. However, there would probably be no interaction if it was only beneficial from a supplier's point of view. How customers' may benefit from supplier involvement in product development is, for example, discussed by Wynstra (1998). Figure 2.1 below illustrates a supplier-buyer interaction within a business relationship.

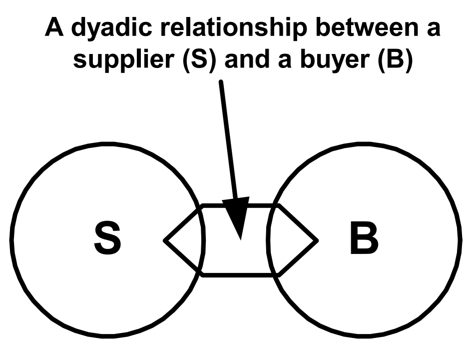


Figure 2.1: A dyadic supplier-buyer relationship.

An important conclusion in many of these studies is that development performed within specific business relationships in various ways both affect and are affected by the interacting parties' other business relationships (e.g. Laage-Hellman, 1989; Pedersen, 1996; Ritter, 2000). Laage-Hellman (1989) points out a large number of occasions on which technical development performed within other business relationship have affected technical development performed within a particular business relationship and vice versa. These mutual effects illustrate the interconnectedness among different business relationships. Pedersen (1996) describes the interconnection among business relationships in terms of actor bonds, activity links, and resource ties. Her description for example shows that one business relationship may have both negative and positive effects on other relationships. Ritter (2000) identifies 10 different ways in which business relationships may have positive and/or negative effects on each other. Hence, apart from analysing the supplier-buyer interaction within the business relationship in which the solution was developed, it is important to analyse how this interaction interrelates with interaction within other business relationships (see Figure 2.2). A literature review on supplier-buyer interaction within business relationships and industrial networks is therefore required. This review will be presented in section 2.2.

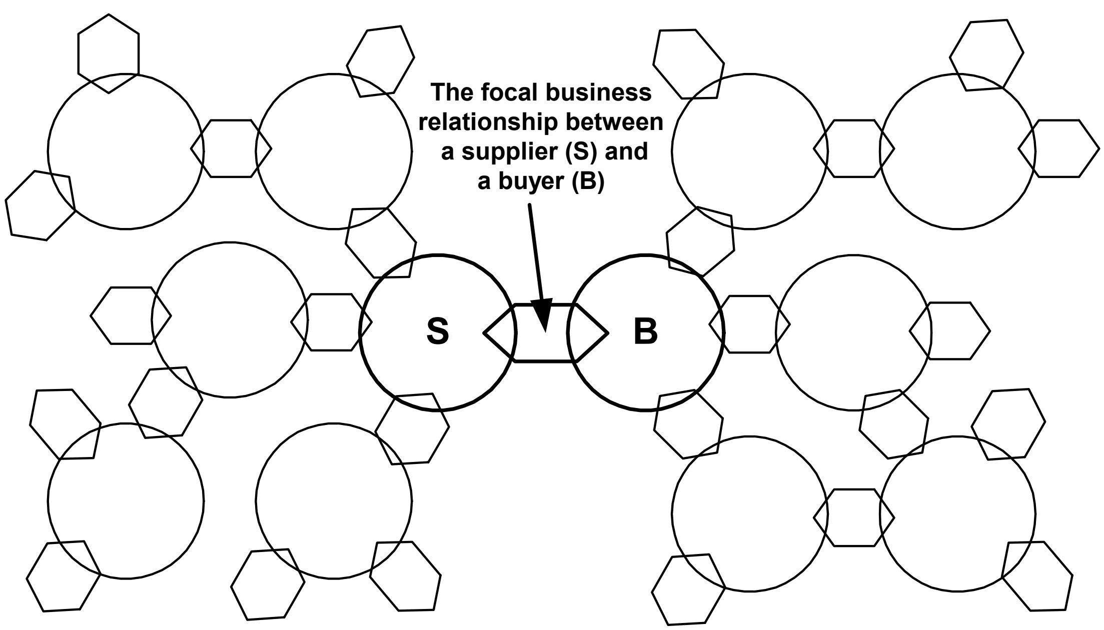


Figure 2.2: A focal business relationship embedded into a network of interconnected business relationships.

The second aim emphasises how a supplier during the development of a specific solution can balance between the company's exploitation on the standard product and its exploration of new product features during the development of a specific solution. This can also be articulated as balancing between resource utilisation and resource development. The balance is determined by the supplier's expected returns from the two alternative options. Compared to returns from exploitation, returns from exploration are less certain, more remote in time, and organisationally more distant from the locus of action. This may favour exploitation over exploration, especially when developers follow the "logic of practice" (Bourdieu, 1990).

According to Hård (1994), "practical logic" is instrumentally oriented towards the solution of immediate problems. Therefore, developers that follow the logic of practice may be more oriented towards returns that are more certain and less distant in time and space. During the development of customer specific solutions that fit with specific customer's use contexts, an important return for a supplier may be to get the most out of available resources at that particular point in time. More efficient resource utilisation may not only reduce the company's costs as such. By making it possible for the company to charge a lower price, it may also give the company a "competitive advantage" towards suppliers of similar products.

Efficient resource utilisation requires knowledge of how resources may be combined, as well as how the value of a particular resource is affected when combined with other resources. In addition, in order to achieve long term efficiency, it is important to know how changes in resource combinations may affect the possibility to combine a specific resource with other resources. A literature review on how the value of a resource depends on how it is combined, how prior combinations affect present combining, and how present combinations in turn may affect future combining, is therefore presented in sections 2.3.

Lastly, the third aim concerns how the development of a specific solution affects the development of the supplier's standard product. This put the searchlight on product development and in particular, how this development is affected by development performed in specific supplier-buyer interactions. When a solution is implemented, the supplier needs to decide which product features the company should integrate into the standard product. These features have been developed in specific supplier-customer interactions in which the product has interacted with certain other resources. Several recent research projects have analysed how resources are developed through interaction with other resources. Their research span over a broad empirical field, covering development of goat milk (Forbord, 2003), steel (Skarp, 2003), paper (Wedin, 2001), cars and trucks (von Corswant, 2003), information technology (Baraldi, 2003), and integrated circuits (Gressetvold, 2004). A framework that can be used for analysing how resources are developed by being combined with other resources is presented in section 2.4. Finally, in section 2.5 the research questions are defined.

2.2 Supplier-buyer interaction in industrial networks

A considerable amount of research on supplier-buyer interaction has been conducted by academics within the IMP-group (cf. Håkansson; 1982, Håkansson & Snehota, 1995, Ford, 2002). The theoretical model, which formed the point of departure for the IMP-group, is known as "The Interaction Model" (Håkansson, 1982). This model presents a way of mapping the richness of relationships in a four element analytical approach: 1) The interacting parties, 2) the interaction process, 3) the interaction atmosphere, and 4) the interaction environment. According to prior research (cf. Snehota, 1990), the interplay between the "ends" (short-term goals) that interacting parties wish to achieve and their "means" to achieve these ends seems to be an important ingredient in supplier-buyer interaction. The presentation of the interaction model below therefore focuses on this interplay.

The interacting parties are characterised by their positions in the market, their products, and expertise. All these three are interrelated. Ford et al. (2003) defines a company's position as its total set of business relationship. These relationships both affect the "ends" they wish to achieve, and their available "means" to achieve these ends (Snehota, 1990). While customer relationships affect the company's desired ends by demanding certain product features, supplier relationships affect available means by providing important resources for the development and production of these product features. Hence, a company's products have an important impact on what is the preferable position, and vice versa, i.e. how new product features should be developed. A similar interrelationship exists between a company's products and its expertise. Concurrent to the development of new product features, a company develops its expertise. Conversely, a company's expertise affects its ability to develop certain features.

During **the interaction process** the interacting parties' different ends and means are confronted and adjusted towards each other. As soon as the companies' different ends and means are confronted with each other, a more or less clearly defined negotiation procedure begins. *"Since any interaction between two companies has to lead to a solution that can create a mutually acceptable economic outcome for both parties, both are more or less prepared to adapt their original means and ends."* (ibid:10-11)

Besides being a negotiation procedure, where the interacting parties' different ends and means are adapted to each other, the interaction is also a learning process. The more two interacting parties learn about each other's ends and means, the more they will understand, not only about restrictions but also about possibilities. In other words, through interacting they will both perceive new means to achieve certain ends as well as new ends to be pursued (Snehota, 1990).

The interaction process is divided into short-term exchange episodes and long-term relationships. These two are closely interrelated. Each episode is conditioned by the overall relationship existing to date. Conversely, the exchange of information in each episode successively builds up inter-organisational contact patterns of individuals and groups of individuals. Together, with various technical, administrative, and knowledge-based adaptations (cf. Gadde & Håkansson, 1993), these contact patterns constitute the very substance of business relationships.

The interaction atmosphere includes the general atmosphere of conflict and co-operation characterising a business relationship. Conflicts are a natural effect of the fact that companies involved in the relationship wish to achieve different ends. These conflicts do not always have to be negative. In a relationship with a low degree of conflict the parties may place too few demands on one another, and are therefore not really trying to explore the potential for collaborative actions. According to Gadde & Håkansson (1998), effective relationships require both cooperation and conflict.

Another important ingredient of the atmosphere is the degree and the direction of power and dependence. The power concept is based on the idea that business relationships commonly entail mutual dependence between parties (Gadde & Håkansson, 2001). This mutual dependence arises because each party is likely to aspire to goals that are in some way conditioned upon the actions of the other party. The power to control or influence the other resides in control over the things he/she values (ibid.). With regard to individual dimensions, the relation between power and dependence is usually unbalanced. However, a certain amount of imbalance in one dimension may be set off against the equivalent but opposite imbalance in another dimension. For instance, a high degree of dependence due to volume may be set off by some technical expertise that is important to the other party.

The interaction environment element tells us that no interaction process should be analysed in isolation. The interaction environment may be analysed in terms of market structure and dynamism. The market structure, which concerns the concentration of available suppliers and customers, decides the number and type of business opportunities available to any company. Moreover, by affecting available means to reach certain ends, it also decides what a company can do.

The dynamism of the environment points to the disadvantages as well as the advantages regarding close relationships. In a dynamic environment the opportunity cost of reliance on a small number of relationships can be very high. Still, many companies choose to develop such relationships. An important reason is that a close relationship increases the knowledge of the other party, and thus the possibility to make forecasts based on inside information. Moreover, a close relationship improves a company's ability to mobilise the other party in a certain development effort.

When developing a theoretical "offspring" of the Interaction Model - the Industrial Network Model - Håkansson & Johanson (1985) define the environment as a network of interconnected relationships. The interconnectedness points to a company's limited ability to switch counterparts and thus change position in the market. In addition, analysing the interconnectedness of relationships increases our understanding of the mechanism behind the dynamism of the interaction environment.

The most widely used industrial network model comprises three basic variables or concepts: actors, activities, and resources (see Figure 2.3). These three variables are defined in relation to each other. *"Actors are defined as those who perform activities and/or control resources. In activities actors use certain resources to change other resources in various ways. Resources are means used by actors when they perform activities"* (Håkansson, 1987:17).

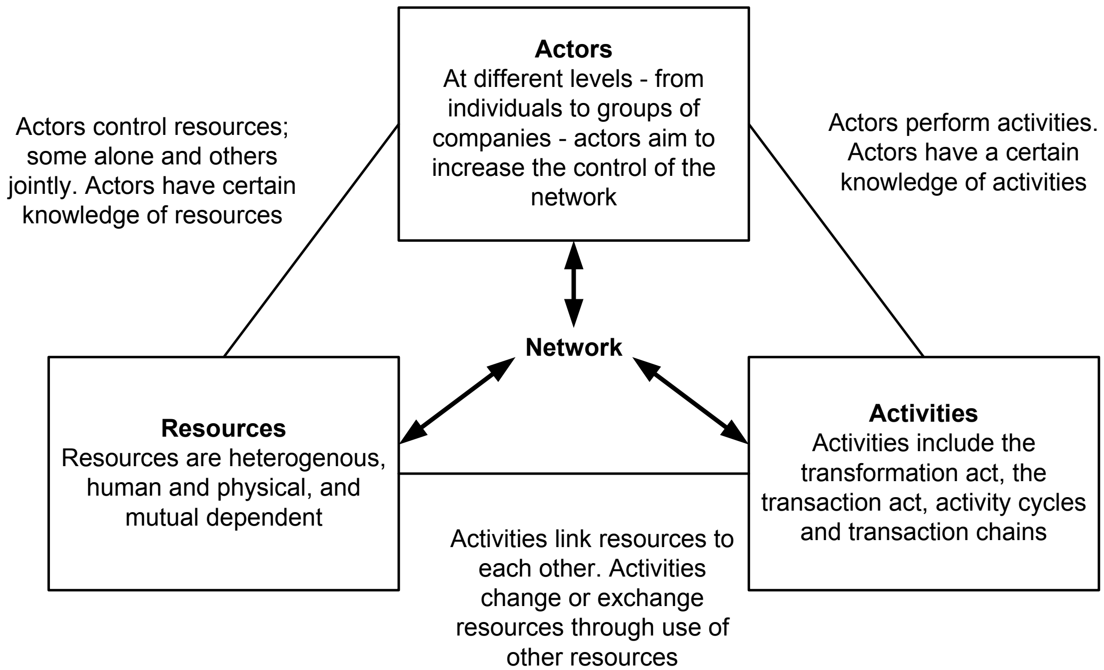


Figure 2.3: The Industrial Network Model (Håkansson, 1987:17).

Actors can be individuals or companies, as well as groups of individuals or groups of companies. Every actor is goal oriented and its general goal is to control resources and activities. While direct control is based on ownership, indirect control is based on relationships to other actors. The emphasis on the control goal follows from the assumption that control can be used to achieve other goals. By controlling resources and activities a company may not only gain access to important means, but also develop knowledge that can improve the company's ability to perceive constraints and opportunities for using these means to achieve certain goals.

Activities constitute parts of more or less repetitive activity cycles, in which a number of interdependent activities are repeated. When activities are repeated many times, formal routines and informal rules are created (Araujo, 1997). However, this is by no means to say that the activity network, in which these activities are carried out, become completely stable. Activity networks are always imperfect in the sense that new activities, changes in old activities, or rearrangement of activities can make it more efficient.

Activities may be divided into transformation and transaction activities. Transformation activities are carried out within the control of a single actor, and change or refine a resource by using another resource. Transaction activities are carried out within the control of one single actor or within a relationship between two actors, and coordinate the dependencies that exist between different actors' transformation activities.

Both transaction and transformation activities may be complementary, closely complementary and/or similar (Richardson, 1972). Complementary and closely complementary relates to the sequential dependencies among activities (Dubois, 1994). While complementary activities can be used for several different purposes, closely complementary activities are restricted to particular purposes (ibid.). According to Gadde & Håkansson (2001), increasing complementarities is about creating more efficient activity structures which then require co-ordination. As close coordination and sequencing of activities relies on use of resources that may be combined, more efficient activity co-ordination may be achieved through more complementary resources (Araujo, 1997).

Richardson (1972:888) defines similar activities as "activities which require the same resources for their undertaking". For instance, several assembly operations resulting in different products may be handled by the same personnel or equipment. According to Gadde & Håkansson (2001), increasing similarity is about more efficient resource utilisation. Apart from leading to cost reductions in manufacturing and distribution, increased similarity may reduce the cost of various design and development activities (ibid.). However, companies trying to capture similarities should always compare potential advantages of increased similarity with its disadvantages. Increased similarity may, for example, reduce opportunities for differentiation.

Resources may be divided into tangible and intangible resources. Tangible resources include physical assets, such as production equipment, components, material, etc. Intangible resources, on the other hand, include knowledge, skills, and routines. All resources, either tangible or intangible, are viewed to be heterogeneous. This means that exactly the same resource, when used for different purposes or in different ways and in combination with different types or amounts of other resources, provides a different service or set of services (Resource heterogeneity is further discussed in Section 2.3.1).

A resource may both be accessed within the company or through the company's relationships with other companies. Since business relationships constitute valuable bridges to accessing other actor's resources, they are not only regarded as important means but also regarded as valuable resources in themselves. Therefore, we need to improve our understanding regarding business relationships. Business relationships are discussed below in terms of their "substance" and "function".

2.2.1 Substance and function of business relationships

Based on the three dimensions of the industrial network model, Håkansson & Snehota (1995) develops a scheme that can be used as a conceptual framework (see Figure 2.4). This framework, which comprises the substance and the function of business relationships, facilitates identification of factors that affect development performed in particular business relationships.

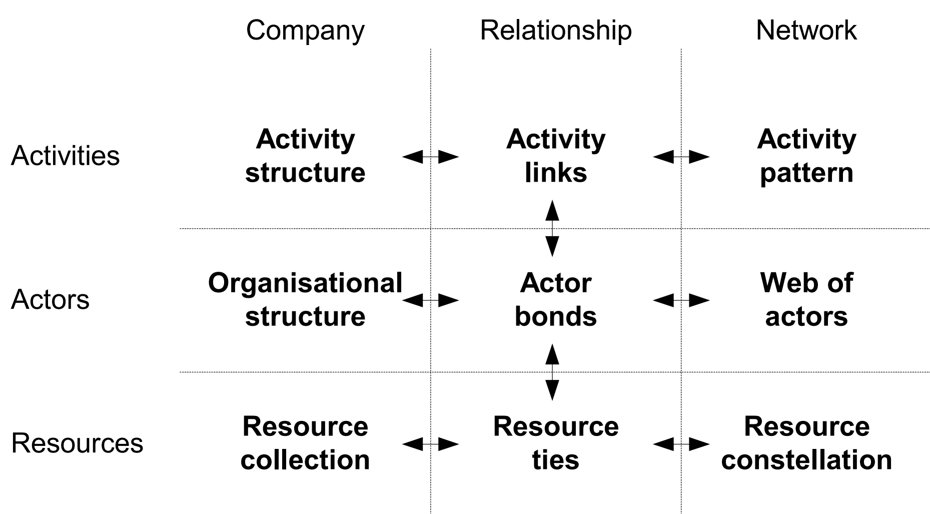


Figure 2.4: Scheme for analysing development effects of business relationships (Håkansson & Snehota 1995:45).

The substance of business relationships

The substance of business relationships can be divided into actor bonds, activity links, and resource ties. **Actor bonds** arise in a relationship between two companies as they direct a certain amount of attention and interest towards each other. Through the relationship the two parties get to know each other's goals and means. This increases not only their possibilities to utilise each other in future situations, but also their possibilities to avoid future conflicts. Actor bonds do not exist in a vacuum. As actor bonds are established between actors, a web of actors emerges. This web changes as the individual actors learn and adjust their bonds. Conversely, the web of actors affect an actor's learning and how it chooses to adjust specific bonds.

When two companies build a relationship, some of their technical, administrative or commercial activities are linked to each other. **Activity links** reflect both sequential and parallel interdependencies of activities. While sequential interdependencies may appear when the buyer tries to influence its suppliers to deliver in a certain order, parallel activities may appear when the same company tries to influence suppliers delivering complementary products to adapt to each other. Since both parties within a relationship have other relationships in which activity links can be important, an activity link in a relationship "links other links" in the activity pattern. This wider activity pattern is so complex that no single individual or group of individuals will ever be able grasp the whole picture.

Resource ties arise in a relationship when the resources of two companies are being brought together, confronted and combined, and thereby become specifically oriented towards each other. Over time the interface between the two companies' structures may become broad and deep, i.e. embrace different types of resources that are activated in various degrees. The process of developing resource ties is similar to an investment process. When developed, resource ties become important assets that must be taken care of and utilised in an efficient way. In addition, the relationships that are developed when a company confronts and combines its resources with those of other companies are important for the company's collection of available resources, and thus for what the company can do.

When resource ties arise, the same resource elements become tied to other resources in the resource collection on each side and, to resources of some third parties. As the same resource element can be involved in several ties, these will be connected in the sense that they affect each other. This structure of connected resource ties is called a resource constellation. Because each tie is an asset that must be taken care of, the resource constellation, in which a resource is an integrated part, may restrict its field of application.

The function of business relationships

In addition to having different layers of substance, relationships have three different functions. Firstly, a relationship has a function for the dyad. The substance of the dyad, the actor bonds, activity links and resource ties, is not just the sum of what two company turn towards each other. Jointly, the two companies can perform activities and utilise resources which none of them could have accomplish in isolation. The function of a relationship for the dyad is its being the locus of such "team effects" (Alchain & Demsetz, 1972). Secondly, a relationship has a function for each of the two involved companies. By affecting the resource collection a company can utilise, its ability to mobilise and influence other actors, and its possibility to carry out certain production and development activities, a relationship may have an important impact on a company's performance potential. Thirdly, a relationship between two companies may have a function for third parties. As relationships are connected, change in the substance of a relationship between two companies may affect their relationships to various third parties. A third party can react on such a change in different ways. The company can choose to adjust its own activity links and resource ties in accordance with the change, and thus try to exploit it. Alternatively, the company can choose to adjust and develop its own relationships in a way that makes the focal relationship less influential in the overall structure, and thus work against it.

In this thesis changes within business relationships are analysed in terms of adaptations. Hence, we need to know more about adaptation within business relationship. Literature focusing on adaptation in business relationships is therefore reviewed below.

2.2.2 Adaptation within business relationships

When a product is exchanged between a supplier and a buyer some adaptations are usually made. According to Gadde & Håkansson (1993), adaptations can be separated into technical, knowledge-based, and administrative. Technical adaptations concern the product sold by the supplier and the product manufactured by the buyer, as well as the production facilities of each. A major driving force for technical adaptations is cost reduction. In one large study it was found that material adaptations appeared to be the most common type of adaptations (Håkansson, 1989). This was explained by the fact that, from a production point of view, input goods are often the main cost factor.

Technical adaptations take the form of both major one-off measures and small successive steps over time. While major adaptations are highly visible and initiated by people working at a strategic level, small successive adaptations are less visible and handled "locally" in the organisation (Gadde & Håkansson, 1993).

Besides reducing costs, one-off measures are used by a company in order to show that it is committed to the long-term future of the relationship (Ford et al., 1998). Minor one-off measures may also be used as bargaining chips in a political process (Brennan & Turnbull, 1998). Because they are not easy to overview, the importance of successive adaptations is often underestimated. Usually, they are not recognised until one of the involved parties wants to implement a major change (Gadde & Håkansson, 2001).

In addition to technical adaptations, companies make administrative adaptations. Besides different production planning routines, these adaptations may involve stockholding, time of delivery, information provision, and various kinds of production processes (cf. Brennan & Turnbull, 1998). Just like technical adaptations, administrative adaptations may either be carried out in terms of one-off measures or in terms of small successive steps over time. One-off measures are made when a company wants to achieve various efficiency improvements, e.g. when the company buys a new information handling system in order to improve the communication, and thus also the co-ordination, among different organisational units. Normally, these kinds of adaptations are carefully planned. Administrative adaptations made through a sequence of small successive steps over time, on the other hand, usually seems to "just happen" as different organisational units strive to co-ordinate their work.

Concurrent to technical and administrative adaptations, companies usually make various kinds of knowledge-based adaptations. Just like administrative adaptations that seem to "just happen", these adaptations are often informal, largely unplanned, and likely to emerge from a socialisation process (Brennan & Turnbull, 1998). Knowledge-based adaptations gain in importance the more development issues are emphasised. By improving its knowledge about the buyer's production processes, a supplier may improve its ability to design and develop an offering that will provide a solution to the buyer's problem (Ford et al. 2002). Conversely, by improving its knowledge regarding the supplier's product, a buyer may both improve its use of the product, as well as its ability to specify the type of demand that meets its requirements (ibid.).

Adaptations may not only differ in type, but also differ in terms of specificity. Ford et al. (1998) point out that as adaptations are costly; companies are likely to try to reduce their costs by making common investments for several relationships. Adaptations that are highly resource demanding and made uniquely for one counterpart may possibly turn a relationship into a burden (Håkansson & Snehota, 1998). First of all, adaptations may lead to a certain "loss of control" in the sense that a company has adapted too much to one particular company at the preclusion of others. Adaptations that make a company highly dependent on its counterpart may also represent a burden in a situation where this counterpart for some reason dramatically changes its requirements or even totally disappears (ibid.).

2.3 Resource utilisation and development

As previously argued, managing the balance between exploitation and exploration concerns combining short term performance and long term performance. While short term performance primarily concerns getting the most out of available resources, long term performance may also require development of these resources. This section presents the literature dealing with resource utilisation and development in five parts. Firstly, resource heterogeneity and its consequences for resource combining are dealt with. Secondly, resource flexibility is discussed, focusing on the possibility to combine a resource with other resources. In particular, how the possibility to combine a resource with certain other resources changes over time is focused on. Thirdly, forces that may hinder or facilitate resource combining are addressed with a focus on structural embeddedness and path-dependence. While structural embeddedness concerns interdependencies among different resources at a particular point in time, path-dependence concerns sequential interdependencies in the development of a particular resource. Fourthly, how new resource combinations may result in new resource features, and how resource features that are developed in certain resource interfaces creates interdependencies between involved resources, is discussed. Lastly, organisational units' abilities to perceive and cope with interdependencies among resources are emphasised.

2.3.1 Resource heterogeneity

Within traditional economics, resources have been regarded as homogeneous, i.e. always providing the same service. However, Penrose (1959:25) claims that *"it is never resources themselves that are the inputs in a production process, but the services that the resources can render"*. Exactly the same resource when used for different purposes or in different ways and in combination with different types or amounts of other resources provides a different service or set of services. Resources should therefore be regarded as heterogeneous. Penrose uses the heterogeneity assumption in order to explain the growth of the firm. She suggests that one *"search into the inherited heterogeneous resources of the firm shape the direction of firms' innovative efforts, diversification and growth"* (1959:77).

Another source of the heterogeneity assumption is Alchain & Demsetz (1972), who, in relation to a discussion of "team production", argued that the output is the result of "team of resources" working together and not the sum of separate inputs. Alchain & Demsetz are interested in providing an explanation as to why firms exist. The profitability of team production and the difficulties with determining the value of each of the resources involved in team production are the main variables in their explanation of the existence of the firm. It is the firm's superior ability to handle difficulties involved in defining and determining the value of resources involved in "team production" which explains the existence of the firm. This superior ability is due to superior knowledge about resources and how they perform in different combinations.

The Resource-Based View (RBV) refers to resource heterogeneity for explaining firms' competitive position. Barney (1991), for example, argues that *"with homogeneous resources, all firms can implement the same strategies; hence, no firm can differentiate itself from other firms, and nobody will have a competitive position"* (Foss, 1997:10). Within the Industrial Network Approach the heterogeneity assumption implies that value is created through exchange and efforts at combining resources across firm boundaries. Snehota (1990) claims that values in exchange are given by its content, its meaning to the parties, and not simply by the characteristics of the object of an exchange transaction. Hence, it is not the resource per se, but rather the possible combinations with other resources that determine its value. By recognising that the value of the firm's resources depends on how they are combined and related to the resources of different counterparts, their value may be increased by trying out different ways in which they can be combined with the resources of counterparts. Apart from creating value by reducing the cost of means to reach certain ends, new resource combinations may create value by making it possible to broadening the array of ends that can be pursued (ibid.).

2.3.2 Resource flexibility

The concept of "flexibility" represents an additional aspect of the "heterogeneity" assumption and refers to a product's ability to be combined with other resources (Holmen, 2001). The flexibility of a product is partly delimited by the knowledge of the business units and the business relationships that organise it, and partly determined by nature (Gressetvold, 2004). According to Araujo (1997), resources may be specific or versatile in nature. Specificity refers to how adapted a resource is to a specific activity pattern or resource constellation. However, specificity is not regarded as a static property of resources, but may evolve over time as firms learn how to turn specific resources into more general-purpose resources. Conversely, general purpose resources may become more specialised and directed towards specific activity structures (ibid.).

Versatility refers to the ways in which a resource may be combined with other resources. Holmen (2001) makes a useful distinction between "versatility of resources due to combination potential" vs. "versatility of resources due to modification potential". In the first situation the resource per se is not changed, but only its combination to other resources. In the latter situation a modification is made of the resource, which affects the combinations in which it can be used. The two situations are interrelated in the sense that a new combination of two resources usually calls for some modification in their interface towards each other.

Apart from being interrelated, the division line between "versatility of resources due to combination potential" vs. "versatility of resources due to modification potential" may be blurred. According to Simon (1962), it is possible to view almost all entities—social, biological, technological, or otherwise—as hierarchically nested systems. At any unit of analysis, the entity is a system of components and each of those components is, in turn, a system of finer components. Hence, every resource may be decomposed into smaller components. Holmen (2001) argues that when the decomposing of a focal resource makes it cease to exist, the issue of "versatility of resources due to modification potential" equals the issue of "versatility of resources due to combination potential" – except that the focal resource is now "extinct" and the sub-resources may be "new". This point to the importance of not viewing a focal resource at a chosen level, since it may be that some components can be singled out and usefully applied in new combinations (ibid.).

Waluszewski (1989) argues that, in principle, resources can be used in an infinite number of ways. However, in practice versatility is unequally distributed among resources (Araujo, 1997). According to Holmen (2001) the concept of "explored versatility" refers to all the different combinations in which a resource has been tried, thus including the memory traces of those combinations that may have been abandoned. When actors' develop new resource combinations, some of these earlier memories may come forward. Although “explored versatility” is positively correlated with time, there is no constant increase in “explored versatility” over time. A resource which has existed for a long period of time may only have acquired a low degree of “explored versatility”, while a resource which has existed for a short period of time, but has been combined with many other resources, may have acquired a high degree of “explored versatility”.

In conclusion, flexibility of a product is partly determined by nature, and partly determined by the knowledge of the organisational units that organise it. Resources may be specific or versatile in nature, when specificity refers to how adapted a resource is to a specific resource constellation, and versatility refers to the ways in which a resource may be combined with other resources. Normally, highly specific resources are less versatile and vice versa. In other words, the more a resource has been specified to a certain resource constellation, the more difficult it may become to use the resource in other constellations. Stinchombe (1968) argues that resources that have become specialised to particular patterns of activities, often acquire a “sticky” or inertial character. In the section below, we will further elaborate on the “sticky” and inertial nature of resource development in terms of resource embeddedness and path-dependence.

2.3.3 Resource embeddedness

According to Wedin (2001), the heterogeneity assumption implies two things. First, resources cannot be analysed as isolated items, and second, the connections between resources are of central importance for any understanding of their development (ibid.). From an industrial network perspective, an individual resource can be described as being used within a network of embedded relationships. This embeddedness entails constraints in the sense that it can restrict certain changes of existing resource combinations, but at the same time an embedded resource may provide opportunities by being connected to other resources (Bångens et al., 1997). When applying the concepts of Håkansson & Snehota (1995), an individual resource is embedded in a company’s resource collection, activity structure, and the organisational units within the firm. Furthermore, through different resource ties, activity links, and actor bonds, individual resources are further embedded into inter-organisational resource, activity, and actor networks.

The conceptualisation of embeddedness within the Industrial Network Approach is inspired by Economic Sociology (cf. Granovetter, 1985; Uzzi, 1997). According to

Granovetter (1985:487), *"actors do not behave or decide as atoms outside a social context, nor do they adhere slavishly to a script written for them by the particular interaction of social categories that they happen to occupy"*. Their attempts at purposive action are instead embedded in concrete, ongoing systems of social relations. This social dimension of embeddedness implies that social relations affect the actor's ability to mobilise other actors in resource development, which regards knowing how to handle different social relations and whom to turn to in order to access certain tangible or intangible resources.

Uzzi (1997) emphasises the "economic consequences of embeddedness" in interorganisational networks. This economic dimension of embeddedness adds the notion that costs have an important impact on actors' choices. According to Wedin (2001), different economic dependencies that exist between firms and the economic logic that different firms act upon are embedded in each other. This has implications for technical change. Even if a change is possible from a technical and social point of view, the economic dimension of embeddedness requires that the change is compatible with the economic logic applied at that time and place.

In addition to the social and the economic dimension of embeddedness, there is also a technical dimension (Håkansson et al., 2002). Hughes (1987) points to the technical dimension of embeddedness by arguing that a technological system consists of different artefacts which interact and are adapted in order to function in the system. If an artefact is removed from the system or if its characteristics change, the other artefacts in the system will alter characteristics accordingly. Thus, the design of a product depends on how the surrounding system of complementary products is designed.

Ford et al. (1998) discuss four central factors that a company has to deal with in relation to technical embeddedness. Firstly, a company has to deal with *knowledge*. Any investment can be connected to different types of other investments among suppliers, customers, or parallel companies. This means that a company needs knowledge beyond the technology itself and its most immediate application. However, all this knowledge would be very costly for one company to acquire. Through its business relationships, every company therefore tries to economise on other companies' knowledge. Moreover, as new resource combinations are tried out, within a particular company or in interaction with another company, the knowledge about the application of the technology develops. Secondly, a company has to deal with *control*. As a single company never has full control of its own technology, a company has to cope with these other actors. Thirdly, a company has to deal with *change.* Different actors interpret the technology in different ways. While one actor may perceive a particular technological investment as an opportunity, another actor may perceive the same investment as a limiting factor. For a company it is important to understand what actors may support a change that the company could benefit from, or the opposite, which actors support a change that is threatening to the company. Fourthly, a company has to deal with *bundling.* A single technology is of no value until it is combined with others. To satisfy the requirements of any user therefore requires a bundle of different technologies each of which is embedded in a network of other technologies, companies and business relationships.

The time dimension of embeddedness

What has happened in the past is memorised in present structures and therefore needs to be considered when analysing companies' actions (Granovetter, 1992). Basalla (1988) notes that Edison's lamp was only a single component in a bigger system of generators, conducting networks, meters, switches, which earlier been developed for the gas industry. *"It is quite obvious that Edison had the gas system in mind when he developed his own system, which shows that history may have a large influence on development"* (ibid:49).

The impact of history has increasingly been explained by the concept of path-dependence. Quite often, path dependence is defined as little more than a vague notion that "history matters" or that "the past influences the future" (Mahoney, 2000). But the notion of path dependence means more than past dependence. Path dependence signifies that the order in which things happen affect their sequence and temporal unfolding (Tilly, 1994). Antonelli (1997) makes a useful distinction between past and path dependence using simple and complex Markov chains. If events within a specific system at an arbitrary time *t* can be predicted on the basis of the state of the system at time *t-1,* independently of how the system arrived at time *t-1,* then we are referring to past rather than path dependent processes. By contrast, if the probability of transition of a system from state *t-1* to t is dependent not only on the state of the system at *t-1* but also on the transitions between previous states (t-2,…, t-n), processes are path dependent.

Path dependency may be seen as a mechanism that hinders some technical development, and facilitates other. David (1985) uses the story of the QWERTY-keyboard to illustrate how path-dependency functions as a hindering force, creating negative “lock-in” effects. His description suggests that engineers of the early typewriters chose to address the problem of jamming typewriter keys by employing the QWERTY layout. The problem of jamming keys disappeared over time with the adoption of the ball key face mechanism and the use of personal computers. Yet, we continue using the QWERTY layout. According to David, there are three important features behind this “lock-in” effect: technical inter-relatedness, economies of scale, and quasi-irreversibility of investments. A “lock-in” effect is usually not something that instantly happens but is caused by a certain number of small events (Arthur, 1989), i.e. it develops gradually over time

Rosenberg (1976) uses the development of the machine tool industry, during the period from 1840 to 1910, to show that one thing often leads to another – not in a strictly deterministic sense, but in the more modest sense that doing some things successfully creates a capacity for doing other things. According to Rosenberg, this industry was generated as the result of specific production requirements of a sequence of industries which adopted techniques of machine production throughout the period.

> *“Because it dealt with processes and problems common to an increasing number of industries, it played the role of a transmission centre in the diffusion of the technology. The pool of skill and technical knowledge was added to as result of problems which arose in particular industries. Once the particular problem was solved and added to the pool, the solution became available, with perhaps minor modifications and redesigning, for employment in technologically related industries”* (ibid:19).

According to Araujo & Harrison (2002), path-dependence contributes to technical development through the reuse of existing knowledge, the “black-boxing” of some problems, and allowing developers to focus on other, more restricted problems (ibid.). Håkansson & Lundgren (1997) illustrate actors' opportunities to gain from previous experiences and investments by using the term “path-crossing”. According to these authors, a “path-crossing” is where actors, activities or resources meet and habits or routines are confronted or combined. A path-crossing can, for example, therefore be a resource which is used to perform different activities.

Departing from path-dependence, Garud & Karnøe (2001) offer a contrasting perspective that they term “path creation” which provides a way of understanding how agents, in our terminology actors, escape “lock-ins”. According to this perspective, agents mindfully navigate a flow of events even as they constitute them. Rather than being passive observers within a stream of events, agents reflect and act in ways other than those prescribed by existing social rules and taken-for-granted technological artefacts. In line with this argument, Araujo & Harrison (2002) argue that actors adjust their temporal orientations in relation to changing circumstances, by selectively engaging with routines and habits of the past, evaluating present possibilities, and projecting hypothetical new paths into the future.

2.3.4 Resource features and resource interfaces

Resource interfaces are areas where different resources meet and have an effect on each other (Wedin, 2001). According to Ulrich (1995), resource interfaces among technical units may primarily be divided into physical and functional interfaces. A physical interface exists when two components are physically attached to each other. For instance, they may be welded or glued together. A functional interface, on the other hand, exists when two components, by working together, provide one or several ”services” (Penrose, 1959).

In addition to interfaces between technical units, there are also interfaces between different organisational units, i.e. between different individuals and group of individuals. According to Gadde & Håkansson (2001), it is important that the competence and knowledge of the companies engaged in designing and producing fit together. Hence, between two organisational units there often is a knowledge interface.

Investments made in certain functional and technical interfaces among different customer specific solutions and customers’ production facilities, together with related investments in other interfaces, create a “heavy structure” (Håkansson & Waluszewski, 2002) which in order to pay off has to be used over time. Aside from the fact that resources per se are often associated with large investments there often exists quite a high degree of uncertainty (Holmen, 2001). This uncertainty may contribute to the heaviness by making a supplier keep existing features as they are. A company’s uncertainty can be related to its bounded knowledge (cf. Simon, 1957) regarding certain technical interdependencies, and consequently also from the complexity of these connections. The more tightly coupled the resources are to each other, the more difficult it may become to discover cause-and-effect relationships (Sanchez, 1999), and thus to predict the effects that a feature change may have on other resources.

Apart from being characterised by certain "heaviness", a resource is characterised by a certain "variety", i.e. a possibility to combine it with other resources. According to Håkansson & Waluszewski (2002), the variety of a resource is an indication of the number of different interfaces it has with other resources and the way these interfaces are interrelated. Hence, an increased density of interdependent technical interfaces may not only impede development due to uncertainty regarding the effects of a certain change, but may also foster development due to new combination opportunities.

Although some of the resources activated in an interface can appear as nicely adapted to each other, they cannot be perfectly adapted in relation to all the resources activated in all the interfaces related to it (Håkansson & Waluszewski, 2003). Hence, there will always be reasons to develop some of them in new directions. Furthermore, as soon as some interfaces are changed there will be effects on the others (Gadde & Håkansson, 2001). Johanson & Wedin (2000) argue that, in order to create value, features of different resources in the network need to be taken care of. Apart from requiring that the companies involved in an exchange recognise that the resource is embedded in a certain network of interdependent resource combinations, this requires that these companies are able to manage the embeddedness (ibid.).

2.3.5 Organisational units' knowledge about resources

Due to the notion of bounded knowledge (Simon, 1958), one may presume that no organisational unit can take all technical interfaces into consideration when it, by adjusting/developing one or several features, tries to fit two resources together. Consequently, every actor may need to "black box" certain interfaces. In a long term perspective "black boxing" may facilitate the performance of more narrowly limited tasks, which in turn stimulates the development of a more finely structured network of knowledge and perception (Loasby, 1999). In a short term perspective "black boxing" brings order to the development work, which helps the actor from being overwhelmed with possibilities and constraints (Hård, 1994). In other words, by limiting the resource network of considered resource interfaces, "black boxing" may improve an organisational unit's ability to deal with interdependencies among certain resource interfaces. Anderson et al (1994) define the network that the actor considers relevant as the actor's network context.

Interdependencies among different resource interfaces may make it difficult to isolate a change to a fixed set of interfaces. Anderson et al (1994), argue that an actor's "bounded knowledge" about the network in which it is engaged is arbitrary and depends on the actors' earlier experiences. In addition, Axelsson (1993) argues that rather than being a predetermined and fixed set of constraints and opportunities, network structures are revealed in action. In other words, an important feature of the actor's network context is that it is "enacted" (Weick, 1995), thus changes over time as the actor carries out changes at different interdependent interfaces.

An extension of the considered network of technical interfaces may sometimes call for interaction in additional organisational interfaces. Interaction with other units may change an organisational unit's "awareness boundary" (Dubois, 1998). Apart from improving the organisational unit's knowledge about how resources controlled by other organisational units may be affected by a change, it improves the unit's knowledge about whom to turn to in order to access certain means. Apart from different technical units, these means may involve knowledge about certain interfaces among these units.

By interacting with other units, an organisational unit may also learn how to interact with these units, including how to mobilise/enrol them in development projects. Metcalfe (2001) claims that more finely structured knowledge is achieved by the exclusion of other knowledge. In addition, Pfaffmann (2000) argues that knowledge of a complex product may be dispersed within a population of specialists. Hence, the development of complex products may require mobilisation of organisational units with complementary knowledge. According to Latour (1987), a way for an actor to enrol another actor in the construction of an artefact is to translate his/her own goal to the ones of the actor he/she wants to enrol. One important strategy to enrol other actors in the development of artefacts is to simply offer them a short cut to the achievement of their goals: *"You cannot reach your goals straight away, but if you come my way, you would reach it faster, it would be a short cut"* (ibid:111).

An organisational unit's ability to mobilise/enrol other units may not only improve as the unit interacts with other units. Nelson & Winter (1982) stress the importance of "remembering by doing" which puts into focus the importance of exercising a skill, more or less frequently over time, in order to prevent it from becoming rusty and decayed. Hence, an organisational unit's ability to mobilise/enrol other units depends on the extent to which the unit remembers previous interactions. Moreover, the ability is partial in its nature. Håkansson & Waluszewski (2003) argue that the ability to work with a new counterpart, or with an old one in a new way, depends on whether the process evokes dormant memories of earlier interactions. These memories may both entail knowledge about facilities or products that were used in a specific way or the experience of the people involved (ibid.). Hence, the ability to mobilise/enrol other units in a specific development project depends on the products and the production facilities in focus, as well as on the involved individuals.

2.4 Analysing resource combining, development, and embeddedness

Analysing how resources are developed by interacting with other resources and how it embeds them into certain structures call for a framework that can support the identification of interfaces and dependencies among resources. For this purpose the model of Håkansson & Waluszewski (2003) is used (see Figure 2.5).

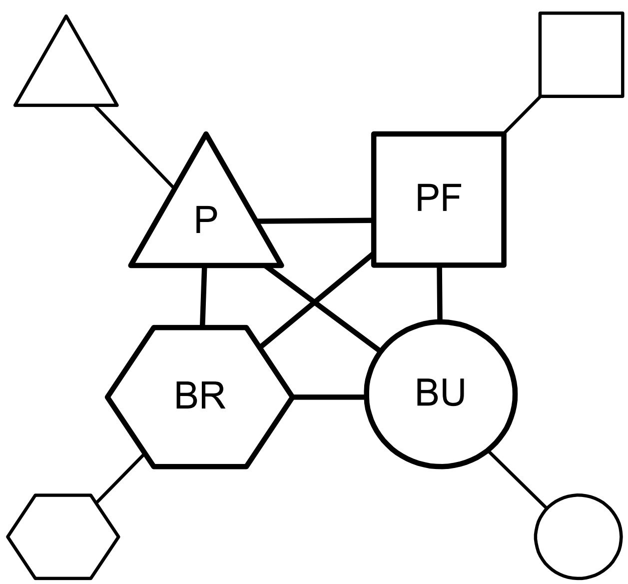


Figure 2.5: Four different resource entities in a business network (Håkansson & Waluszewski, 2003).

The model divides resources into two categories: technical resource units and organisational resource units. While the first category is further divided into products (P) and production facilities (PF), the second category is further divided into business units (BU) and business relationships (BR). All four categories of resources are highly dependent on each other. In order to produce a product, a facility that is owned by a business unit is needed, and in order to sell the product a relationship is needed.

Products (P) may both be single physical items as well as system of items including additional services such as training and support. The features of a product (goods and/or services) are primarily developed when the supplier, by itself or in interaction with various buyers, tries to combine the product with certain other resources. However, other companies may also influence the development of a product. Apart from suppliers of complementary products, the buyer's customers may have an important impact on the development of a product. Features that are developed in order to make the product fit in and contribute to the performance of a certain resource combination, may be viewed as imprints of this combination. When a product is brought from one interaction to another, these imprints bring seeds from the earlier resource combinations to the subsequent one (Lundgren, 1994).

Production Facilities (PF) include equipment, routines, and skills used in the production of products. The division between production facilities and products is a matter of perspective. A resource, from which a supplier's point of view is perceived as a product, may be perceived as a facility from a buyer's point of view. For example, when ABB provides a robot to Volvo, ABB perceives this robot as product produced in the company's production facility. Volvo, on the other hand, perceives the same robot as a production facility used in the company's production of automobiles. In other words, what is one company's production facility is another company's product.

Just like products, production facilities may be developed when being used in new resource combinations. During the combination process some latent features may be discovered and brought forward. This may, for example, increase a company's possibility to gain through similarities, and thus improve its utilisation of certain production equipments. Some production facilities are more difficult to change than others. Production facilities that involve capital-intensive equipment such as large machines, and skills that take time to develop, are often viewed as fixed points to which other resources are adapted (Ford et al., 1998).

Business Units (BU) organise both products and production facilities. A vital characteristic of business units is their memories with regard to how they organise products and production facilities due to earlier interaction. Just like products and production facilities, a business unit is not given once and for all. Every interaction may change business units' knowledge with regard to how they organise products and production facilities, as well as their abilities to work with other business units. The ability to work together with a new counterpart, or with an old one in a new way, depends on whether the interaction evokes memories of previous interaction.

Business Relationships (BR) make it possible for business units to influence the utilisation and development of technical resource units that are controlled by other business units (cf. Araujo et al., 2003). Aside from giving access to other companies' resources, and thereby being important resources in their selves, business relationships can be described as "quasi-organisations" (Blois, 1971; Richardson, 1972). This means that they can organise the exchange of products and connect different companies' production facilities. In this aspect, business relationships are similar to business units. However, one important difference is that they do not hold as strong identities (Gressetvold, 2004). Apart from knowledge about how to organise certain technical resource units, business relationships consist of connections among technical resource units that have been built during previous interaction.

Interaction between the four different resource categories (products, production facilities, business units, and business relationships) may take place in: 1) the interface between two technical units, 2) at the interface between a technical and an organisational unit, and 3) at the interface between two organisational units. Interaction at the interface between two technical resource units takes place when they are combined. In order for the units to fit with each other and as an integrated whole generate required services, new combinations usually call for some adaptations. Through the modification of certain technical features, these adaptations may contribute to the development of the involved units.

Technical resource units are not automatically combined, but are in accordance with certain long-term and short-term goals (ends) combined by organisational units. When organisational units combine technical resource units, and figure out how different technical resource units can be adapted towards each other, their knowledge about how to combine different resources changes through "learning-by-doing" (Arrow, 1962). This concurrent development of technical and organisational features (knowledge) is made at the interface between a technical and an organisational unit.

As mentioned above, combination of technical resource units is both performed within business units and business relationships. When it is performed within business relationships, learning also occurs in terms of "learning-by-interaction" (ibid.) and/or "learning-by-listening" (Bångens, 1998). These two kinds of learning may not only change the organisational unit's/units' knowledge about various technical resource units, including their knowledge about which organisational unit/units that controls which technical unit, but also their knowledge about other organisational units' goals. Both kinds of learning appear at the interface between two different organisational units.

The development of new technical and organisational features may be viewed as investments in certain technical and/or organisational interfaces. Due to the interconnectedness among technical resource units, investments that are made in one technical interface may call for additional investments elsewhere. Together with the original ones and various concurrent investments in additional organisational features, these investments embed the unit into a specific resource constellation which in order to pay-off has to be utilised over time. However, investments in technical and organisational interfaces are not the only reason for the embeddedness. Another important source is organisational units' bounded knowledge about these interfaces, and thus their limited abilities to perceive and deal with them.

2.5 Defining four research questions

Based on the reviews made above, it is now possible to define the research questions of this thesis. As stated in Chapter 1, the first aim of this thesis is to analyse how a supplier and a buyer in interaction arrive at a solution involving a mix of standard and customer specific features. This mix results from a negotiation process that appears when the supplier sells a product to a buyer who will use the product as a part of its production facility (see Figure 2.6).

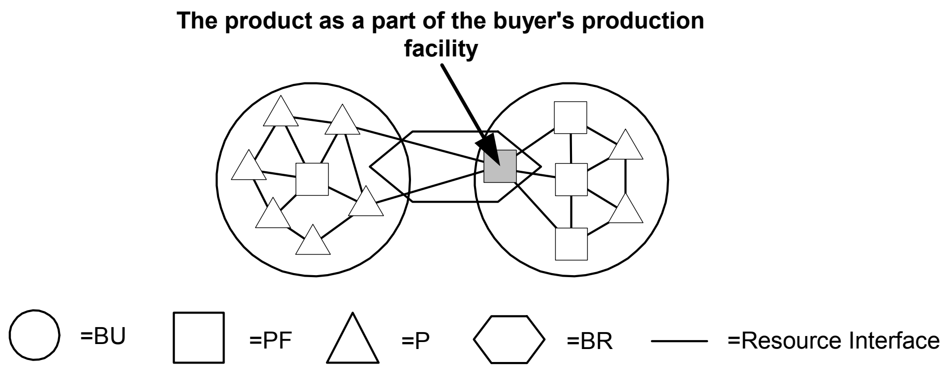


Figure 2.6: The exchanged product and how it is embedded into the supplier's and the buyer's different resource collections.

For the product to fit into the buyer's production facility, both the supplier and the buyer need to make different kinds of adaptations. While the supplier may need to customise some of the features of the product to other parts of the buyer's production facility, the buyer may need to adapt some of these parts to the features of the standard product. The need for adaptations may be different for different kinds of business transactions. Gadde & Håkansson (1998) divide business transactions into four cases (se Figure 2.7).

	No previous relationship	**Well-developed relationship**
Simple episode	**Case 1**	**Case 2**
Complex episode	**Case 3**	**Case 4**

Figure 2.7: Business transactions: four cases (Gadde & Håkansson, 1998:60).

Case 1 describes situations where there is no history and no likelihood that the transaction will lead to the initiation of a relationship. These purchases usually regard highly standardised raw materials, or very simple products purchased in small amounts. Consequently, they do not require any adaptations. Cases 2 and 4 describe situations where each individual transaction is seen in relation to an already established relationship. Apart from contact patterns that are built on successive episodes of interaction, the substance of these relationships are created by various kinds of adaptations. As argued in Section 2.2, technical and administrative adaptations may both take the form of small successive steps over time and major one-off measures. While major adaptations are highly visible and initiated by people working at a strategic level, small successive adaptations are less visible and originate from the continuous daily work of people at different operational levels. Case 3 describes situations characterised by an individual transaction episode that is complex in itself, i.e. involves a lot of objects that need to be mutually adapted to each other. Just like in Case 1, there is no established relationship. The case may therefore constitute a typical first episode that leads to further transaction within an established business relationship. However, it may also constitute a one-off purchase, for instance, when a company buys a piece of production equipment. Although these kinds of adaptations take the form of one-off measures, they do not only involve people at a strategic level, but owing to the complexity, they also involve people at different operational levels.

While most previous research on adaptations conducted with an Industrial Network Approach has focused on adaptations within well-developed business relationships (cases 2 and 4), this thesis primarily regards adaptations that are carried out during a single episode that is complex in itself (case 3). In addition to the reasons previously presented in Chapter 1, the fact that case 3 is not well explored by industrial network researchers is one further argument for making this study.

When the supplier adapts its product to the buyer's production facility, the company may apply different customisation approaches. As argued in Chapter 1, these approaches, reaching from pure standardisation to pure customisations, involve different mixes of standard and customer specific product features. Conversely, the buyer may carry out various adaptations of the company's production facility. Besides new/modified production equipments, adaptations of the buyer's production facility may involve new/modified work routines. Hence, the first research aim - how a supplier and a buyer in interaction arrive at a solution involving a mix of standard and customer specific product features - may be refined to the research question: ***How is a specific mix of standard and customer specific product features developed through mutual adaptations during a single transaction episode that is complex in itself?***

Owing to the large number of different interdependencies that always exists within a network of resource units (see Figure 2.8), the effects of an adaptation between two companies may have on other resources may be widespread and difficult to predict.

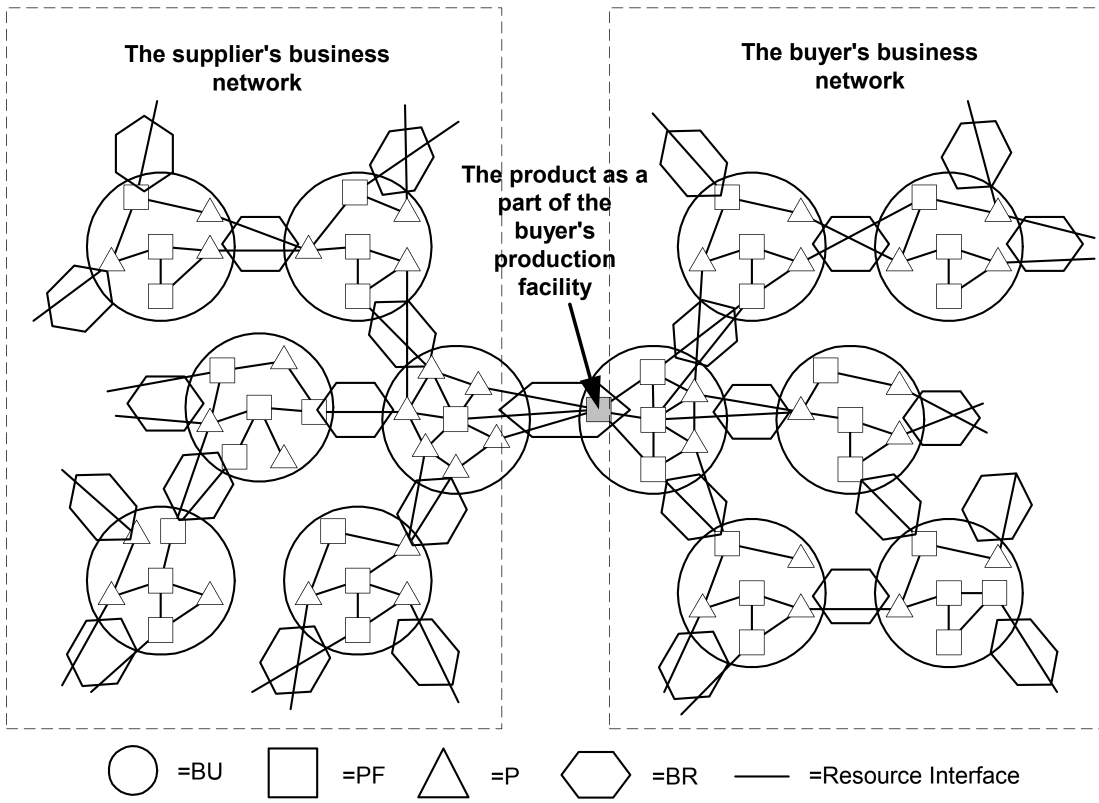


Figure 2.8: The exchanged product and how it is embedded into a network of inter-connected products and production facilities extending the boundaries of several companies.

A company's uncertainty regarding possible affects on other products and production facilities, and thus about the total cost of a certain adaptation, may make the company try to keep an existing product/facility design as it is. The degree of uncertainty depends on the complexity of the network in which the product/production facility is embedded. According to Weick (1995:87), "*an increase in complexity can increase perceived uncertainty because a greater number of diverse elements interact in a greater variety of ways*". When different products and production facilities are closely coupled to each other, it may become difficult to discover different cause-and-effect relationships (Sanchez, 1999), and thus to predict the effects that a new/modified feature of a certain product or production facility may have on other products and production facilities.

Besides trying to limit the costs of modifications within their own resource collections, both the supplier and the customer may try to avoid changes that might have a negative impact on the resource collections of various third parties. Inspired by *"the principle of non-proportional growth"* (Boulding, 1953), Dubois et al. (2002) argue that there are *"not necessarily decreasing impacts when getting further out from the focal relationships"* (ibid:60). The principle of non-proportional growth says that: *"when any structure grows, the proportions of its parts and of its significant variables cannot remain constant. That is to say, it is impossible to reproduce all the characteristics of a structure in a scale model of different size"* (Boulding, 1953:335). Therefore, "*subsequent adjustments of a change are not necessarily proportional to the change itself"* (Dubois et al, 2002:60).

Hence, there are several reasons why a supplier and a buyer may try to limit the extension of an adaptation. Apart from reducing the costs for changing the two companies' own resource collections, preservation of established resource structures might reduce possible negative effects on the resource collections of various third parties. A second research question that originates from the first aim of this thesis therefore is: ***How do the two interacting parties handle the effects that a certain adaptation may have on other parts of the network?***

Based on the reviews, it is also possible to refine the second and the third aims of this thesis which concern how the development that is performed during a single transaction episode interplay with the development of the standard product. While the discussion made in this section has so far focused on how a customer and a supplier in interaction deal with structural embeddednes, this aim calls for another view. Apart from changing from an interaction perspective to a supplier's perspective, we need to broaden the time frame of relevance. According to Halinen & Törnroos (1998:188), *"business actors are not only dependent on one another and the broader contextual setting specific for each company, but also on the temporal reality – past, present and future time"*. In Section 2.3 the time dimension of embeddedness is discussed in terms of path dependence. One important aspect of path dependence is that the time and sequence of different development efforts affect how they unfold.

Figure 2.9 shows the development of the supplier's standard product. This development is based on customer specific features that are integrated into the standard product. Through the integration of these features, development that is made in interaction with one specific buyer (B_2) at a particular time *t* is affected by previous development efforts that have been made in interaction with a buyer (B_1)

at time *t-1*. Similarly, the development efforts that are made at time *t* affects succeeding development efforts that later are made in interaction with a subsequent buyer (B_3) at time *t+1*, and so forth. A third research question is therefore: ***How is the development of product features shaped by past, present, and expected future supplier-buyer interactions?***

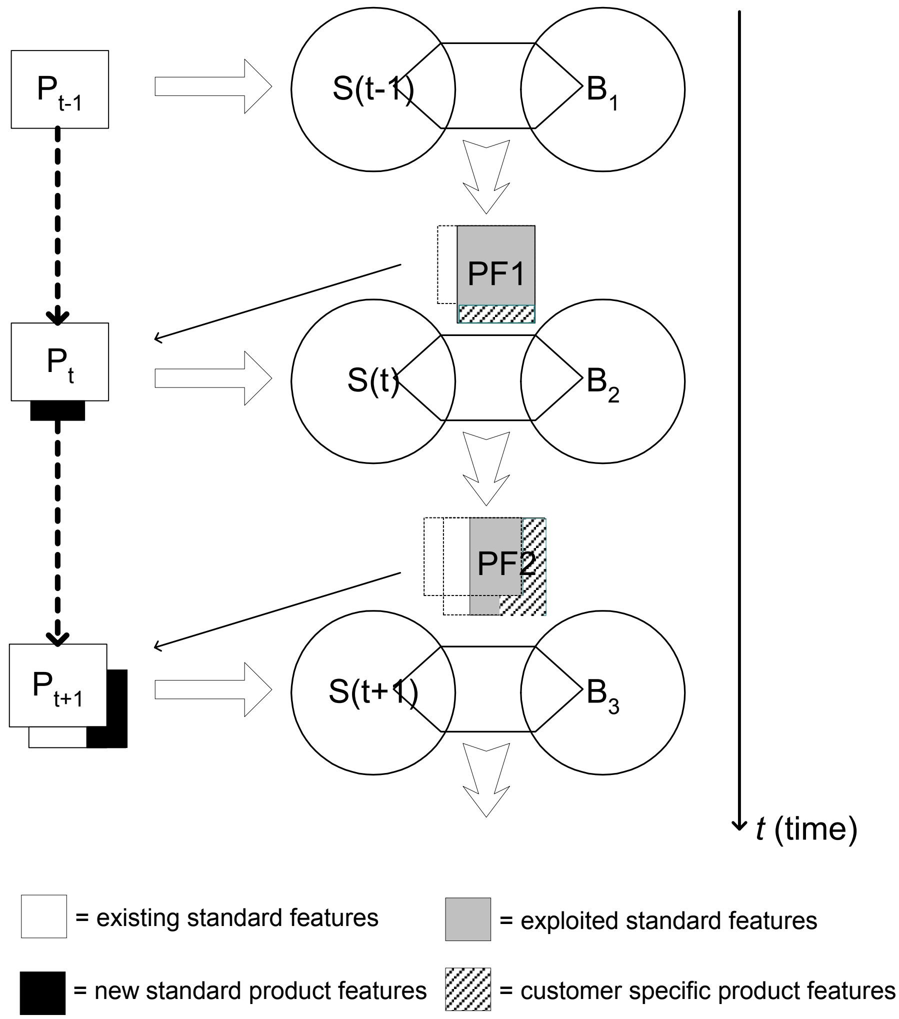


Figure 2.9: Schematic picture of how development of specific customer solutions (PF1, PF2) during different supplier-buyer interactions results in new features of the standard product (P), and how it successively develops the standard product.

The figure above also illustrates that a supplier's exploitation of standard products and exploration of new features during the development of customer specific solutions, both is affected by how the supplier in interaction with specific buyers choose to customise its solutions, and by how the company based of certain customer specific product features choose to develop the standard product. As argued in Chapter 1, customisation and standardisation concern two different logics, i.e. the logic of individualisation and the logic of aggregation. Individualisation primarily concerns the issue to develop efficient customer specific solutions, which involves identifying particular customer's requirements. Aggregation, on the other hand, concerns the issue to develop standard products that can be utilised in many different customer applications, which involves identifying groups of customers that share certain product requirements. As the logic of individualisation and the logic of aggregation concern two different ways to focus when developing products, they are not easily combined. However, for a company that has to develop its standard product over time and adjust the current versions of it to individual customers, both aspects need attention. This brings us to research question number four: ***How can a supplier combine the logic of aggregation with the logic of individualisation in order to maintain an appropriate balance between exploration and exploitation over time?***

3 METHOD

This chapter concerns the method applied in this thesis. Firstly, the research design is discussed. This is followed by a discussion of how the theoretical approach has evolved parallel to the case through a process of direction and redirection of the study, and how the case boundary gradually has developed during this process. Lastly, the data collection is discussed.

3.1 The use of a case study

In Chapter 2, it was argued that the aims of this thesis call for an industrial network study. A research method that can support the study of industrial networks is therefore required. Several researchers have argued for the usefulness of case studies when studying industrial networks (cf. Easton, 1995; Harrison & Easton, 2002; Araujo & Dubois, 2004; Halinen & Törnroos, 2005).

> *"Industrial networks comprise a large number of organizational actors where the boundaries between one net and another are at best, indistinct. The connectedness among and between actors means that Yin's prescription that cases should be used where the boundaries between the phenomenon and the context are not clearly evident is wholly applicable. The notion, for example, of surveying networks as a sample of independent actors or links or dyads or triads is risible. The essential element of a network view is lost in this situation since connectedness is assumed away. Conversely a sample of one looks far more defensible if the one is a net comprising large number of actors. Similarly, the complexity of the links within and between actors requires a methodology which can handle rich sources of data and multiple forms of data collection. Networks have consistently been portrayed as dynamic forms. Again the case method with its attention to changes over time is well suited to providing longitudinal data" (Easton, 1995:385).*

Case studies may be divided into single and multiple case studies (Yin, 1994). Multiple case studies may be, in turn, divided into independent and embedded multiple case studies (Harrison & Easton, 2002). In the latter case, multiple case studies are carried out within a closely similar context. While a case context could be a particular industrial network, the embedded cases could be the behaviours of individual actors within this network. Harrison and Easton argue that although the similarity of context in embedded cases allow for more detailed understanding of the processes leading to an observed outcome, independent cases might most sensibly be used when analysing how the context may affect these processes.

Embedded multiple case studies may be further divided into vertically and temporally embedded case studies (ibid.). Vertically embedded multiple case studies are situated at lower hierarchical levels within the overall case and are described within the same time period. For example, the overall case could be a particular industrial network and the embedded cases could be individual actors within this network. Temporally embedded case studies, on the other hand, concern a series of cases depending on the period of time being researched and described. The division into different periods does not only increase the number of cases in analysis, but also facilitate identification of interrelations among processes within different periods.

Halinen & Törnroos (2004) suggest a framework for network analysis that includes both the temporal and vertical dimension of embeddedness (see Figure 3.1). While the horisontal axis represents the temporal dimension in terms of past, present, and future, the vertical axis denotes the various levels in the context of a network, which are likely to influence the processes of network change.

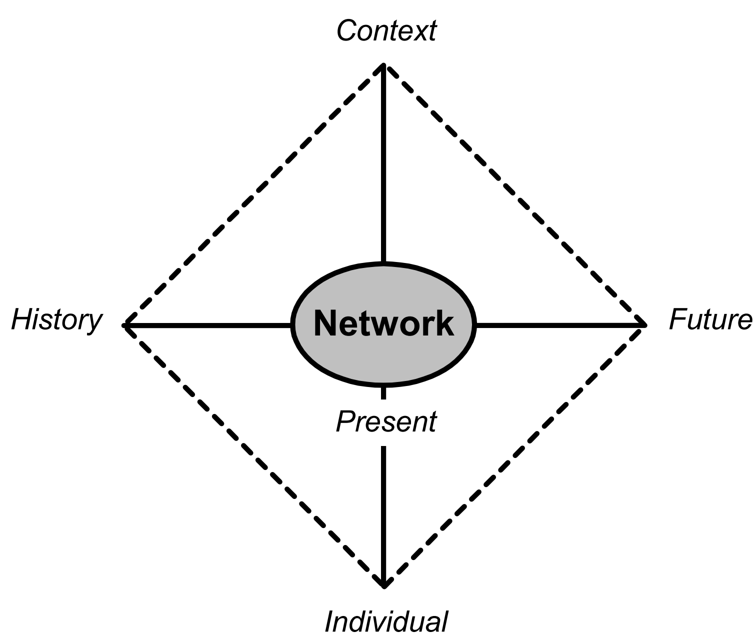


Figure 3.1: A general framework for the analysis of business networks in a contextual time-space (Halinen & Törnroos, 2004:1290).

With this framework, Halinen & Törnroos (2005) propose that there are simultaneous processes occurring at different vertical levels. For example, the development of a product may have an important impact on a company's possibility to position itself in the industry. At each contextual level, the development is dependent on the events of the past, on the present situation, and the future. When designing a network study, it is therefore not only important to investigate the present situation. In order to understand actors' actions it is also important to be alert as to how they are guided by their past and to which pasts they are connected with, as well as where they want to be and what they want to become (ibid.).

The case study of this thesis can best be described as an embedded multiple case study. While the overall case concerns the interplay between development of customer specific solutions and development of standard products, the embedded cases concern different supplier-customer interaction outcomes. The focal implementation was carried out at Borgstena Textile. From this implementation I have not only expanded my frame of analysis vertically to involve Borgstena Textile's different production facilities and business relationships, but also expanded this frame temporally to involve some of IFS's preceding and subsequent implementation projects. The vertical expansion of the case and the temporal expansion of the case and how they interplayed with the development of the theoretical framework is discussed below.

3.2 The emergence of the particular case and the theoretical framework

In accordance with an abductive approach, the theoretical framework and the case description was developed simultaneously. According to Alvesson & Sköldberg (1994), an abductive research process alternates between theory and the empirical world, where both are gradually reinterpreted in the light of each other. Through this interpretation, everyday language is interrelated to different theoretical concepts (ibid.).

Since the main difficulty of case studies is handling the inter-relatedness of the various elements in the research work, case studies based on abduction require what Dubois & Gadde (2002) label "systematic combining" (see Figure 3.2). Systematic combining can be described as a non-linear, path dependent process of combining efforts with the ultimate objective of matching theory and reality. This objective is in line with Ragin (1992), who argues that our primary goal as researchers is to use theory to make sense of empirical evidence and to use this evidence to sharpen and refine theory.

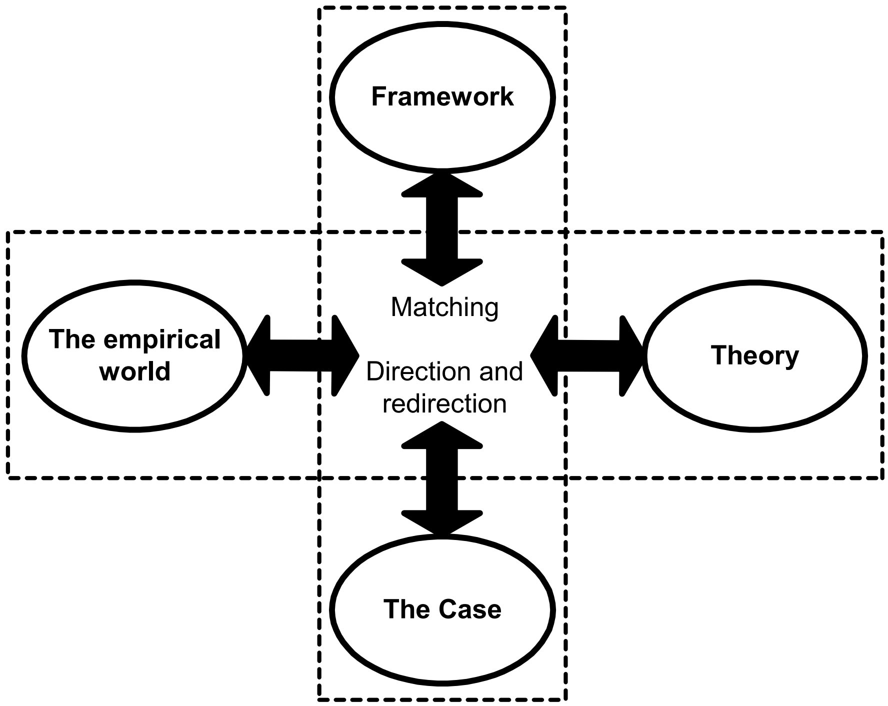


Figure 3.2: Systematic combining (Dubois & Gadde, 2002:555).

Dubois & Gadde (2002) state that there is never one single way of matching, but some ways may turn out to be better than others. This is, however, a result of the process which is derived by the interplay between direction and redirection. *"The evolving framework directs the search for empirical data. But empirical observations might result in identification of unanticipated yet related issues that may be further explored in interviews or by other means of data collection. This might bring about a further need to redirect the current theoretical framework through expansion or change of the theoretical model" (ibid:555)*. Apart from continuous iteration between theory studies and data collection, the interplay between direction and redirection is fostered by multiple sources of data. Multiple sources of data may, for example, contribute to revealing aspects unknown to the researcher, i.e. discover new dimension of the research problem (ibid.).

This description fits well with the process underlying this thesis. During the whole research process I have linked theory with empirical data and vice versa.

Important tools for this work have been papers written for different workshops, conferences, seminars, and doctoral courses. In particular the doctoral courses and the seminars have directed me to apply new theoretical concepts. However, the process has not been systematic in the sense that it was planned from the beginning. Several times I have followed various "side-tracks" which eventually have appeared to be "dead-ends". Although these side tracks put me in the "wrong" direction, they constitute important parts of the research process. Apart from affecting the gathering of empirical data, they have affected the development of the theoretical framework.

In one of my side-tracks I tried to use the Industrial Network Approach for explaining the underlying mechanisms producing "entrepreneurial alertness" (Kirzner, 1973), i.e. the mechanisms producing every individual actor's unique alertness to possibly newly worthwhile goals and possibly newly available resources (I was introduced to Kirzner's book, "Competition & Entrepreneurship", when I attended a doctoral course called "The Theory of Firms and Markets" which was hold at Stockholm School of Economics and the University of Uppsala). Basically, the idea was that entrepreneurial alertness is generated when actors try to combine resources in new ways, and thereby not only learn about new resources that can be used to achieve certain goals, but also about new available goals to pursue. The underlying mechanism producing this alertness was assumed to be interdependencies among different technical and organisational resource units. For example, interdependencies between an organisational unit's knowledge and the features of the different technical resource units it combines, as well as interdependencies between this knowledge and the knowledge of the other organisational units that the unit interacts with. Analysing these interdependencies aimed to explain the importance of individual supplier-buyer interactions and the sequence of these interactions for a supplier's ability to innovate. My efforts to explain the underlying mechanisms producing Kirznerian entrepreneurial alertness resulted in a paper (Hjelmgren, 2001). Although this thesis in its present form does not aim to explain the Kirznerian entrepreneurial alertness, writing this paper turned my interest to the role of knowledge and perception in various product development efforts. The theory which I then gathered, concerning different organisational units' knowledge about resources, facilitated my analysis of how a supplier manages the balance between the company's exploitation of its standard product and the exploration of new product features during the development of specific solutions.

According to Araujo & Dubois (2004) industrial network studies tend to start with some theoretically and/or empirically inspired notions. In this case, the starting point was an interest in the interplay between development of customer specific solutions and standard products, and the access to a key actor (IFS). Owing to earlier interactions with certain individuals at IFS, my supervisor had learnt that 75% of the standard functionality within IFS Application originates from prior customer specific adaptations. That, in combination with the fact that IFS during individual implementation tries to limit the extent of customer specific adaptations, this extensive utilisation of prior adaptations made the interplay between development of customer specific solutions and standard products an interesting topic for a doctoral thesis. Besides my supervisor's earlier experiences with IFS, the company had a large branch department in Göteborg. This did not only improve my access to empirical data as such, but was also convenient from a practical point of view. Denscombe (1998) argues that due to time and resource limits, it is reasonable for a researcher to consider such pragmatic reasons.

The decision to take the implementation at BTAB as the point of departure for the study was made together with one of IFS's Product Directions Managers in Göteborg. While the choice of a focal business relationship was natural, given my theoretical approach, the choice of the specific business relationship with BTAB was mainly due to the fact that both standard features and customer specific features had been developed. Furthermore, the implementation had just been finished and thus fresh in mind.

In the study that followed, the case developed gradually. Araujo & Dubois (2004) argue that the research object, its boundaries, context, and horizon are emergent and unfolding outcomes of the research process.

> *"Using the industrial network model as a theoretical platform implies that the dimensions/components/items of the network(s) are assumed to be interdependent and/ or interacting with means; (1) that they cannot be studied in their totality, and (2) that there are no natural, pre-fixed boundaries given by independence amongst components of the system…Departing from the chosen centre, the study and thus the boundaries of the case typically develops by analyzing items/ elements connected to the centre. Important theoretical tools in this process are concepts such as interdependence, links, ties, bonds etc depending on the particular empirical phenomenon and focal dimensions of the theoretical model"* (Araujo & Dubois, 2004:221).

My early interviews at IFS concerned the company's general work routines. It also concerned the specific implementation work at BTAB, e.g. the kinds of problems that had turned up and how they had been handled through the development of different standard and customer specific product features. Furthermore, they provided a general description of BTAB's planning situation and how different planning routines had been adapted to the features of the ERP-system. In order to further improve my understanding of the implementation work at BTAB, I observed two real time implementation meetings at another buyer. Along with an additional interview with one of the responsible implementation consultants, these observations gave me a better picture of how implementations are carried out, how the formal communication between the project department and the R&D-department is designed, and how and where in the system different adaptations are made.

Based on the interviews and the experiences from the implementation meetings, I wrote a paper about product development performed in interaction with buyers (Hjelmgren, 1999). According to Eisenhardt (2001), overlapping data analysis with data collection not only gives the researcher a head start in analysis, but also allows researchers to take advantage of flexible data collection. While writing the paper I found out that, in order to improve my analysis of the development project, I needed to gather more data regarding BTAB's requirements. This resulted in further interviews at BTAB. Apart from data regarding the requirements as such, these interviews provided me with data concerning BTAB's planning situation. It turned out that the planning situation was rather complex, and consequently difficult to grasp. In an effort to get everything right, I asked the distribution manager at BTAB if he could take me on a guided tour. After this tour I was able to write a detailed description of BTAB's planning situation. This description was essential for understanding the problems BTAB needed to deal with, thus for understanding the reasons behind the developed mix of standard and customer specific product features.

In order to further improve my understanding of the reasons behind the developed mix, I needed to know more about the reasons behind the current design of the standard modules. In the autumn of 1999 I attended a doctoral course called "The Technological Firm", hold at the University of Uppsala. This course introduced me to the "path-dependence" concept. Together with my ambition to learn more about the reasons behind existing standard product features, this concept inspired me to investigate the temporal embeddedness of the BTAB-project. Therefore, I decided to gather data about preceding implementations, and how they had affected the present design of two focal standard modules.

Based on the data that was gathered regarding preceding implementations, I wrote a paper about how different customer requirements, through the development of new features, put certain imprints on the standard product (Hjelmgren, 2000). While working on this paper, I realised that present development efforts were not only affected by existing standard features, but also by the expected future. This is due to the assumption that present development has an important impact on future utilisation and development. Therefore, the next step in my study was to find out how the standard product features, which had been developed during the BTAB-project, were utilised and developed during succeeding implementation projects. Then I needed to be able to show that present development efforts have an important impact on future utilisation and development. I decided to gather data about at least three succeeding implementation projects.

When gathering data on BTAB's planning situation, I had learnt that an important part of BTAB's requirements had its origin in the company's business relationships. Consequently, I later decided to supplement my temporal expansion of the case with a vertical expansion. Apart from more data about BTAB's subcontractors and customers as such, more data on how these companies affected BTAB's requirements was gathered. This vertical expansion on the buyer side was, in turn, supplemented with more data on different technical interdependencies on the supplier side. In order to learn more about these interdependencies, I interviewed different system developers involved in the BTAB-project. Through these interviews I managed to gather data on BTAB's customer specific solution, in terms of standard modules included, the different standard and customer specific features that were developed, how the modules were interconnected, and how certain adjustment of one of these modules called for additional adaptations of other modules. This data did not only improve my understanding of why IFS normally tries to limit the extent of adaptations, but also why the company, in particular, tries to limit the extent of adaptations in the standard version.

Eventually, I had enough empirical data for being able to grasp the "total picture" of the BTAB project's embeddedness. At least it was enough for analysing the interplay between development of customer specific solutions and standard products. Already from the beginning of my study, the Industrial Network

Approach was used as a theoretical frame of reference. The fundamental assumption underlying this approach is the view of firms being embedded in a network of other firms. Although this assumption guided me from the start in my fieldwork, especially in asking questions and in structuring the data, I had not yet been able to sufficiently analyse the embededness and how it affects the development of new resource combinations.

In an effort to improve my analysis, I chose to use Håkansson's & Waluszewski's (2003) analytical framework for analysing resource combinations and embeddedness. My interest for this framework evoked when I attended a course called "Network Theory" at Chalmers University of Technology. During the course I got the opportunity to read a doctoral thesis in which this framework was applied. Inspired by this thesis, I chose to see IFS's modules as products, and BTAB's production plants (including all production equipments and routines), as well as the plants of its customers' and supplier's, as production facilities. The division of technical resource units into products and production facilities improved my ability to catch the interconnectedness among different standard features, customer specific features, and the customers' additional changes of certain work routines. However, it called for more data about the system architecture. In order to gather this data, further interviews were conducted at IFS. According to the analytical framework, products and production facilities are viewed to be organised by business units and business relationships. While I chose to see IFS and BTAB as two different business units, I saw BTAB-project as a business relationship. During my work on this thesis, the division of organisational resource units into business units and business relationships improved my ability to analyse the possibility for a supplier to organise the interplay between exploitation and exploration.

My first attempt to apply Håkansson's and Waluszewski's analytical framework resulted in a fourth paper (Hjelmgren & Dubois, 2002). After having written that paper, I soon began to write on this thesis. An important part of the work concerned structuring the case, which involved interpreting data. Just like prior interpretations, these interpretations got the stamp of my research tools. According to Ragin (1992), theoretical ideas and principles provide ways to see the empirical world and to structure our descriptions of this world. In this thesis, the Industrial Network Approach had an important impact on how the case was structured. Apart from explicitly dealing with interaction between companies during different implementation projects, the case came to involve how the interaction affects and is affected by different business relationships. Conversely, the empirical world had, through prior matching between this world and theory, an important impact on how my theoretical framework was designed. Due to prior matching, the theoretical framework came to involve theory concerning path-dependence, actors' bounded knowledge, and Håkansson's and Waluszewski's framework for analysing resource development.

To summarise, the starting point for this thesis was an interest in a particular empirical phenomena: the interplay between development of customer specific solutions and standard products. According to Ragin (1992), it is impossible to do research in a conceptual vacuum. In my case, the Industrial Network Approach was used as a theoretical frame of reference. Already from the start my "Network Spectacles" affected my empirical field work, especially in asking questions, in structuring the data in a systematic way, and giving some meaning to the empirical material.

The case and the theoretical framework concurrently evolved through a process where new empirical findings directed the search for theoretical concepts, and where the use of new theoretical concepts conversely directed the empirical field work. In this process, papers and doctoral courses constituted important turning points, at which the search for theory and empirical data was directed and redirected. While writing this thesis, the oscillation of the direction and redirection process was gradually narrowed down to minor adjustments between the case and the theoretical framework.

3.3 Sources of data

Interviews were used as the main source of data. A total of 45 interviews were performed with 36 different individuals, involving 6 firms. The interviews were conducted in the period of 1999 to 2004 (see Table A.1. in Appendix). On the supplier side, I interviewed 11 system developers, 6 Group Managers, 3 Product Directions Managers, and 2 Application Consultants. On the buyer side, I interviewed 7 production planners, 2 IT Managers, 2 Distribution managers, and 1 Production Manager. The emphasis on the supplier side may partly be explained by the general interest of the study, which was to analyse the interplay between development of specific customer solutions and development standard product. Another important reason was the complexity of the ERP-system. At least it appeared so for a Mechanical Engineer specialised in Production Management, who had graduated just before the major IT boom in the end of the twentieth century.

The first contact with the interviewee was either made by phone or e-mail, where he/she was informed about the general interest of the study. He/she was also told about the person who had recommended me to contact him/her. Although the length of the interviews varied, all people that I contacted agreed to participate without any hesitation. Each interview lasted anywhere from 30 minutes to three hours, but most had an average length of about two hours.

I began every interview with a short presentation of myself, my research, and the aim of the interview. During the interview I tried to ask short question and not use an academic language. When the interviewee spoke I always tried to be alert to "active" data, i.e. to data that is not explicitly asked for but which during an interview may be brought forward by the interviewee. Dubois & Gadde (2002) make a distinction between two types of data – "active" and "passive". While passive data is what the researcher has set out to find, active data is associated with discovery. They further argue that a very active interviewer will only come across passive data. By being alert to "active" data I, for example, discovered the CBS Module. However, I never let the interview get too far away from my research focus.

As revealed above, the empirical data has been gathered by interviewing people with very different competences, where many of these were quite different to my own. This made it necessary for me to regularly make interpretations that the interviewee either could confirm or neglect, and thereby make sure that I had gotten everything right. In addition, I sometimes needed to confirm ideas about possible interdependencies that I had gotten from reading preceding interview protocols and making analyses. Kvale (1997) argues that an interviewer should not be afraid to ask guiding questions, and that the issue to avoid guiding questions which traditionally has been advocated originates from a naive view on empirical data, i.e. the illusion of an objective reality. My view on empirical data, as not reflecting an objective reality, also made me try to avoid literal interpretations and consider the everyday context of the interviewee. Pettigrew (1997) argues that as a researcher, one always has to be aware of that the context limits an actors' access to information and thus affects his/her perception of certain processes.

I ended every interview by asking the interviewee whom I could turn to in order to access empirical data that related to the data I just had been provided, but which partly concerned technical and organisational resource units beyond the present interviewee's awareness boundary. This made it possible for me to, bit by bit, extend my own awareness boundary regarding different interconnected technical and organisational resource units. The problem, however, was when to stop trying to expand this boundary. As suggested by Kaijser (1999), I decided to stop my search for empirical data when I thought I had enough data for answering my research questions.

After having finished an interview, the first thing that I always did was to make a clean copy of my field notes. While doing this, I extended my notes with facts I recalled from the interview. This led to more descriptive notes from the interview. After the first ten interviews, I began to write on a "raw-case". This work made it possible to compare different answers, and thus identify ambiguities in my empirical data that I needed to deal with. Normally, these ambiguities were cleared out during subsequent interviews. The work on the raw case also enabled me to in an early stage detect "white spots" in my empirical framework which I needed to fill in. This usually resulted in some extra interviews. However, the work on the raw-case did not replace the work of making clean copies, but rather complemented this work. According to Eisenhardt (2001), one key to useful field notes is not to sift out what may seem important because it is often difficult to know what will and will not be useful in the future. By continuing the work of making clean copies, I was always able to go back and reinterpret preceding interviews in the light of subsequent ones.

A second source of data was official company information provided on websites, in brochures, annual reports, daily papers, magazines, and books about computer programming. Apart from confirming interview data, this secondary data improved my understanding of the firm's different business contexts as well as my knowledge about certain technical issues. In some cases it was also used when preparing for interviews. More "intangible" data was, in addition, gathered through observations. This data primarily concerned the ERP-system's user interface and the design of different production facilities.

When I finished my field work, I had managed to gather data about a wide network of interdependent resource units. Some of this data concerned companies about which I only had gathered second hand data, i.e. companies with which I had never been in direct contact. In retrospect, making contact with these companies would have been very time-consuming. Therefore, I decided to rename these companies.

4 EMPIRICAL BACKGROUND[1]

This chapter provides a background description to Industrial Financial Systems (IFS) and Borgstena Textile AB (BTAB). In the case of IFS, the description focuses on the company's ERP-system and how it is developed by the company's two different departments. The first department is the Project Department, which is responsible for the implementation of the ERP-system at different customer's sites. During these implementations the department tries as much as possible to utilise existing standard components. However, most implementations require some additional customer specific components. The second department is the R&D Department, which is responsible for the development of the standard components.

The background description of BTAB primarily concerns the company's production and how it relates to the production of different customers and suppliers. BTAB's production is divided among three production plants with different production planning situations. The first plant is a knitting work located in Borgstena, the second plant is a dying work located in Timmele, and the third plant is a laminating work located in Getinge.

4.1 IFS

IFS (Industrial Financial Systems) was founded in 1983 by five engineers from the University of Linköping. As the technical platform for the company's software they selected Oracle´s development tools and relational database. During its first years of operation IFS built up specific expertise in relational database technology, which they combined with their knowledge of preventive maintenance acquired from an assignment in the nuclear power industry. This resulted in the development of IFS Maintenance, the first software product of IFS, launched in 1986. Eleven years later (1997), the company was ready to provide it first ERP-system.

[1] This presentation of IFS is primarily based on data that was gathered during the period between 1999 and 2001.

4.1.1 IFS Application

IFS's ERP-system is called IFS Application. In 2001 this system included 56 standard modules divided into eight different groups of modules (see Figure 4.1). Apart from the modules included in "Maintenance", the system includes modules for "Distribution", "Manufacturing", "e-Business", "Financials", "Front Office", "Human Resources", and "Engineering". For each implementation different modules are combined into customised systems. In addition to this, some modules are typically adjusted to fit specific customer needs. Apart from making it easier to sell a sub-set of the ERP-system, the division into different module groups facilitates the implementation of the system.

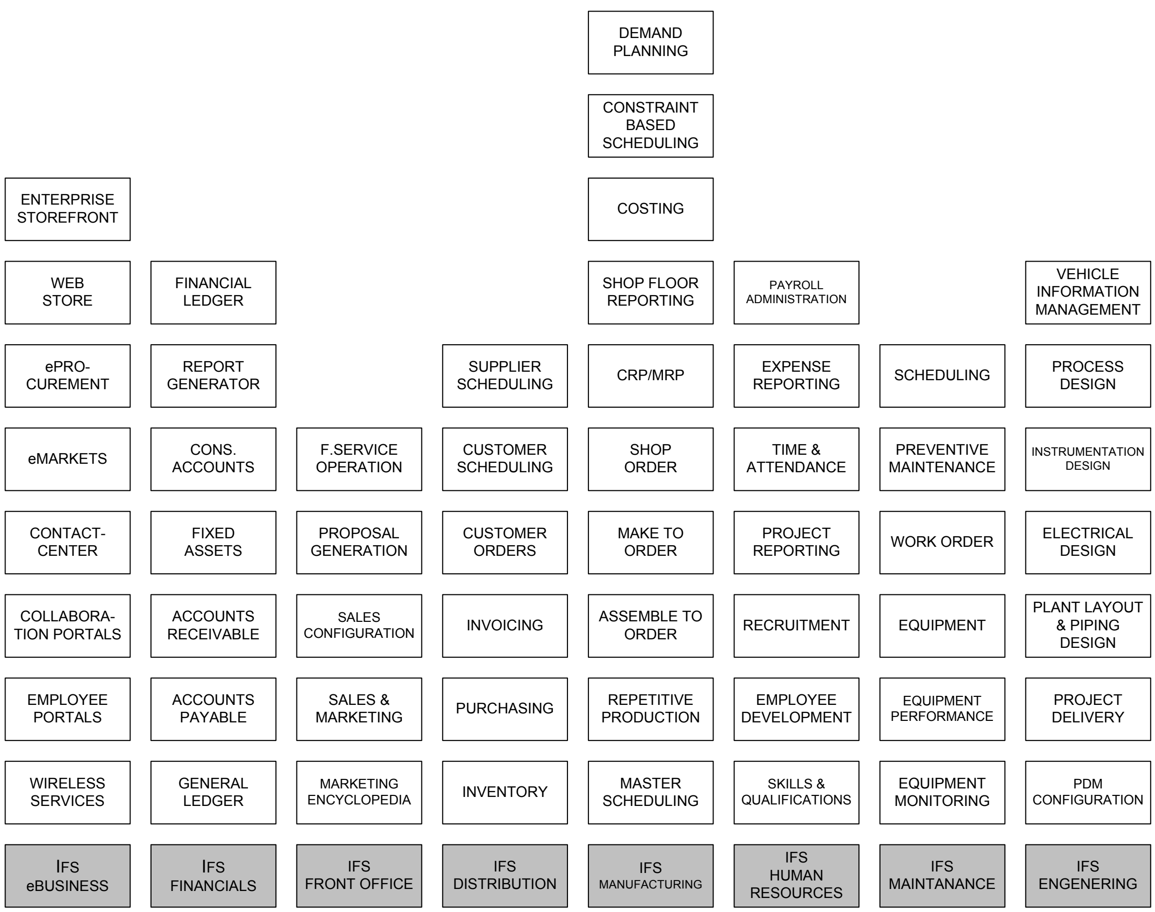


Figure 4.1: IFS Application (2001).

Within the Project Department different implementation consultants are responsible for different part of the total functionality of the ERP-system. While one consultant is responsible for the distribution functionality, another one is responsible for the manufacturing functionality, etc. The specialisation on certain parts of the system improves each consultant's knowledge, not only about the technical features of the product but also about the customers' processes.

Besides eight different groups of modules, IFS Application is divided into nine different "verticals". Each of these verticals consists of certain set of standardised modules, which has been made to fit with and contribute to the performance of certain segments of customers. The one which has been developed with supply and manufacturing chains in focus is called IFS Automotive, and primarily aims to minimise lead times, administration costs, and capital tied up in inventory. Other verticals within IFS Application are "Process Industry", "Service Industries", "Telecommunications", "Engineering & Construction", "Defence", "Commercial Aviation", "Energy & Utilities", and "Hi-Tech". Apart from facilitating the marketing of the system, the division into different verticals improves the Project Department's ability to perform fast implementations. This is due to the modules being more suitable and more integrated.

IFS Application's functionality is divided between a "server" and a "client". The server which may be further divided into a "database" and a "business logic" is programmed in a software language called "PL/SQL". The client, on the other hand, is programmed in "Centura", except from the CBS Module and all Internet solutions. While the CBS Module because of its extra need of calculation capacity is programmed in C^{++}, all Internet solutions are programmed in JAVA.

The Database

A database consists of a large number of tables containing different categories of data, like descriptions of the business, operative data, and historical data. Data describing the business includes information about different operations that are made within the business. Operative data includes variables like lead times, product structure, included components, and prices. Historical data includes information about historic events, such as business transactions, delivery times, and purchase prices. Each table only stores information about one single aspect. If a database needs to store information about more than one aspect, it does so by using more than one table. As everyone knows, a telephone book includes information about both people and businesses. A database would generally store such information by having one table containing all the information about people, and another table containing all the information about businesses. Within each table there is one column for each type of information being stored. Hence, while one column would store information about names another one would store information about addresses. In addition to different columns, every table includes a number of different rows, and each row contains the information for one of the items defined by the table's name. In the case of the address table, for example, each row contains information about a single address.

The Business Logic

Since the database uses separate tables to store different types of data, there must be a way to connect data stored in one table with relevant data stored in other tables. In addition to tables, each module therefore contains "methods" for communicating with other modules. Every time a module needs information stored in another module, it calls for a certain "method" within this module to transfer the information.

Two common "methods" are "functions" and "views". A "function" may transform information into another format. For example, it can change the way data appears, like turning a date value into the related day of the week. However, a "function" may also subtotal the data in the way that is specified. Moreover, it can alter the content of the data, for example taking one set of codes and translating it into a different set of codes.

In the "client" (on the screen), a "view" looks exactly the same as a table. However, the data appearing in the view comes from one or several tables. Views are usually used for joining data from two or more tables and present it to users in one easy-to-read list. Since views allow the developer to limit columns and rows returned to the user, they also enforce security. If the developer does not want a certain user to access a personal salary column/row, he/she just does not include this column/row when he/she defines the view.

In the business logic it is also possible to define who will be able to insert new information, update existing information, or delete information. In databases like the one in IFS Application, a specific set of privileges are gathered into something called a "role". Whenever users are added to the database, they are assigned one or several roles. However, this requires additional role descriptions. These role descriptions are generally developed in combination with specific job descriptions where the privileges of each user relate directly to his/her job description.

The Client

The client includes instruction on how different kinds of data should be presented on the computer screen, and it is usually implemented on an Intel-based Personal computer running Windows NT. The basic building blocks are different standard "forms". Each form includes a certain number of "fields" where the data is presented or typed in. To the user the client acts as a window to the server. Hence, a new table in the server usually requires a new "form" in the client.

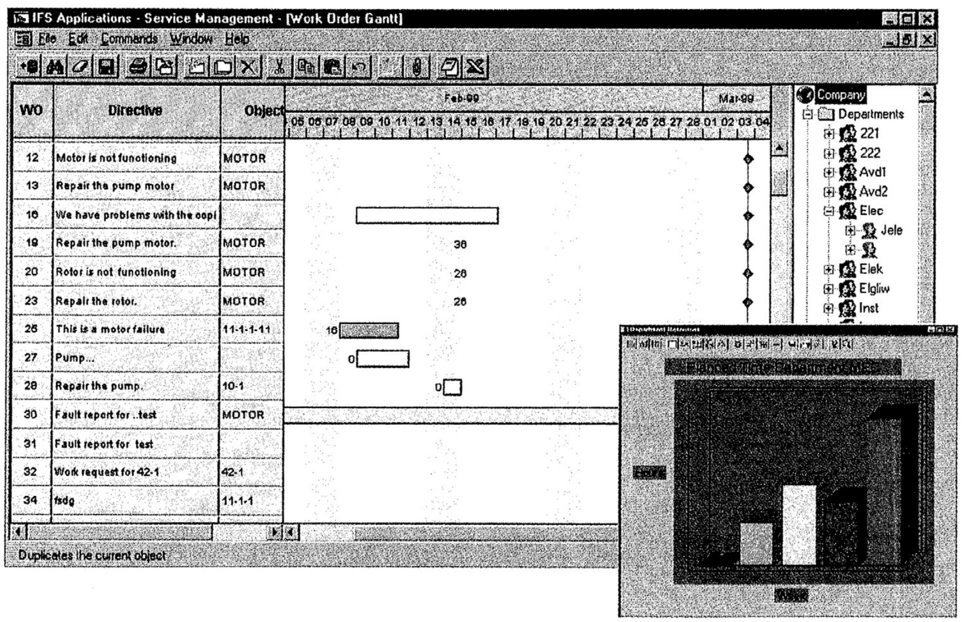


Figure 4.2: Picture of a typical master form with an additional detail form.

Generally there are two different types of "forms", overview forms and master-detail forms (see Figure 4.2). A master-detail form may be further divided into master forms and detail forms. Each detail form is connected to different master forms. Together with different overview forms, different master forms are in turn gathered into client files, which in turn are gathered into a master file. Every ERP-module includes at least one master file. On the computer screen this file appears as a yellow folder, from which it is possible for the user to scroll between different "forms".

4.1.2 Implementation and development

When the system developers at IFS develop new functionality they use “Rational Rose”, a development tool divided into two components. The first component is a Unified Modelling Language (UML) used for specifying, visualising, constructing, and documenting the artefacts of software systems. The second component is a compiler translating UML code into PL/SQL code (the code used in IFS’s database).

The UML code consists of many different “classes” including a certain number of “attributes”. If a “class” is an invoice, the attributes will be the name of the invoice, the invoice amount, the name of the customer, and the date of expiry. Every single class is divided into subclasses, and each subclass inherits certain features from superior classes. This may sometimes make it difficult for a developer to understand the relation between causes and effects. Consequently, when a developer develops new class structures, he/she always tries to create as flat structures as possible.

After a system developer has developed new UML-code, he/she activates the compiler which then translates the developed structure of “classes” into a system of “tables” and “methods”. When he/she has checked that the right PL/SQL code has been generated, he/she opens Centura where he/she then links each “table” and “method” to an additional standard ”form”. These standard forms are collected from a certain library of standard “forms” and “fields” developed by IFS’s Foundation group. However, these standard “forms” may not always be used exactly as they are, but often need to be adjusted in some way. This is usually managed by some pulling and dropping of certain “fields”. However, sometimes an entire new “field” is required. Hence, once again the developer needs to enter the library. This time he/she will look for a new “field” which will help him/her to modify the previous collected “form”. Eventually, when all forms have been connected and adjusted, the developer finally ends his/her development by the creation of a new program file.

The Project Department

The system developers at IFS’s project department develop customer specific ERP-systems. Apart from system developers the department involves a large number of implementation consultants. In contrast to many other ERP-system providers, IFS uses internal consultants, since it facilitates the communication between consultants and system developers. The consultants and the system developers are divided into groups of eight to ten individuals. For each group there is a group leader managing two or three different implementations simultaneously. These projects are usually displaced in time, which facilitates the group leader's utilisation of the group. If one project group needs to fulfil an implementation within a certain time period, it may acquire assistance from other project groups.

Every implementation project starts with the establishment of a project team including members from both IFS and the customer's organisation. Each single implementation consultant is assigned a certain contact person in the customer's organisation. The consultant, who is responsible for the implementation of the distribution modules, usually gets the customer's distribution manager as his/her contact person. Similarly, the consultant, who is responsible for the purchase modules, usually gets the customer's purchase manager as his/her contact person, etc.

Each implementation project is managed by two project leaders. While one of these project leaders is IFS's group leader, the other one is a manager from the customer's organisation. If, for instance, the implementation is focused on the development of an ERP-system that primarily will support the customer's production, the customer's project leader will probably be the company's production manager. The customer's project leader controls that all required customer specific adaptations fit together. He/she also makes sure that the adaptations are deeply rooted in the company's business. IFS's project leader's primary concern is to check that certain adaptations that need to be carried out within one part of the system do not have any negative effects on other parts. In short, the project leaders' most important task is to synchronise the work of different team members in order to avoid possible sub optimisations.

The work of the project team always begins with a couple of meetings, where each consultant together with his/her contact person tries to find out how the customer's processes can be kept or improved within the limits of IFS Application. This work is facilitated by a work tool called "Business Modeller" in which all processes are modelled in certain process diagrams. Possible gaps between the customer's needs and the standard functionality within IFS Application are usually closed by some adjustments of the customer's processes. However, they may also be closed during a later phase of the implementation by the development of customer specific adaptations within IFS Application's "client", "user logic", or/and "database".

When all processes have been modelled and adjusted to the existing functionality within IFS Application, the implementation consultants, together with their contact person, start to develop work descriptions. These work descriptions help different system users to find, enter, or extract the information he/she needs. In other words, they aim to improve the usability of the system. During this development, further requirements of customer specific adaptations may be identified. These adaptations usually regard the “client”, i.e. how data is presented and typed in. After the development of the work descriptions, the implementation succeeds with the development of additional role descriptions, where the responsibilities for different tasks are assigned to different members of the customer’s organisation. The role descriptions ensure that the right person is always provided the right data. Even this development may result in further customer specific adaptation. These adaptations usually concern the “business logic”, i.e. how data is transferred and transformed among different modules.

When all work and role descriptions have been developed, the system developers start to program the customer specific adaptations. Most customer specific adaptations concerns minor adjustments of the “client” or the “business logic”. While changes in the way data is presented or typed in usually concern minor adjustments of some “forms” within the client, changes regarding personal access and type in of certain data usually concerns new “methods” within the business logic. However, entirely new functionality usually requires an additional module including a set of new “tables” within the data base, together with additional “methods” and “forms” within the “business logic” and the “client”.

Before the implementation the consultants finally transfer all data from the customer’s old business system to the newly developed system, the customer’s project members always check that there are no system shortages. Shortages are immediately reported to the implementation consultants, who then check that there actually is something wrong with the system, and not just the customer who has used the system in an inappropriate way. In the second case, the consultants only need to instruct the customer about the usage of the system. However, in the first case, he/she has to tell the responsible system developer to carry out some system adjustments. When all necessary adjustments have been carried out, the system is sent back to the customer who continues testing until everything seems to be OK.

The R&D Department

The system developers at IFS's Research and Development (R&D) department develop the standard version of IFS Application. The department is divided into a large number of development groups. Apart from the Foundation Group responsible for the development of IFS Foundation (a library of different standard "tables", "methods", and "forms"), the department involves a Direction Group and a large number of development groups responsible for the development of different standard modules. Each development group is usually responsible for the development of one or two standard modules. Almost 75% of the functionality within these standard modules emanate from prior customer specific solutions. All customer specific adaptations are stored in a certain library called QDS. However, the R&D department usually does not reuse program codes, but merely the basic ideas behind the functionality.

IFS:s Direction Group picks up ideas from previous implementations. They specify functionalities missing in the standard system on certain specification lists. Based on these lists, each responsible system developer at the R&D department suggests how the new functionality should be developed. If the Direction Group gives its approval, the system developer begins to develop the functionality. However, usually some kind of adjustment is required before the system developer is allowed to do this.

Apart from previous implementations, the Direction Group often gets important input from "user groups" consisting of different existing customers. Since many of these customers have used IFS Application for more than five years, they may discover shortages which usually turn up when a system has been used for a while. However, one disadvantage with these groups is that they primarily consist of small companies. Hence, IFS has a reason to believe that their requirements are not general for the company's total bulk of customers.

In addition to the user group's extensive user experiences, the Direction Group seeks information about major trends and fashion within their industry. The main source for this kind of information is business systems analysers. However, these companies are usually only focusing on the "Fortune 500" (the 500 biggest users in the US). In other words, they never analyse the needs of medium sized customers in Sweden, which is IFS's most important group of customers.

In order to be able to cope with problems before any customer encounters them, the Direction Group gathers information about future rules and regulations. One important source of information considering different countries' taxes and rules for different goods and services is Nafta. Another important way for the Direction Group to follow up changes of rules and regulations is to subscribe to some revision periodicals.

Although the Direction Group is an important initiator, it is by no means the only one. Individual development groups may also initiate development of the standard system. This development is usually performed in cooperation with certain customers. Customers who have been taking part in a development project are called β-customers. STS (Saab Training System) is one of IFS's oldest β-customers. The company makes training material for military purposes, mostly laser simulators that can be mounted on guns in order to simulate the bullet path. When Saab Marine decided to buy IFS's MPS-system in 1994, STS decided to do the same. However, STS also needed a graphic interface. In order to deal with this situation IFS started up a development project together with STS, where they developed such an interface. Just like many other β-customers, STS contributed with its user knowledge and early needs of certain functionality. However, STS also contributed with its experience from previous in house development.

Apart from being developed in cooperation with β-customers, standard modules may also be developed in relation to the implementations of a similar module. In these cases, the module is in the shape of a prototype, which the customer is not committed to buy. For example, the early development of the module supporting complex production was performed in relation to implementations of the previously mentioned MPS-system. Both the MPS-system and the module supporting complex production were designed to support customers' production planning. However, in contrast to the MPS-system, the module supporting complex production enabled the system to support production based on customer orders, which called for entire new optimisation functionality. The early involvement of the customer provided an opportunity to get early feedback on the functionality, which in turn facilitated a fast development of a module ready for implementation.

When a module is ready for implementation it is sometimes further developed during its own implementation. The succeeding presentation (in Chapter 5) of IFS's implementation at Borgstena Textile AB will exemplify this kind of development. At this implementation, the scheduling modules and the module supporting production were further developed in order to support more complex planning situations. The development, which was carried out directly in the standard modules, saved time by facilitating the correction of bugs and other system shortages. Moreover, apart from faster corrections, it saved money through less customer specific adaptations.

The communication between IFS's two different departments

The communication between the R&D and the Project department is usually handled through a database called IFS-link. Every time a consultant identifies a shortage of the standard system, he/she types in a message into the data base. According to the type and localisation of the problem, the messages are then automatically distributed to the responsible system developer at the R&D department. The system developer starts to investigate the problem. If it turns out that it is an actual system shortage, the system developer corrects the shortage and then enters a message where he explains how he solved the problem. Conversely, if it turns out that the consultant probably used the system in a wrong way, the developer only types in instructions on how to use the system.

Apart from facilitating a standardised communication, IFS-link provides an opportunity to make use of the knowledge of the whole R&D organisation. A consultant who encounters a problem during an implementation in Sweden may, for example, get help from one of IFS's system developers in Singapore. Furthermore, because all messages are stored in the same data base, every consultant may check if his/her problem has turned up before and how it was managed.

In addition to IFS-link, experienced consultants usually use their personal relationships with certain developers at the R&D department. Instead of typing in a message in IFS-link and then waiting for an answer, the consultant gets an immediate answer by making a phone call to one of these developers.

4.1.3 Important issues to deal with

During every new implementation, IFS's primary issue is to develop a customer specific ERP-system that efficiently supports the customer's processes. Another important issue is to perform the implementation as quickly as possible. Fast implementations save money in terms of reduced consultant costs as well as reduced costs of tying up important parts of the customer's work force. The implementation time is partly decreased by the use of standard modules, and partly decreased by the use of certain implementation tools such as “Business Modeller”. In addition to decreased implementation time, the use of standard modules also reduces the development costs.

In relation to the development of the standard system, IFS’s primary issue is to develop standard functionality which efficiently supports different customers’ processes. Since the variety of processes is large, thus making it impossible to develop a system that fits all, the R&D department first needs to identify certain “target segments”. With these segments in mind the development will become more effective. However, apart from developing functionality which efficiently support different customers’ processes, it is important to develop at a competitive cost. If the costs are not kept on a reasonable level, customers will choose other solutions. This makes it important to design flexible systems, which improves the opportunities to split the development costs on a large number of customer applications. Furthermore, it makes it important to economise on previous development.

In short, IFS has two primary issues. The first issue is to provide ERP-systems that support individual customers’ processes at reasonable implementation, service, and maintenance costs. The second issue is to develop functionality which increases the usability of the standard system, i.e. makes it more suitable for a group of customer and/or increases the number of possible applications. These two different issues are handled by two different departments. While the first issue is handled by the Project Department, the second issue is handled by the R&D Department. However, their work is interrelated. Many customer specific adaptations that are carried out during an implementation are later integrated into the standard version. This may make the standard system more suitable for a certain group of customers’ and/or increase the number of different settings in which the system can be used. In addition, it may decrease the future need of customer specific adaptations.

4.2 BTAB

BTAB (Borgstena Textile AB) was founded in 1925. Back then BTAB’s main business consisted of underwear production made with circle knitted tricot fabric. However, since 1972 the company is mainly a sub-contractor on the second tier in the automotive industry manufacturing fabric used in both car and truck seats.

When it comes to production of tricot used in car and truck seats, BTAB was actually some kind of a pioneer. The former owner got the idea to produce fabric for the automotive industry when he on a trip to Tennessee discovered that car seats could get tremendously hot when the car had been parked in the sun. He soon learned how to deal with the problem by putting tricot towels on the seats. Hence, in addition to its stretchiness he discovered a new important quality of the circle knitted fabric, i.e. its conductivity. Consequently, he also discovered a new way to utilise BTAB's knitting machines, and thus extended their use applications.

At the end of the seventies and in the beginning of the eighties the competition within the cloth industry was dramatically increasing, greatly due to the increasing production in low wage countries such as Portugal, Poland, Estonia, Malaysia and Thailand. Therefore, in 1986, BTAB decided to produce fabric exclusively for the automotive industry. However, at that time, also the automotive industry experienced increased competition. Not only the automotive manufacturers, but also many of their first tier suppliers intensified their efforts to reduce capital locked into raw material and semi finished products by forcing the second tier suppliers to reduce lead times. This was a big challenge for BTAB, especially since many automotive companies simultaneously tried to reduce the costs of input material by forcing suppliers to cut prices. For example, at the end of the 1990's one important end-customer demanded that BTAB cut its prices by 2% per year.

The automotive manufacturers' efforts to reduce lead times and the costs of input material made BTAB to integrate vertically. While the first vertical integration was made in 1993 by the acquisition of BTAB's contract worker at Timmele, the second one was performed in 1998 by the acquisition of another contract worker in Getinge. Through increasing Timmele's and Getinge's priority to BTAB's fabrics these integrations improved the coordination between the three different production plants. Apart from facilitating the utilisation of different production equipments, and thus reducing the production costs, this improved coordination, in turn, facilitated reduced lead-times to the customers.

In addition to vertical integration, BTAB also integrated horizontally. The first horizontal integration was performed in 1996 by the acquisition of a German producer of weaved fabric, and the second one was performed in 1997 by the acquisition of a Swedish producer of warp-knitted fabric. Through these two acquisitions BTAB was able broaden its range of products and thus, reduce its customers' need of complementary suppliers.

4.2.1 Production

BTAB's production is divided between three different production plants (see Figure 4.3). The first plant is a knitting works located in Borgstena. An important input in this production is different types of synthetic fibres. The second plant is a dye works located in Timmele. Apart from fabric from Borgstena, an important input in this production is different colour pigments. The third plant is a lamination works located in Getinge. Apart from fabric from Timmele, important inputs in this production are foam rubber and backing. All three of them have different production conditions in terms of efficient batch sizes, product varieties, setting times, and lead times.

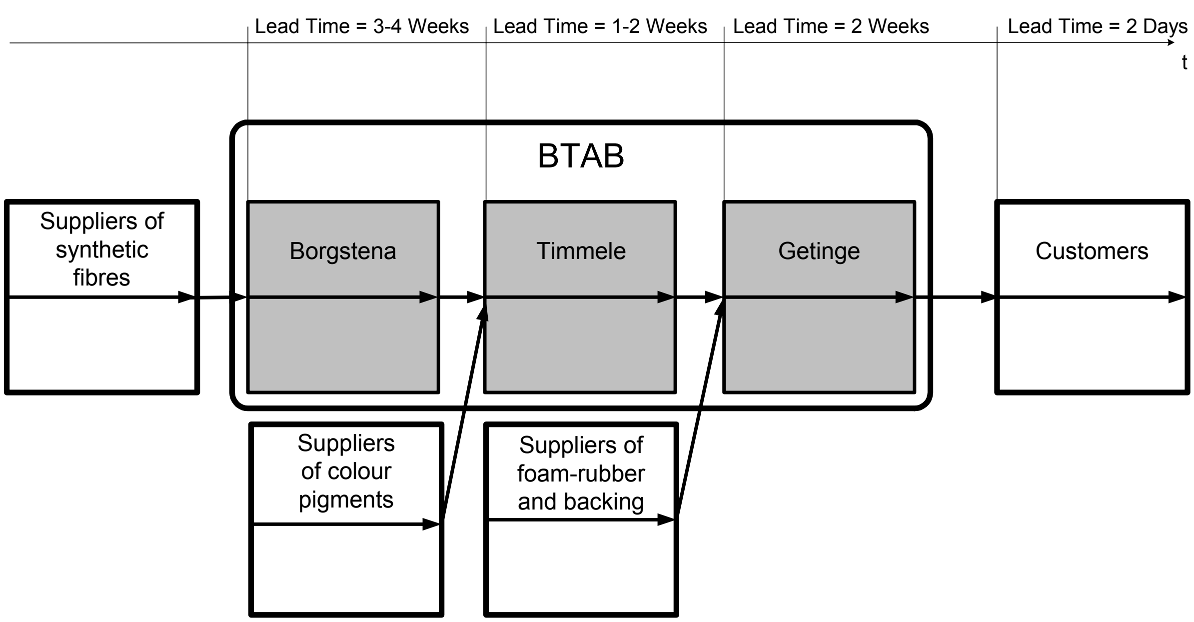


Figure 4.3: Different lead times that needs to be considered.

While all strategic issues regarding BTAB's production and distribution are handled by the production manager and the distribution manager, all operational issues are handled by BTAB's eight different production planers. Three of these are central planners developing master plans. The other five are local planers who later refine these plans into local plans. Each local planer plans his/her production within certain limits set by the production capacity in his/her production plant and the delivery dates specified by the central planers. During this work the communication among different planers is frequent. The communication between planers within the same production plant is frequent because they, to some extent, make use of the same manpower and production equipment. The communication between planers working at different production plants is frequent because of the sequential interdependency that exists between different production steps.

Borgstena

Borgstena is BTAB's original production plant and is divided into two different production lines: one for the circle knitted fabric and one for the warp knitted fabric. The production plant includes about 50 different circle-knitting machines and 15 different warp-knitting machines, many of which are unique in terms of the number of needles, knitting speed, knitting pattern, and allowed size of batches. The most important input consists of yarn, coloured yarn for the circle knitted fabric, and uncoloured yarn for the warp knitted fabric. In addition, BTAB also uses oil which lubricates the needles during the knitting process.

Warp and the circle knitted fabrics are knitted in separate rooms. In order to make the knitting conditions for the needles as good as possible, warp knitted fabrics are knitted in a room holding constant temperature and humidity. Before the yarn is put into the knitting machine, yarns from about 600 different rolls are gathered on one single roll. This process requires that the number of rolls is constant and that the yarns on different rolls hold the same quality. Otherwise the knitted fabric may become striped. The demand of an exact number of rolls puts high demands on the suppliers' delivery capabilities.

Timmele

BTAB's planning situation in Timmele is regarded as the most complicated one, greatly due to its long sequence of different production steps. Just like in Borgstena, the production of automotive fabric is divided into two different production lines, one for the circle knitted fabric and one for the warp knitted fabric. In addition to these two, there is one line dedicated for the tricot industry. While about 60% of BTAB's production in Timmele is dedicated to the automotive industry, about 20% is dedicated to the tricot industry. The remaining part is dedicated to the yarn industry. The preparation of tricot helps to increase its use of Timmele's production capacity. A large part of the production equipment in Timmele is used both in the preparation of tricot and in the preparation of fabric used in the automotive industry. There is also equipment that are specific for either of them. For example, two inspection tables and some closed colouring machines are exclusively used in the preparation of tricot.

There are two local production planners in Timmele, one for fabrics which are used by automotive customers and one for fabrics which are used by tricot customers. Because they share the same equipment, production of the two products may sometimes collide. However, the preparation of the two fabrics collided more in the past than the present. One important reason for this is the preparation of circle-knitted fabric. This fabric has already been coloured and does not occupy any room in the colouring machine, thus causing a hold-up with the fixing and washing machines only.

BTAB's production in Timmele is divided into eight different production steps: 1) pre-cutting, 2) lorry transportation, 3) trimming, 4) washing, 5) fixation, 6) colouring, 7) inspection, 8) lamination. Although their sequences may differ, Timmele's three production lines share many of these steps.

Step 1

The circle knitted fabric is usually multi-coloured and arrives at Timmele in the form of a large tube. In step number one, a specific machine (e1) first cut up these tubes along the seam. Different batches of fabric are then sewed together into larger batches. Finally, the fabric is rolled up on bigger rolls. Since these machines only run 16 hours a day (when others run 24 hours a day), this production step constitutes an important bottleneck in Timmele's production. A way to decrease the time spent in step one has been to increase the length of each batch of fabric produced in Borgstena.

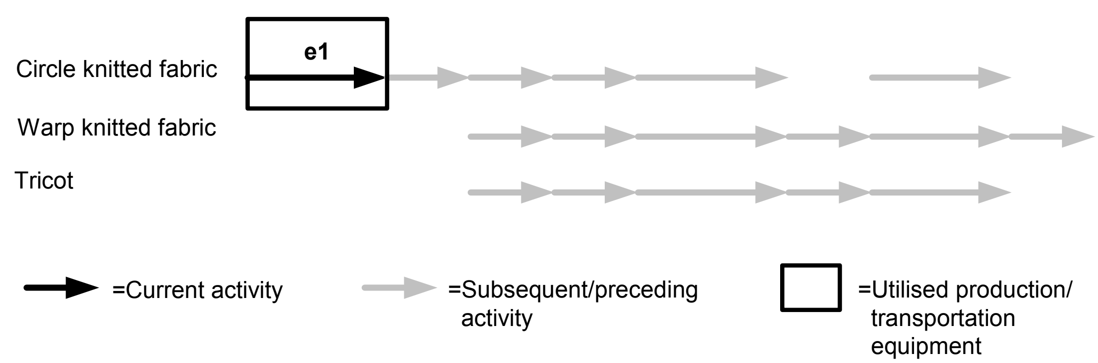


Figure 4.4: In Timmele's first production step different batches of circle knitted fabric are gathered into larger ones.

Step 2

In production step number two, the circle-knitted fabric is shipped by lorry (e2) to the other side of the production plant. For this BTAB uses a lorry, which in addition to this transportation twice a day, transports the fabric from Borgstena to Timmele. Although it improves BTAB's utilisation of the lorry, the company does not consider this to be the optimal solution. BTAB had instead preferred to locate its first production steps closer to the succeeding steps. However, the company's ability to do this is limited by the size and the location of the plant. The production plant is placed right between a road, a river, and a graveyard, which makes it difficult for BTAB to expand. Hence, the only available solution would be to close down the yarn production, which now is located right in the middle of the production plant.

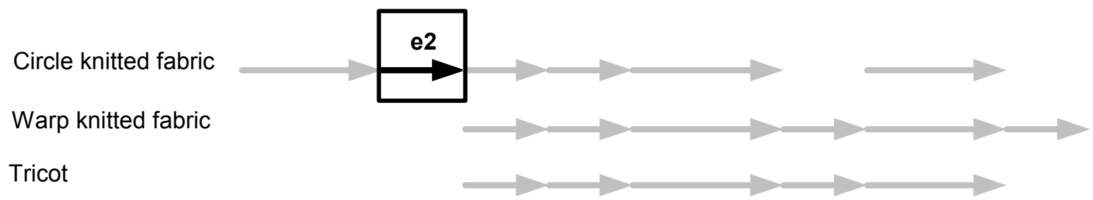


Figure 4.5: In Timmele's second production step the circle knitted fabric is shipped from one side of the plant to the other.

Step 3

In step number three the multi-coloured circle-knitted fabric have to share the production equipments with the uncoloured warp-knitted fabric and the tricot fabric. The production equipment primarily consist of three trimming machines (e3) cutting the pile on the surface of the fabric.

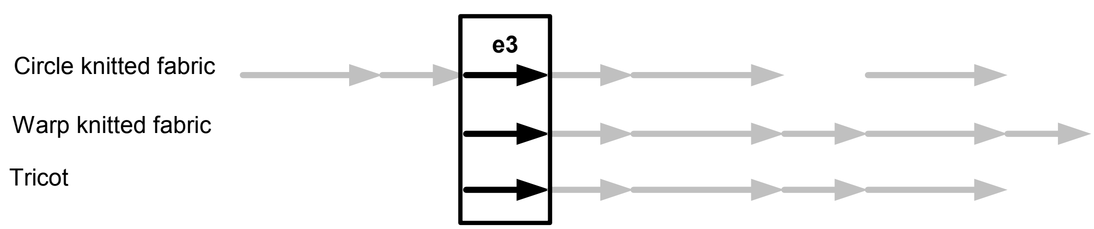


Figure 4.6: In Timmele's third production step three trimming machines cut the pile on the surface of the fabric.

Depending on the length of the pile, the fabric is either cut in one or two steps. This result in a large amount of naps gathered into certain dust bags. The replacement of these bags usually causes some set up times. However, if the naps are not regularly removed they may cause stripes on the fabric. In order to ensure that the fabric is not cut too short, laser beams carefully control the thickness of the fabric. Errors more frequently appear on fabrics with complicated patterns.

Step 4

In step number four BTAB washes the fabric in order to get rid of the oil which was added to the fabric during the knitting process. Both open and closed washing machines are used. Since circle-knitted fabric easily gets squeezed in the closed washing machines, BTAB primarily uses its open washing machines (e4) for washing this kind of fabric. However, in order to save money BTAB tries to wash as much as possible in closed washing machines (e5). Before the fabric is put to dry, water is removed in big centrifuges.

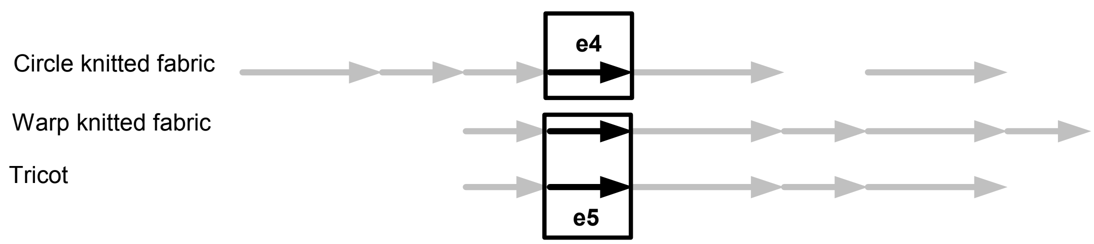


Figure 4.7: In Timmele's fourth production step all fabric are washed in open or closed washing machines.

Step 5

When the fabric been washed and dried, it is shipped to the fixing machine (e6) where it is fixed at a high temperature. This step is critical in the sense that the fabric easily gets squeezed or burnt (The temperature may sometimes exceed 170°C). BTAB only has one fixing machine which the company utilises 24 hours a day. The fixation process is undertaken in production cycles starting with low temperatures and then gradually rising to higher temperatures.

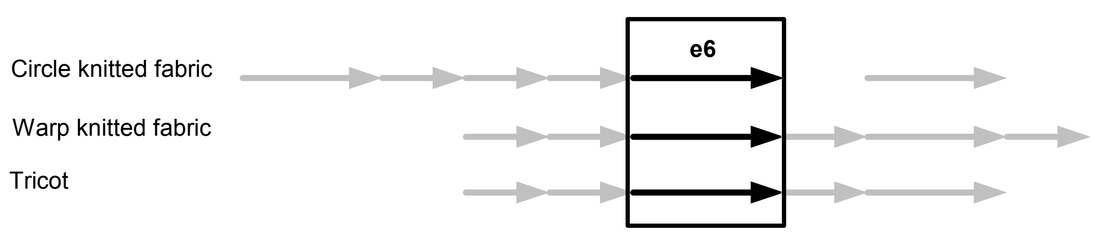


Figure 4.8: In Timmele's fifth production step all fabric are fixed in a fixation machine.

Step 6

In step number six BTAB colours the warp-knitted fabric and the tricot fabric in opened and closed colouring machines (e7). Since each machine has been programmed in a certain way and the size of the rolls may considerably differ, different machines are used for different types of fabric. The colouring process is undertaken in production cycles starting with light colours and then gradually moving on to darker colours. Before the fabric is put to dry, water is removed in big centrifuges.

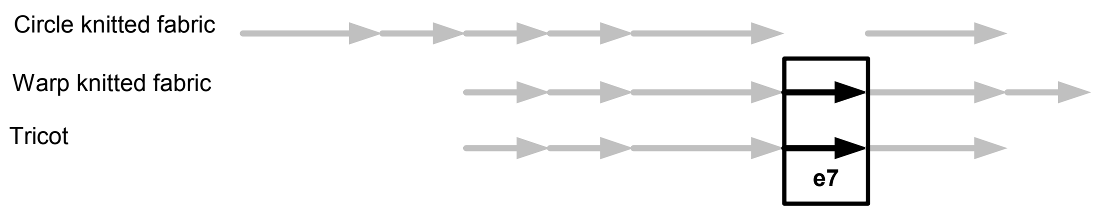


Figure 4.9: In Timmele's sixth production step all tricot and warp knitted fabric are coloured in open or closed washing machines.

Step 7

In step number seven, BTAB inspects the fabric by the use of some inspection equipment (e8). While errors longer than three meters are immediately removed, others are usually only recorded. It takes about 50 minutes to inspect a fabric which does not include any errors. However, some fabrics may include a lot of errors. Usually errors appear more frequently on fabrics with complicated patterns. It may take about three hours to inspect fabrics that include a large number of errors. Consequently, in case of time shortages BTAB does not inspect fabrics that normally not include any errors.

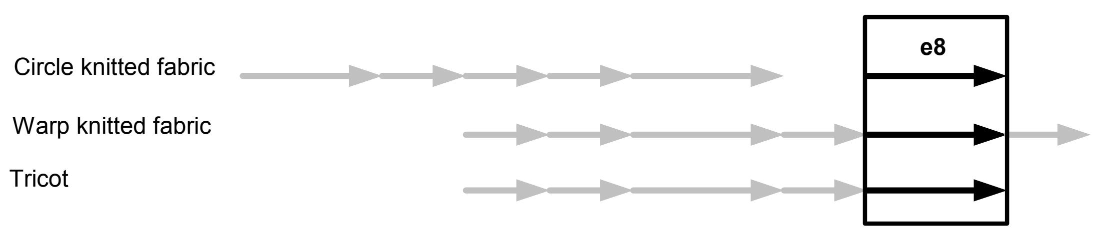


Figure 4.10: In Timmele's seventh production step fabrics are inspected.

Step 8
In step number eight, BTAB laminates the warp knitted fabric that will be used for truck curtains. Two different pieces of fabric are melted together with a black plastic film placed in between the fabric pieces. BTAB's production plant in Timmele has previously laminated all fabric. However, because of the high level of pollution, the local authorities put an end to this.

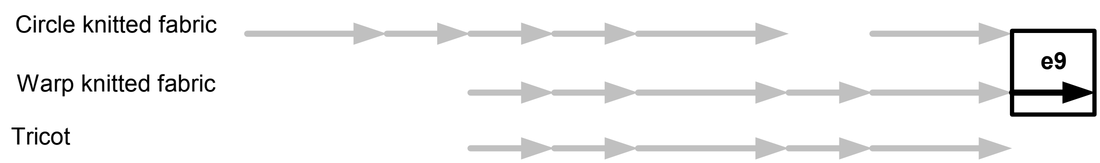


Figure 4.11: In Timmele's eight production step some batches of warp knitted fabrics are laminated.

Getinge
About 35% of the automotive fabric coloured in Timmele is distributed directly to the automotive manufacturers. Of the remaining part, approximately 20% is sent to σ-Lamination and 45% is sent to BTAB´s production plant in Getinge. The production in Getinge, which is exclusively dedicated to automotive fabrics, is divided into three different production steps: 1) lamination, 2) cutting, and 3) inspection.

Step 1
In production step number one the fabric is laminated. While fabric used in door panels and ceilings is laminated with only foam rubber, fabric that is used in seats is laminated with both foam rubber and backing (i.e. a thin layer of plastic film).

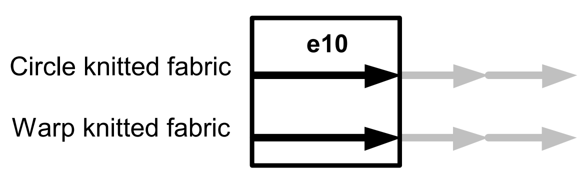


Figure 4.12: In Getinge's first production step the fabric is laminated with foam rubber and a plastic film.

There is a huge variety of foam rubber and backing. In 2000 Getinge bought 50 different types of foam rubber (from two different suppliers) and 10 different types of backing (from three different suppliers). The plastic film is primarily added in order to make it easier to sew. Both the foam rubber and the plastic film are either glued or taped to the fabric. In case of big holes in the fabric, these two methods can cause production stops by jamming the rollers that are feeding the fabric forward. However, if the hole has been detected in Timmele, the operators at Getinge can prevent this by putting a piece of paper between the fabric and the foam rubber.

Step 2

In step number two, BTAB cuts down the fabric to the width that the customer has ordered. How much the fabric is cut depends on how much the fabric has shrunk during preceding production steps. However, on average, BTAB cuts off about 2-3 cm on each side.

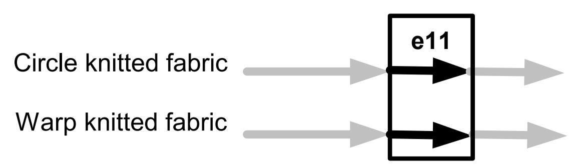


Figure 4.13: In Getinge's second production step the fabric is cut on the sides.

Step 3

In the third step the fabric is given a final inspection. Apart from holes and blotches, BTAB primarily looks for air bubbles between the fabric and the foam rubber. While holes and blotches usually arise in relation to the transportation of the fabric from Timmele to Getinge, air bubbles arise every time the lamination machine is shut off. The machine is either shut off in the end of a production batch or when a material (i.e. the fabric, the foam runner, or the plastic film) is not properly fed into the lamination machine.

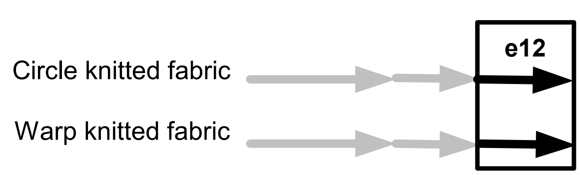


Figure 4.14: In Getinge's third production step fabrics are inspected.

4.2.2 Customers

BTAB's end customers involve many of the world's leading automotive manufacturers. The main part of the knitted fabric produced by BTAB is distributed through system suppliers. However, woven fabric, which is usually only cut into smaller batches without any further cultivation, is normally distributed directly to the automotive manufacturer.

One important system supplier is ξ-Components which represents about 20% of BTAB's turnover. BTAB delivers fabric to ξ-Components in Trollhättan, Portugal, and Thailand. When it comes to short lead-times, ξ-Components is one of BTAB's most demanding customers. The company makes its call-off a week prior to delivery, while the time required by BTAB to produce the items is about 9 weeks, including the time required to get yarn deliveries.

Besides the call-off ξ-Components provides its suppliers with delivery plans. These plans span about 60 weeks in advance and are updated once a week. Although the accuracy of these plans are improved when getting closer to call-off, they are subject to substantial deviations. These deviations make it difficult for BTAB to fulfil ξ-Components' demands on short lead times and at the same time efficiently utilise all production equipment. The situation is further complicated by the fact that ξ-Components, in the role of being BTAB's largest customer, requires that BTAB gives the highest priority to ξ-Components' products. Even other automotive customers do not take BTAB lead times into consideration. BTAB has therefore tried to make its customers sign an agreement committing themselves not to send orders differing more than 20-30% from previously planned quantities. However, no customer has yet signed such an agreement.

In addition to automotive customers, BTAB also has some customers within the tricot industry. These customers do not demand lead times as short as automotive industry customers, but often accept lead times exceeding three weeks. However, they are usually more price sensitive. Another important difference is that the tricot customers, contrary to the automotive customers, own the fabric. The tricot customers regularly ship large quantities of fabric to Timmele and then divide their orders into different sets. These orders are usually sent by fax or e-mail. The tricot customers do not send any plans. In order to deal with this situation, BTAB has tried to develop some primitive forecasts based on history data and information which have been gathered during previous visits to the customers' production plants. Fortunately, the order deviations are usually small.

Furthermore, if there are major changes, BTAB is usually informed at an early stage.

4.2.3 Suppliers and sub contractors

BTAB only colours yarn of wool, while the upholstery is made from synthetic fibres. Hence, although BTAB colours some yarn in Timmele, the company has to buy all the yarn it needs in its production of automotive fabric. About 85% of the synthetic yarn used in Borgstena is bought from a company in Denmark, where it is coloured in big dying baths. One disadvantage with this method is that it may cause tone differences between different dying baths. Consequently, BTAB also buys some synthetic yarn from a German company, where it is coloured during the spinning process. This method makes it possible to colour large quantities of yarn without getting any tone variations. The fact that one type of coloured fabric can be produced in large quantities reduces the production costs. However, two major disadvantages arise with this method: long set-up times and long colour development times. While it usually takes two or three weeks to develop a new dying bath recipe, it takes about two or three months to develop a new spin coloured yarn recipe. Hence, when it comes to spin coloured yarn, BTAB always tries to use already developed colour tones. This is only possible when the fabric will be put on the back of a car seat.

Besides yarn suppliers, another important group is the suppliers of different kinds of chemicals, such as colour pigments and backing. BTAB has five different suppliers of chemicals. A major vertical integration has recently been performed in the chemical industry. In 1999 almost every supplier had colour pigments for polyester, wool, and cotton. However, since different suppliers' colour pigments might result in different colour tones, BTAB still uses many different suppliers. Even the price and light resistance may differ among pigments that are received from different suppliers.

In addition to different suppliers of yarn, colour pigments, and backing, BTAB has three contractors. One of these is π-Curtains, who sews curtains used in trucks. Another contractor cuts up pieces of fabric for panels and headrests. Finally, a third contractor is σ-Lamination who, in addition to Getinge, laminates fabric with backing and foam rubber. Even if BTAB tries to utilise its own production capacity in Getinge, about 30-40% of the fabric knitted in Borgstena is shipped to σ-Lamination. This is mainly due to the fact that many customers demand that the fabric is laminated by σ-Lamination.

4.2.4 Important issues to deal with

As previously been argued, BTAB's customers demand short lead times. An important reason behind this demand is their wish to reduce capital locked into raw material and semi-finished products. I addition, these companies have tried to reduce the costs of input material by forcing their suppliers to cut prices. For example, in the late nineties one important end customer demanded that BTAB cut its prices by 2% per year. Hence, BTAB's most important issues are to reduce its lead times and at the same time improve the utilisation of its different production equipments, manpower, and input materials. This calls for improved coordination, both within the company as well as towards its customers. One way to improve this coordination is to implement an ERP-system with functionality that may support the company in dealing with these issues.

5 THE IMPLEMENTATION OF IFS APPLICATION AT BTAB

This chapter discusses the implementation and development of BTAB's ERP-system. Apart from general descriptions of the implementation work, the chapter includes a description of different integrated modules. These descriptions are made in section 5.1. The chapter also includes a more in-depth description of how IFS adapted three of its scheduling modules to BTAB's production planning. These descriptions are made in Section 5.2 and 5.3. Furthermore, the chapter also includes a description of how the ERP-system was connected to two already existing information systems. This description is made in Section 5.4. Finally, in Section 5.5 it is described how the implementation of the ERP-system affected BTAB's production planning.

BTAB tried first to implement an ERP-system developed by another ERP-system supplier. However, the implementation failed because the system had too many shortages. Firstly, it could not support a decentralised production planning, and thereby impeded BTAB's utilisation of the local production planners' finely structured knowledge and perception of the local production planning situation. Secondly, it was not compatible to BTAB's inspection and recipe systems and it was too difficult to develop this inspection and recipe functionality in the ERP-system. Thirdly, the ERP-system had no graphic user interface which made it less "user friendly". The implementation was therefore interrupted in the spring of 1998.

In the autumn of the same year BTAB got in touch with IFS's project department. As soon as they entered the negotiation process it became obvious that the standard functionality of IFS Application had to be modified. One major shortcoming of the system was its inability to support decentralised production planning. The Project Department seriously doubted it would be able to develop the required functionality within the frame of the implementation project. For instance, an additional module would probably become too costly. However, the department soon found out that IFS's R&D Department was developing some useful functionality in terms of two scheduling modules supporting the flow of orders between customers and suppliers. By facilitating the division of BTAB's production planning into three steps, this functionality enabled the development of a customer specific ERP-system that could support BTAB's decentralised production planning.

The Project Department immediately began to persuade the R&D Department to use the implementation project at BTAB as a pilot study. Besides pointing at the opportunity to acquire immediate feedback on developed functionality, the Project Department pointed at two other important reasons for using the BTAB project as a pilot study. Firstly, as the flow between BTAB's different production plants was very similar to the ones between different companies, it would facilitate the design of a system where the customer's (sender's) and the supplier's (receiver's) situation was equally considered. Secondly, the pilot study would make it easier to match the scheduling modules to each other.

5.1 The customer specific ERP-system

When the R&D-department eventually agreed to join the implementation at BTAB, the Project Department preceded the implementation by the establishment of a project team. The ERP-system that this team developed consisted of 14 different modules connected in the way that is shown below (see Figure 5.1).

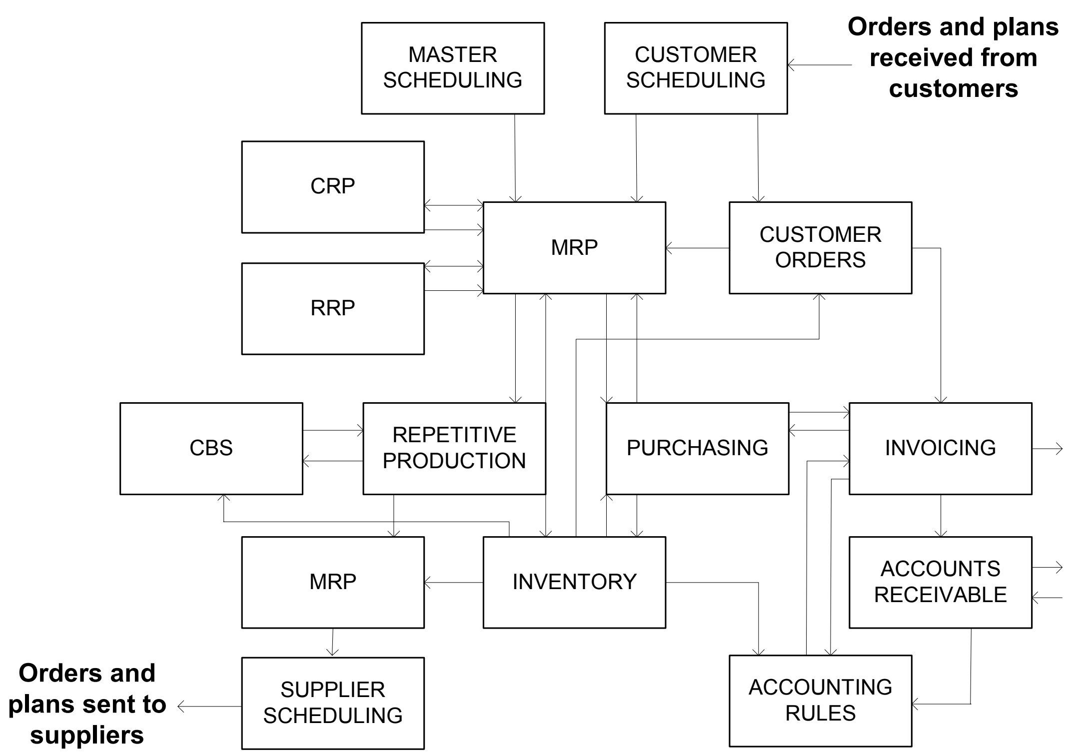


Figure 5.1: The flow of data within the customer specific ERP-system.

1. **Customer Scheduling (CS)** receives orders and plans from customers. When the module receives a new order it always checks latest recorded delivery against the latest shipped quantities. The calculated difference is then deducted from the shipped quantities. In addition, it also checks all received schedules against allowable tolerances. While schedules that do not stay within the allowable tolerances are automatically reported to each responsible operator, approved plans are distributed to the MRP (Material Resource Planning) Module and approved orders are distributed to the module handling customer orders.

2. **Master Scheduling** supports the generation of production plans by using history data which is received from the MRP Module. These production plans, which normally reach about six months into the future, are regularly updated.

3. **Customer Orders** records all customer orders in order to further distribute them to the MRP Module. However, before it does this, the module first compares data about received orders against data about current inventory levels. In case of an inventory on ordered products, these quantities are deducted from the orders that are distributed to the MRP Module. The Customer Orders Module also makes delivery notes which it sends to the Invoicing Module.

4. **Material Resource Planning (MRP)** divides a customer's product into smaller pieces of need by using previously established product structures, article data, and different planning rules. Examples of different planning rules are least unit cost, lot for lot, and fix size of lot. This need is later sorted into articles to be produced and articles to be bought. Calculations always start from present stock levels and then subtract all articles which already been bought or produced. In relation to this calculation it also considers planed deliveries and developed production schedules. The possibly gap between needs and accesses finally results in a production or a purchase order. These orders include information about the number of articles needed and at what time they are needed. There are three different kinds of output; (1) schedules, (2) orders, and (3) requests. Together, with the division between purchase and production orders, this results in six different kinds of output. The article number decides which of these six alternatives is to be chosen.

5. **Capacity Resource Planning (CRP)** provides the MRP Module with information about the company's long-term utilisation of different kinds of production equipment.

6. **RRP** provides the MRP Module with information about the company's long-term utilisation of manpower.

7. **Repetitive Production** provides work descriptions to different operators. It also stores data about performed tasks and production errors, which the operators have typed in.

8. **Constraint Based Scheduling (CBS)** supports complex production situation by calculating the production times and the number of units which should be produced. When doing this, it both takes date of order and maximum capacity into consideration. The module is activated every time the MRP Module provides the Production Module with new information about received orders. The input consists of information about priorities and previous production schedules stored in the Production Module. This information is combined with additional information about other article specifications provided by the Inventory Module. Updated schedules are returned to the Production Module, where they are stored until the next time the MRP Module provides new data.

9. **Purchasing** makes purchase requests and purchase orders. It also compares the suppliers' invoice against arrived quantities. Furthermore, it stores circumstantial history descriptions about support and the origin of different products.

10. **Invoicing** creates customer invoices from received orders. Each received order gets a specific reference number. This number is then checked against previously created purchase orders stored in the Purchasing Module. Invoices are both made in the form of ordinary documents and EDI-messages. The invoices are sent to the Payment Module which in turn sends them to the customer. Apart from making its connection to the Payment Module, the Invoice Module also has a direct connection with the Account Module which checks that all invoices are in accordance with previously specified transaction rules.

11. **Accounts Receivable** sends invoices to the customers. In relation to this it creates a payment file which it sends to the bank. If a customer's invoice has not arrived within a specified number of days, the Payment Module creates a demand note which is sent directly to the customer. The demand is calculated by comparing data of arrived invoices with data of sent invoices stored in the Invoice Module.

12. **Accounting Rules** checks that all transactions are in accordance with previously stored data about existing articles, user groups, accounts, and recorded currencies.

13. **Inventory** optimises the use of different storing facilities. It also calculates trade rates of different articles and the use of different resources.

14. **Supplier Scheduling (SS)** sends orders and plans to suppliers. The module, which is designed as the mirror image of the CS Module, receives its input from the MRP Module, reconciles, checks tolerances, and then sends delivery schedule to the Out-box Module.

In their efforts to find out how BTAB's processes could be maintained or improved within the limits of IFS Application, the sub-teams used "Business Modeller", where all processes were modelled into certain process-diagrams. Based on these models, IFS later developed BTAB's ERP system. Like every other implementation, there were no perfect matches between BTAB's processes and the existing functionality within IFS Application. While some of the gaps were bridged by certain adjustment of BTAB's processes, others required certain adjustments of the ERP-system. For most modules these adjustments only concerned minor changes in the "client" in terms of new or modified "fields". However, the module supporting complex production and the previously mentioned scheduling modules also required some development within the server. Moreover, IFS had to develop a connection to BTAB's inspection and recipe systems. This development was partly performed in terms of customer specific adaptations and partly performed directly in the standard system. While the Project Department carried out all customer specific adjustments, the R&D Department developed the standard system.

5.2 The CS and the SS Modules – two modules sending and receiving orders and plans

The CS (Customer Scheduling) Module receives orders and plans from customers. When the module receives a new order it always checks latest recorded delivery against the latest shipped quantities. The calculated difference is then deducted from the shipped quantities. In addition, it also checks all received schedules against allowable tolerances. While schedules that do not stay within the allowable tolerances are automatically reported to each responsible operator through the Event server, approved plans are distributed to the MRP Module and approved orders are distributed to the Customer Order Module.

At the time of the implementation, the standard version of the CS Module could only receive orders. However, BTAB needed an ERP-system that enabled the company to handle both orders and plans. As previously mentioned, BTAB's production is divided into three major production plants with very different planning situations. BTAB's production in Getinge is exclusively based on customer orders. This is possible because lamination is the last activity before delivery. Furthermore, the amount of possible combinations of foam rubber and backing is small compared to the number of possible combinations in previous production plants. Few possible combinations facilitate a low number of settings. Hence, compared to previous production plants it is relatively easy to achieve a high utilisation of Getinge's production capacity. Moreover, when developing new production plans, the automotive planner in Timmele usually takes Getinge's utilisation into consideration.

Timmele's production is based on both orders and plans. Normally the number of different processed fabrics is very large. Hence, in order to reduce the setting times, and thus increase the utilisation of Timmele's fixation and dying equipment, different orders are gathered into one production batch. This gathering of different orders into one production batch makes it difficult to only produce on customer orders, especially since Timmele's dying and fixation activities ought to be carried out in a certain sequence. In order to avoid large stocks of semi-finished products between dying and fixation, BTAB gathers orders of products that have the same colour tone and fixation temperature. This gathering of different orders into one single production batch may sometimes cause large displacements in time. However, BTAB's customers' requirements for short lead-time do not allow any delays. Hence, BTAB need to produce some fabric before it has been ordered.

To be able to produce in advance without running the risk of ending up with loads of unwanted fabrics, Timmele needs access to the customers' production plans.

Borgstena's production is entirely based on customer plans. The production plant produces a large number of different fabrics, many of which need to be knitted, trimmed, washed, coloured, fixed and laminated in a specific way. Furthermore, yarn is often specifically made for a certain type of fabric, especially when it comes to yarn used in the production of circle-knitted fabric. However, the long production lead times of Timmele, together with the long supply lead times of the yarn suppliers and the short lead times required by the customers, make it impossible for Borgstena to produce on customer orders. Hence, in order to deal with the specificities, without ending up with large security stocks and loads of rejected fabrics, customers' production plans are required.

Along with an ERP-system capable of handling both orders and plans, BTAB needed an ERP-system that could support decentralised production planning. The company's production plants include a large number of different production equipments such as knitting, fixation, trimming, and lamination machines. Many of these equipments have unique features in terms of setting times and possible batch sizes. For example, what is optimal in terms of batch sizes for one equipment may be far from optimal for some others. This causes a complicated coordination problem, which is made even worse by frequent unforeseeable production errors, a large number of different qualities of fabric, and customers' late order changes. It is therefore important for BTAB to be able to utilise its local production planners' knowledge about the local production situations.

In order to meet BTAB's needs IFS extended the scheduling functionality. First of all, IFS developed functionality making the CS Module able to handle plans. This functionality included "tables" for storing plan data, "forms" for presenting the data, and "methods" for processing the data. One method either replaces a plan with an actual order or automatically transforms it into a call off. Another method checks every new order against the customer's most recent plan and when the deviation exceeds a certain level alarms for high or low capacity utilisation. By catching the planner's attention of a problem at an early stage, this "method" improves his/hers ability to deal with the problem. In combination with signed agreements where the customers commit themselves to not sending orders that differ more than 20-30% from planned quantities, the "method" may also improve

BTAB's ability to persuade its customers to reduce the deviations between their plans and orders.

In order to make the ERP-system support BTAB's decentralised production planning, IFS also developed the SS (Supplier Scheduling) Module. This entirely new scheduling module was designed as a mirror image of the CS Module. In other words, every table line of the SS Module corresponded to a specific line in the CS Module. The two different modules were then connected by some additional methods transferring data between these corresponding table lines. Some data had to be transformed before it was transferred. Fore example, in Borgstena the size of each single batch was stated in square meters, while it in Timmele was stated in kilograms.

Between Borgstena, Timmele, and Getinge, plans and orders are sent through electronic messages. Even the communication with π-Curtains, which sews curtains on contract, is carried out in this way. However, before π-Curtains could receive any messages, the company first had to implement a "client" connected to BTAB's server in Timmele. Apart from facilitating the flow of orders and plans, this implementation improved BTAB's access to information about π-Curtains' stock rates. BTAB needed information about π-Curtains' stock rates in order to create invoices. Although BTAB is the automotive manufacturers' supplier of curtains, all curtains are shipped from π-Curtains. The implementation of the "client" at π-Curtains also improved BTAB's access to information about the process stages of certain articles. This information enables BTAB's to support its customers' just-in-time production. BTAB's customers often call in order to ask when they will receive a certain batch. By providing information about the exact position of every batch, the "client", that was implemented at π-Curtains', improved BTAB's possibility to answer these questions.

BTAB's communication with other companies required an EDI-converter able to deal with the Odette standard used in the automotive industry. Since IFS did not consider EDI-conversion as a part of its business, the company decided to use an EDI-converter developed by ρ-Software. This EDI-converter transforms all received electronic messages to a format that can be read by the module receiving and sending messages to external systems. Conversely, it also transforms all messages from the module into readable messages according to EDI-standards. In relation to the implementation, the EDI-converter did not require any adjustments of the ERP-system nor did the system affect the EDI-converter in any substantial way. In principle, ρ-Software only adjusted some parameters in order to make the EDI-converter able to read and write in the module receiving and sending messages to external systems. However, when IFS develops a new electronic message, they always take different EDI-standards into consideration. For example, the length of a new typing field in a table is always adapted to the EDI-standard which uses the largest corresponding field.

Unfortunately, σ-Lamination's business system was not compatible with ρ-Software's EDI-converter. Consequently, in spite of the fact that BTAB constituted 30% of the company's production, σ-Lamination chose not to carry out the necessary EDI investment. One important reason may have been BTAB's continuously increasing utilisation of its internal lamination plant in Getinge. At the time of the implementation of the ERP-system, BTAB's order volumes constituted about 60% of Getinge's production. In order to reduce the number of different product specifications in Getinge, BTAB increased its share of Getinge's production. BTAB's response to σ-Lamination's decision to not invest in the EDI-technology was to further increase the utilisation of Getinge's production capacity. However, this may complicate BTAB's relationship with a certain end customer, which, in accordance with its single sourcing strategy, demands that its fabric is laminated by σ-Lamination.

Besides the development of two different scheduling modules supporting decentralised production planning, BTAB's production errors resulted in the development of a functionality measuring the production in terms of produced articles. At the time of the implementation, IFS Application was only able to measure the production in terms of input materials. This only works if the company has very few rejections. In that case the level of output is nearly equal to the level of input, which makes it easy to estimate the level of input data from measured output data. However, BTAB's frequently appearing production errors often caused loads of rejected fabric, which made it impossible to estimate the level of input by only measuring the level of output.

BTAB's frequent production errors also required a functionality that would improve BTAB's ability to trace the cause of errors. IFS's solution was to make each production schedule inherit the article numbers that are stated in the schedule received from the most immediate preceding production plant in the supply chain. While Borgstena's production schedules inherited article numbers stated in the schedules received from Timmele, Timmele's production schedules in turn inherited the article numbers stated in the schedules received from Getinge, etc. The development of this feature required some minor adjustments of certain table columns where the data was stored. The improved traceability affected BTAB's possibilities to track certain errors and coordinate the production, not only within the company but also in relation to its different customers'. A major reason for this improvement was the enhanced possibility to identify the exact position of every article.

A way for BTAB to reduce its level of waste due to production errors is to deliver batches of fabric including some errors. The number, magnitude, and location of these errors are reported to the customer on an enclosed delivery note. This provides an opportunity to use certain parts of the rejected fabric and thus increase the utilisation of the fabric. The extra work required for cutting out pieces of usable fabric is compensated by a certain discount. BTAB's rule for these discounts is fairly simple; a customer that allows many errors is provided the products to a lower price than one that does not allow as many errors.

Customers buying batches including errors usually pay for gross quantities. Invoicing fabric in gross quantities is commonly used in Portugal. However, in other countries such as Sweden, customers usually pay for net quantities. In order to make BTAB able handle the variation among its different customer interfaces, IFS's Project Department developed functionality within the ERP-system making it possible to state quantities of fabric both in gross and net quantities. The functionality that makes sure that every article inherits the customer's article number is used to find out what is applied for each single batch.

BTAB's large number of articles made it necessary to develop functionality for simultaneously changing supplier schedule generation parameters for a large number of agreement part setups. Right after the implementation, BTAB had to enter each and every agreement part setup in order to change the wanted parameters. For example, although each and every agreement had the same setup, a change saying that all supplier schedules should be valid from Tuesdays instead of Mondays resulted in hundreds of changes. IFS´s project department's solution to this problem was a new functionality grouping schedule parameters into objects connected to different agreement part setups. A change of an object now got an immediate impact on all agreements connected to the object.

Within the ERP-system no module is an island, i.e. there are interdependencies between different modules. Hence, changed tables and/or methods within a particular module often calls for additional changes in complementary modules. The changes made in the scheduling module receiving plans and orders from customers called for a method within the module creating customer's orders which, every time the module created a new order, read in the scheduling module. The incorporation of the scheduling module, sending plans and orders to suppliers, called for some additional changes in the Purchasing Module. Instead of only creating a purchase request, it now created a delivery schedule including a delivery plan. Furthermore, new "tables" were added to Purchasing Module enabling the module to store information about raw material arrivals provided from the scheduling module. Conversely, these adjustments required some additional adjustments of the scheduling module. Firstly, it required that the scheduling module, sending plans and orders to suppliers, is able to divide a one day need among different times of delivery. Secondly, it required that the scheduling module enable division of a need among different suppliers.

In order to perform accurate calculations, the CBS Module requires updated order-data from the Repetitive Production Module, which in turn requires that the MRP runs twice a day. However, every time the MRP runs, it also produces new production plans, which obstructs the production planners' ability to coordinate. IFS's Project Department therefore developed a customer specific functionality making it possible to state how often the Supplier Scheduling Module should receive new plans from the MRP.

Not only existing modules were affected, but the implementation of the scheduling modules at BTAB also gave IFS some new ideas regarding a complementary module. This module will inform earlier about changes in the automotive manufacturers' production. The flow of information between the automotive manufacturers and the second tier suppliers passes through some of the first tier suppliers. In order to increase the speed in which the information is transferred the new module will short-circuit this flow. The functionality may be compared to a highly placed brake light. When something gets wrong in the car manufacturer's production the brake light improves the second tier suppliers' possibilities to make early adjustments.

5.3 The CBS Module – a module supporting complex production

The CBS (Constraint Based Scheduling) Module assigns operations to resources in time. The determination of a schedule is a decision-making process. A variety of constraints affect this process: operation durations, precedence constraints, transfer and set up times, resource availability constrains, and resource sharing. These constraints define the space of admissible solutions. In addition, there are also relaxable preference constraints such as inventory levels, frequency of tool changes, and due dates. Which preference constraints should be satisfied and to what extent others should be relaxed is decided by the relative costs of different scenarios. For example, is decided by the costs of higher inventory levels compared to the costs of more frequent tool changes. A solution to the scheduling problem is a set of compatible scheduling decisions (e.g. perform operation *B* as soon as possible after operation *A* on machine *M1*) satisfying all constraints. When a certain set of possible solutions has been generated, the CBS identifies the most cost effective production schedule out from several possible ones, by comparing the estimated costs of different solutions against each other.

When IFS developed the CBS Module, the company used a programming language that is called C^{++}. The main reason why IFS decided to use C^{++} instead of PL/SQL was its superior calculation capacity. A C^{++} program consists of a hierarchic structure of different objects (see Figure 5.2). Apart from different "properties" (categories of data) such as setting time, operation time, qualifications etc., each object includes "methods" for collecting and transforming data from other objects. Every object may inherit "properties" and "methods" from objects on higher levels. In order to facilitate future upgrades, system developers usually try to identify "properties" and "methods" that can be utilised in many different applications. The more general a certain "property" or "method" is the higher up it is placed in the structure.

Initially the CBS Module/system primarily consisted of three different "objects", i.e. the order, product, and resource objects (e.g. equipment, tools, and personnel). By their "properties" each object defines certain constraints. The "order object" defines what products are to be produced and when they should be delivered. The "product object" defines the sequence in which different operations should be performed, and thus when certain resources and materials are needed. Finally, the "resource object" defines the setting times, capacity, and qualifications (field of applications) of different production resources. These three were later supplemented with the "material object" (resources consumed during the production process), which defines the "qualifications" of certain materials and the inventory levels. All four objects may be divided into several customer specific sub objects. The "resource object", for example, could be divided into different production equipments (e.g. drilling machines, lacquering robots, fitter, etc.).

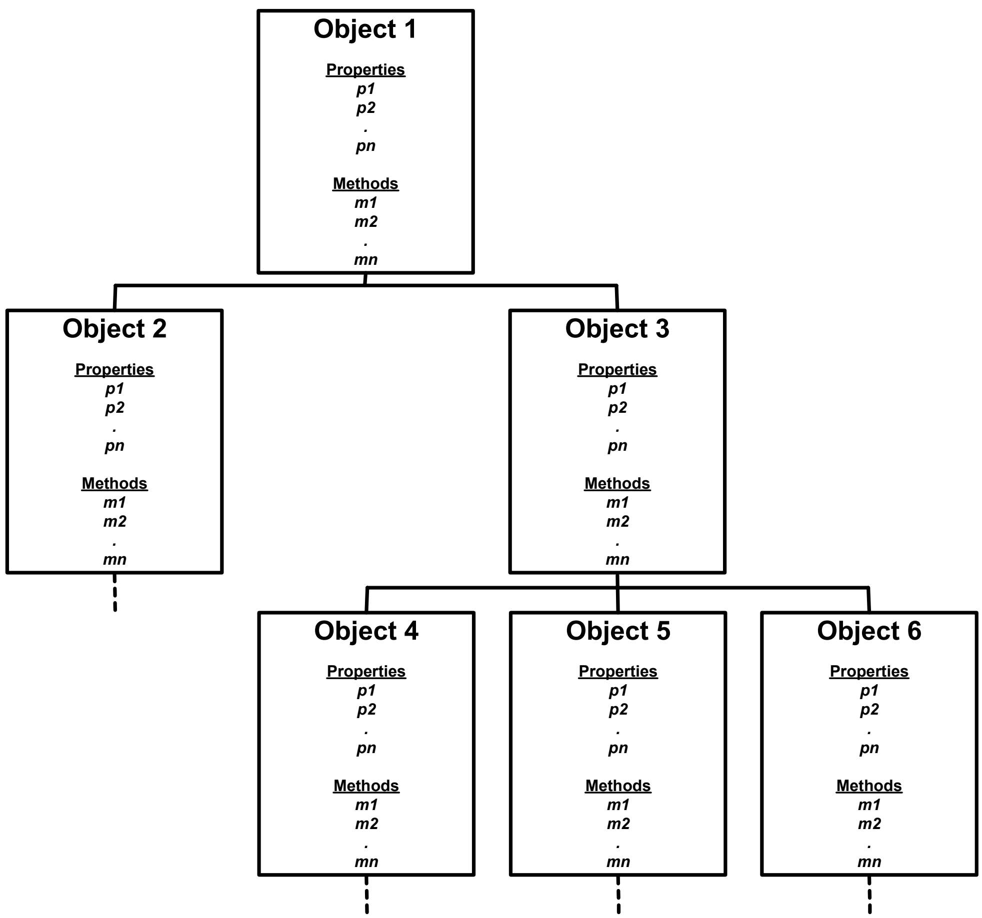


Figure 5.2: The hierarchic structure of a C^{++} program.

The CBS Module/system usually begins every scheduling process by placing all orders as late as possible. This is done in order to complete each order just on time for delivery, and thus to minimise inventory costs. When doing this it always starts occupying resources for the order with the earliest due date. In this first scheduling scenario, the operations required by the order with the earliest due date are performed directly after each other, while the operations required by the later ones are performed where there still is some unoccupied capacity left. In step number two, the module/system shifts operations backwards in time by searching for unoccupied capacity. In step number three, the direction is changed, i.e. operations are shifted forward in time. This iteration between shifting backwards and forwards is executed a certain number of times. The cost of each scenario is calculated in the order object. These calculations are based on data about different costs stored within the order object, as well as cost data stored in the resource and the material objects. By comparing all generated scenarios against each other, the order object finally identifies the most cost-effective solution.

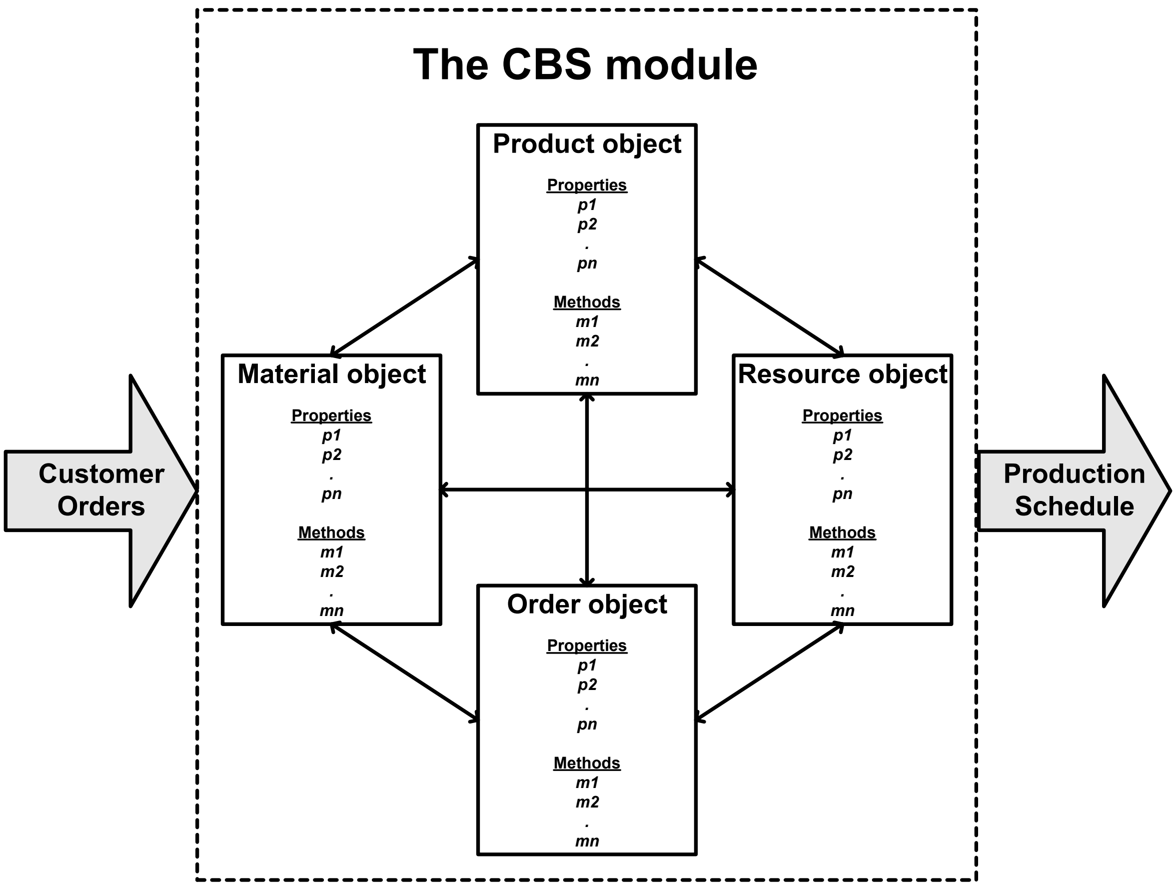


Figure 5.3: Illustration of how the four objects are related to each other and to the input in terms of orders and the output in terms of a schedule.

Apart from a lot of "properties" defining certain constraints, the scheduling process requires a large number of different "methods" for collecting, transforming, comparing, rearranging, and storing data. The complexity of the process, and thus the required time for running it, varies with the number of constraints to be considered.

When IFS implemented the CBS Module at BTAB, the sequencing problem at Timmele required a system that in relation to the development of new production plans took both fixing temperature and colour tone into consideration. The tolerances regarding tone differences between different batches of an article are usually narrow. Hence, in relation to every new setting it is important to clean the dying equipment, especially if the previous batch is darker than the succeeding one. It can take a long time to make a dying bath perfectly clean. Consequently, in order to reduce the cleaning work, Timmele's dying process is always performed in production cycles that starts with light colours and gradually get darker. Similarly, because of the extra time and energy required for cooling off the fixing equipment, the fixing process always starts with lower temperatures that gradually rise. Hence, BTAB's production in Timmele required an ERP-system planning sequences according to both colour tone and fixation temperature.

At the time of the implementation, the CBS Module included an embryo of the required sequencing functionality enabling the module to consider setting times due to colour tone. However, in order to make the module support BTAB's planning situation, IFS needed to add an additional functionality enabling the module to also consider setting times due to fixation temperature. Apart from minor modifications of the CBS Module's sequencing capability and a "method" transferring fixation temperature data from the Inventory Module, the new functionality required a new "column". This new "column", which store data about different fabrics' fixation temperatures, was developed in the Inventory Module.

When BTAB began to use the CBS Module, it was soon discovered that some orders were heavily displaced in time. To cope with this problem IFS's developed a functionality enabling BTAB to give different priority to different production orders. This priority was put both before colour and temperature. Consequently, the CBS Module intermittently began scheduling the production of dark coloured fabrics before the production of light coloured fabrics. This happened despite production perspectives of lighter fabrics being produced before darker. Apart from further modifications of the CBS Module's sequencing capability and a new "method" transferring priority data from the Repetitive Production Module, the new functionality called for a new “table”. This table, which store data about the priority of different fabrics, were developed in the Repetitive Production Module.

IFS also modified a functionality dividing the utilisation of production resources in time. Timmele’s planners can not “optimise” the utilisation different production equipment if they do not know the exact number of available workers. The production is divided into three different work shifts, and since the number of available workers may vary among these shifts, different production plans are needed. Therefore, IFS developed a functionality soon after the implementation making it possible to divide the utilisation of Timmele’s production equipment in less than 24 hours.

5.4 Connections to external systems

BTAB’s production facilities in Timmele and Getinge include two different inspection systems performing important calculation operations. While the inspection system in Timmele had been developed by ω-Recipe - a company specialised on inspection systems for textile companies - the system in Getinge had been developed by Jirotex (the previous owner of Getinge) in cooperation with an external consultant. In relation to the implementation of the ERP-system, IFS considered three different alternatives: 1) Integrate the functionality into the ERP-system. 2) Connect the ERP-system to BTAB’s two different inspection systems. 3) Connect the ERP-system to Timmele’s inspection system and then try to persuade BTAB to implement the same system in Getinge.

In interaction with BTAB, IFS decided to choose the third alternative. The first alternative was dismissed since it would be difficult and thus costly to include the calculation features into the ERP-system. Moreover, at the time of implementation, IFS did not perceive any opportunity to reuse these features in succeeding implementations. The second alternative was dismissed since it would demand two new connections instead of just one. However, before any final decision was made, some operators from Getinge visited Timmele in order to ensure that their work operations did not significantly differ from those of the operators at Timmele.

The developed connection transfers data from Timmele’s inspection system to the ERP-system in four steps. Firstly, the inspection system’s database makes a copy of the two files in which the data is stored. Secondly, a method within a specific additional module in BTAB's ERP-system transfers the data to two different tables in a customer specific module. Thirdly, the transferred data is transformed into the format normally used in IFS Application. Finally, all data concerning checked/refused quantities is sent to two different tables in the Repetitive Production Module, while data regarding stored quantities is sent to a table in the Inventory Module. However, before BTAB could use the additional module, the provider of the recipe system first had to install a new version of its database. This new version had a standardised interface which made it compatible to many other databases. In addition, it was compatible to previous versions, which made it possible to transfer and thus reuse all data previously stored in BTAB's version.

The ERP-system was also connected to Timmele's recipe system. This connection was very similar to the one developed between the ERP-system and the inspection system. Together, with some complicated calculation operations, the recipe system contains a large number of different recipes. The development of a new recipe always starts with a request from the customer. Based on this request BTAB develops a number of different prototypes. When the customer has accepted a prototype, BTAB recalculates all stated quantities in order to make the recipe valid for a large number of different quantities of fabric. Every time BTAB receives a new order, a specific additional module within BTAB's ERP-system transfers the accurate recipe from the recipe system to a customer specific module, where it is transformed to the format used in IFS Application. The transformed recipe data is stored in the Inventory Module, where the Repetitive Production Module is able to read it every time BTAB runs the MRP. From the Repetitive Production Module each planner is able to print out a recipe regarding the actual quantities of fabric. However, before BTAB could use the additional module, ψ-Inspection - the provider of the recipe system - first had to install a new database connectable to other databases.

5.5 Modifications at BTAB

The fact that the implementation project was used as a pilot study made IFS more willing to learn about the use context than economise on the standard functionality. Therefore, the implementation at BTAB did not result in any radical changes of BTAB's planning work. By using the same planning tools, BTAB's planners began to work in a more standardised way. Before the implementation each planner had developed his/her own way of working, thus making it difficult for each planner to perform the work of another planner. This rigidity made BTAB vulnerable to sick-leaves. By making the planners more interchangeable, the standardisation of the planning work enabled BTAB to deal with this problem. Furthermore, the automation of some activities gave each planner more time for personal interaction with other planners. The increased interaction improved the coordination of their planning work.

In order to improve BTAB's resource utilisation, Timmele's two production lines share some dying equipments. The planners responsible for these lines usually coordinate their work through personal interaction, where both Timmele's capacity utilisation and different customers' requirements are considered. Furthermore, in order to handle sequentially interdependent operations Timmele's automotive planner frequently interacts with the planners at Borgstena. Unforeseeable production errors at Borgstena and customers' late order changes often cause gaps within Timmele's production. In order to find a way to utilise these gaps, Timmele's automotive planner often asks the planners at Borgstena if they are able to send some fabric in advance. This act of cooperation was improved by the use of shared data provided by the ERP-system.

In order to efficiently support the planners' coordination work, all stored data had to be accurate. Each single operator along the production line was given the responsibility of typing every production error into the system. Because previous error registration was performed by foremen only, BTAB's foremen now received extra time for making adjustments to the planners' production plans instead. This was seen as a positive side effect. Another new routine that helped improve the accuracy of stored data was the use of carefully designed picking lists.

6 ANALYSIS OF THE IMPLEMENTATION AT BTAB

Concluding from Chapter 5, BTAB's ERP-system consisted of a mix of standard and adapted product features. In this chapter, this mix is analysed. For this purpose, the model of Håkansson & Waluszewski (2003) is used. As argued in Chapter 2, the model divides resources into technical and organisational resource units. While technical resource units are further divided into products (P) and production facilities (PF), organisational resource units are further divided into business units (BU) and business relationships (BR). According to the model, new technical features are developed when two or more technical resource units are adapted to each other in order to fit and work as an integrated whole. During their combination and adaptation of different products and production facilities, business units and business relationships change their knowledge of how to combine certain resources, as well as where and how to access complementary resources.

This chapter focuses on products and production facilities. While IFS's ERP-modules are seen as products, BTAB's ERP-system is seen as a production facility. Other important production facilities are BTAB's three different production plants: 1) Borgstena, 2) Timmele, and 3) Getinge. Important facilities are also BTAB's inspection and recipe systems.

During the implementation at BTAB, a certain set of IFS's standard products (in terms of different modules) were combined into a specific production facility (in terms of BTAB's ERP-system). In order to fit with, and contribute to the performance of, BTAB's existing production facilities (e.g. the production plant in Timmele), the new production facility (the ERP-system) was adapted to the features of these facilities. Conversely, BTAB adapted its existing facilities to the features of the ERP-system. IFS's and BTAB's adaptations resulted in some new product and facility features.

Why, and in what interfaces, new product and facility features were developed is analysed in Sections 6.1 to 6.3. In these sections, it is also illustrated how this development, due to investments made in features at certain functional and technical interfaces, embedded IFS's and BTAB's products and production facilities in each other (see Figures 6.1-6.7). Section 6.1 deals with the standard product features which IFS developed in order to adapt the ERP-system to the features of BTAB's three different production plants (Borgstena, Timmele, Getinge). An important part of these adaptations concerned three scheduling modules (the CS Module, the SS Module, the CBS Module). Section 6.2 discusses three customer specific adaptations and how they resulted in different customer specific product features. Section 6.3 focuses on how BTAB adapted the features of its existing production facilities to the features of the ERP-system. The section also addresses how the implementation of the ERP-system affected two of BTAB's business relationships.

In order to, in certain figures, be able to illustrate at what interfaces different features were developed and thus also the embeddedness, each product and production facility is given a certain number. This number includes two digits. The first digit indicates whether the resource unit is controlled by IFS or BTAB. While each resource unit controlled by IFS has a number that begins with 1 (e.g. P12 and P13), each resource unit controlled by BTAB has a numbers that begins with 2 (e.g. PF23 and PF24). The second digit (e.g. 2 in P12 or 3 in PF23) indicates the number of the resource unit.

Every product and production facility is seen as a collection of different features. In the figures, unfilled dots are used for pointing out the features that were developed during the implementation project. In addition to these dots, black lines are used for illustrating the interfaces in which new features were developed. Features are divided into product features and facility features. Facility features include new routines, new or modified production equipments, and new functionality of the ERP-system. Product features include new or modified "tables", "methods", and "forms" that, in combination, generate new ERP-system functionality.

Based on the analyses made in sections 6.1 to 6.3, the specific mix of standard and adapted product features is analysed in Section 6.4.

6.1 Adaptations of three standard products

BTAB's production facility is divided into three sequentially interdependent production plants: 1) Borgstena (PF22), 2) Timmele (PF23), and 3) Getinge (PF24). At the time of the implementation, their total production time always exceeded the lead time required by the customers. This called for some new features at the interface between BTAB's production plants and the ERP-system (PF21), enabling the system to deal with both orders and plans (see Figure 6.1).

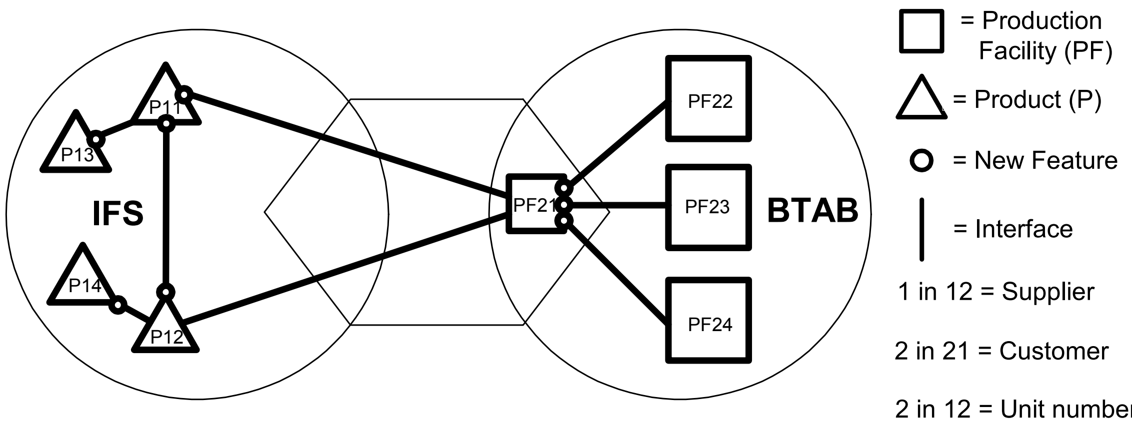


Figure 6.1: New features were developed at the interface between BTAB's production plants (PF22, PF23, PF24) and the ERP-system (PF21), at the interface between this system and the CS and the SS Modules (P11, P12), and at the interface between these products and two other products (P13, P14).

In order to generate these facility features, IFS developed some standard product features at the interface between the ERP-system and the standard version of the CS Module (P11). Apart from a new "table" for storing plan data, these features included "forms" for presenting this data. In addition, IFS also developed some new features of the Customer Order Module (P13). As previously mentioned, the Customer Order Module distributes orders to the MRP Module. In order to enable the Customer Order Module to distribute plans, IFS needed to modify its features. Apart from a new "method" collecting plan data from the CS Module, IFS also developed a new "table" storing this data.

Besides its customers' requirements on short lead times, BTAB needed to deal with late order changes and unforeseeable errors. This called for some further features at the interface between BTAB's production plants (PF22, PF23, PF24) and the ERP-system (PF21), enabling the ERP-system to support decentralised production planning. In order to generate these facility features, IFS supplemented the CS Module (P11) with the SS Module (P12). Together they supported decentralised production planning by facilitating the division of BTAB's material resource planning into three steps. This, however, required that they were matched against each other. For example, every set of data sent from a particular "table" in the SS Module called for a similar “table” within the CS Module. Furthermore, since the SS Module in turn received these orders from the Purchasing Module (P14), IFS also needed to develop some additional features of the Purchasing Module (see Figure 6.1). These features primarily concerned a “table” within the module storing plan data.

The utilisations problem at BTAB’s production plant in Timmele (PF23) called for some new features of the CBS Module (P15). These features, enabling the CBS Module to consider setting times with respect to both colour tone and fixation temperature, were primarily developed in order to improve BTAB’s utilisation of the company’s fixation and colouring equipments. Just like during the development of the CS Module and the SS Module, IFS economised on previously developed standard product features. These features primarily concerned a “method” collecting temperature data from a particular “table” within the Inventory Module (P17).

As previously mentioned, some of BTAB’s customers require that BTAB gives the highest priority to their products. In addition to the “method” collecting temperature data from the Inventory Module (PF17), IFS therefore developed a “method” within the CBS Module (P15) collecting priority data from a “table” within the Repetitive Production Module (P16). Where the new features were developed is illustrated in the figure below.

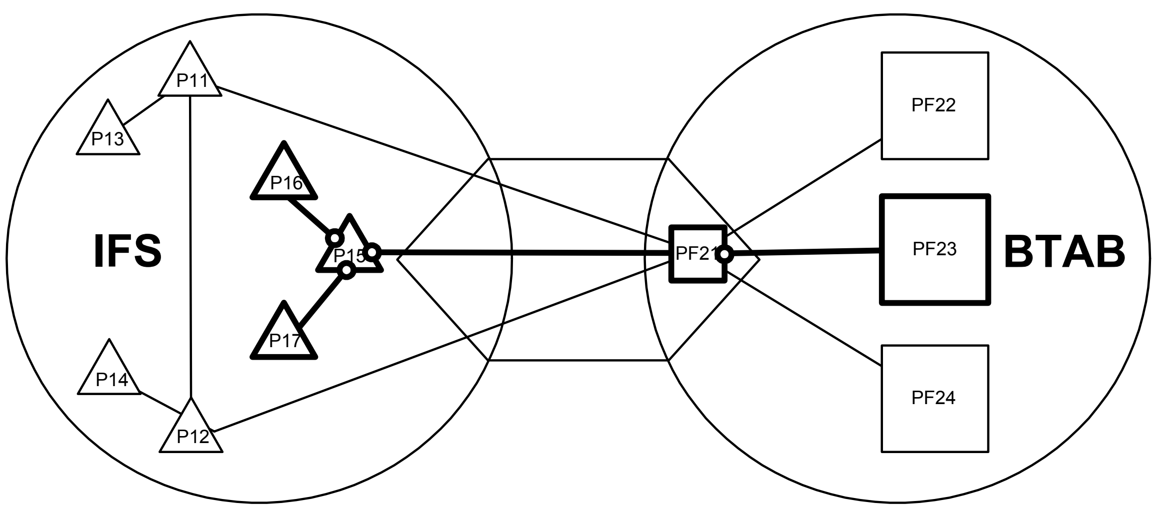


Figure 6.2: New features were developed at the interface between BTAB’s production plants (PF22, PF23, PF24) and the ERP-system (PF21), at the interface between this system and the CBS Module (P15), and at the interface between this product and two other products (P16, P17).

6.2 Three customer specific adaptations

One of IFS's most important customer specific adaptations was to develop a connection between the ERP-system (PF21) and BTAB's inspection system (PF25), thus enabling a continuous use of the inspection system's user interface. This facility feature was primarily generated by a customer specific module (P18) including 1) a "method" transferring data regarding the type and the length of a certain error from the inspection system to two customer specific "tables", and 2) an additional "method" transforming the data to the format normally used in IFS Application. Apart from a customer specific "method" within the Repetitive Production Module (P16) collecting data about checked/refused quantities, this module was supplemented with a customer specific "column" within the Repetitive Production Module storing this data. Similarly, a customer specific "method" and a customer specific "column" collecting/storing data about stocked quantities were added to the Inventory Module (P17). Where the new features of the ERP-system (PF21), the customer specific module (P18), and the new features of the Repetitive Production Module (P16) and the Inventory Module (P17) were developed is illustrated in the figure below.

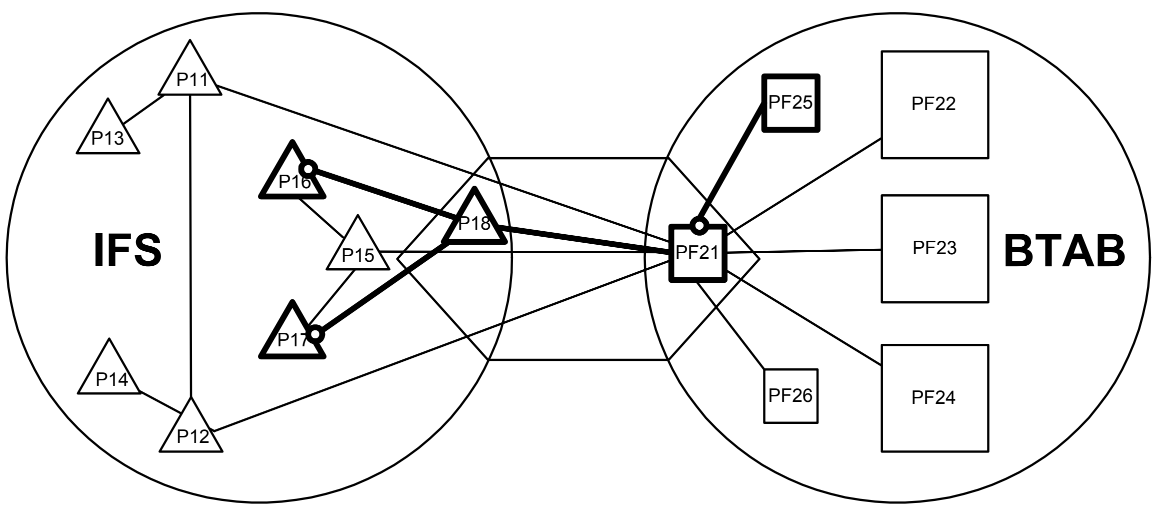


Figure 6.3: New features that were developed at the interface between BTAB's inspection system and the ERP-system, the customer specific module (P18), and the features that were developed at the customer specific module's interfaces towards the Repetitive Production Module and the Inventory Module.

A second important customer specific adaptation was to develop a connection between the ERP-system (PF21) and BTAB's recipe system (PF26), thus facilitating a continuous utilisation of the recipe system's calculation capacity. This facility feature was primarily generated by a customer specific module (P19) including 1) a customer specific "method" transferring the recipe data to a certain customer specific "table", and 2) an additional "method" transforming the data to the format normally used in IFS Application (see Figure 6.4). In addition to this module, IFS also developed a customer specific "method" within the Inventory Module (P17) transferring the transformed data to a customer specific "table" within this module. Furthermore, IFS developed a customer specific "method" in the Repetitive Production Module (P16) collecting recipe data from the Inventory Module every time BTAB runs the MRP Module. Where the new features of the ERP-system (PF21), the customer specific module (P19), and the new features of the Inventory Module (P17) and the Repetitive Production Module (P16) were developed is illustrated in the figure below.

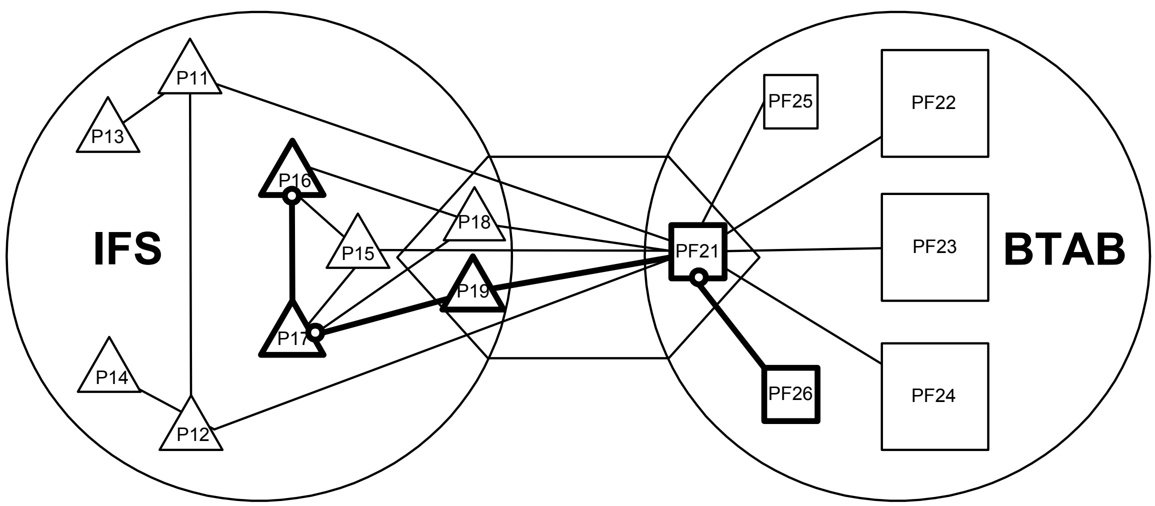


Figure 6.4: New features were developed at the interface between BTAB's inspection system (PF26) and the ERP-system (PF21), at the interface between the ERP-system and the Inventory Module (P17), and at the interface between this module and the Repetitive Production Module (P16). An important part of the features that were developed at the interface between the ERP-system and the Inventory Module (P17) were integrated into a customer specific module (P19).

A third customer specific adaptation was to develop a connection between the ERP-system (PF21) and ρ-Software's EDI-converter (P31). This facility feature did not call for any major product modifications. ρ-Software only needed to adjust some parameters in order to enable the EDI-converter to read and write in the ERP-system. Where these product features were developed is illustrated in the figure below.

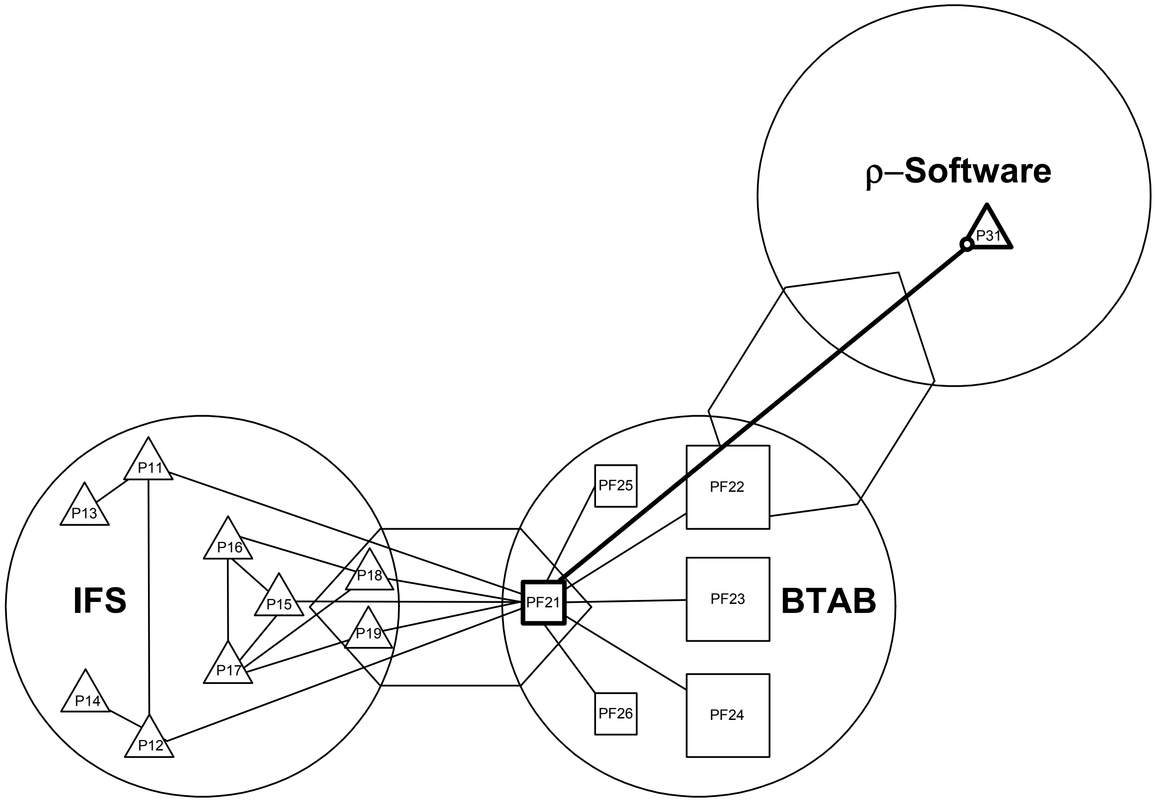


Figure 6.5: New features were developed at the interface between BTAB's ERP-system (PF21) and ρ-Software's EDI-converter (P31).

6.3 Adaptations of BTAB's production facility

The implementation did not only result in adaptations of IFS's products to the features of BTAB's existing production facility, but conversely, this production facility was also adapted to the features of the ERP-system (see Figure 6.6). Apart from new versions of BTAB's recipe and inspection systems, BTAB changed its planning routines. Four different ways in which BTAB's planning routines were changed can be identified. Firstly, the planning routines became standardised. By making the planners more interchangeable, this standardisation improved BTAB's ability to deal with sick-leaves. Secondly, each single operator along the production line became responsible for reporting production errors that appear during their respective production step. This improved BTAB error registration. Thirdly, the production output was now shipped in accordance to carefully designed picking lists. This reduced the degree of shipment delays. Fourthly, the ERP-system made the production planners better informed about each others production. In addition, the automation of some planning activities gave them more time for personal interaction with each other. The knowledge that the planners gained about each others planning changed their ability to coordinate the production between BTAB's different production plants. In other words, not only the plants' (PF22, PF23, PF24) interfaces towards the ERP-system (PF21) were changed, but also their interfaces towards each other.

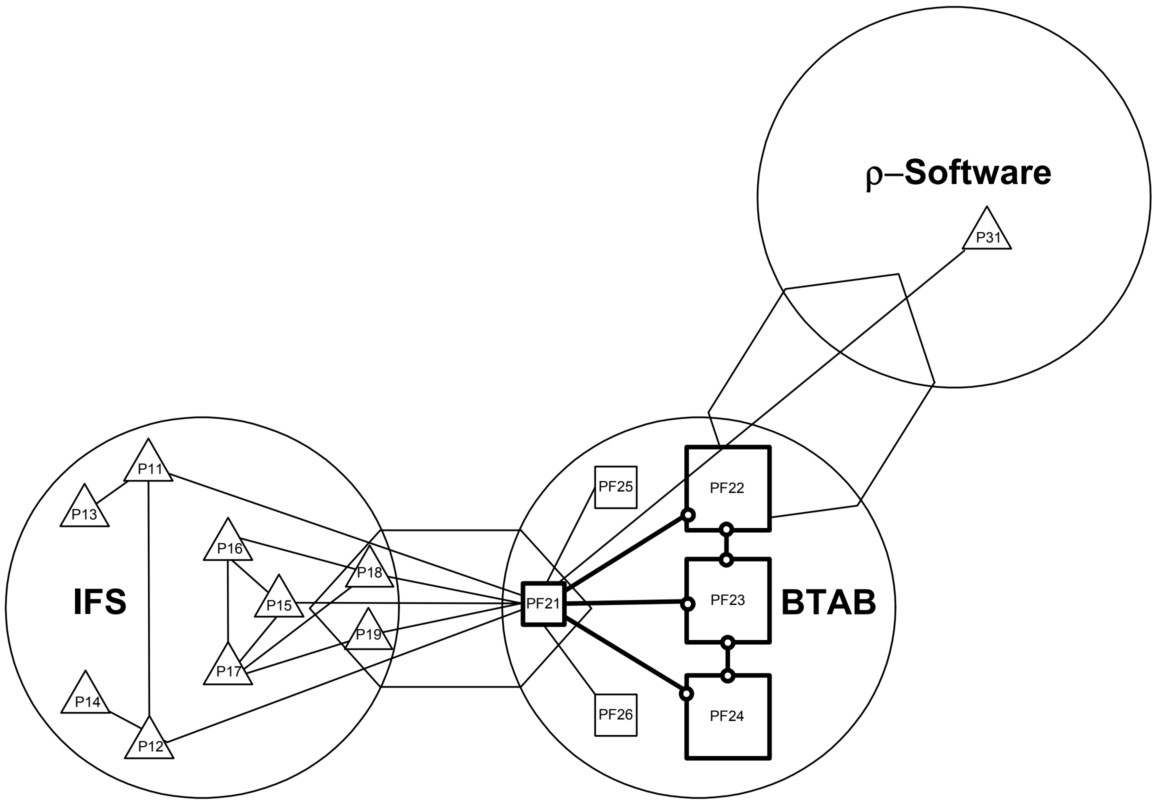


Figure 6.6: New features were developed at the interface between the ERP-system (PF21) and BTAB's production plants (PF22, PF23, PF24), and at the interfaces between these plants.

Owing to certain sequential interdependencies, the implementation of the ERP-system also affected two of BTAB's business relationships (see Figure 6.7). Firstly, it affected BTAB's business relationship with π-Curtains (BR21). Although π-Curtains delivers directly to BTAB's automotive customers, all communication with these customers are handled by BTAB's production planners in Timmele. In order to be able to provide the automotive customers with information about the production status of different articles, and thus support their just-in-time production, BTAB needed to improve its access of information about π-Curtains' production. For dealing with this situation, BTAB persuaded π-Curtains to implement the "client", i.e. the part of the ERP-system making it possible to put-in and take-out data. This implementation changed the interface between π-Curtains production plant (PF41) and BTAB's production facility.

Secondly, the implementation of the ERP-system affected BTAB's business relationship with σ-Lamination (BR22). As σ-Lamination's computerised business system was not compatible with ρ-Software's EDI-converter, the company was not able to receive BTAB's electronic messages. This trigged BTAB to send less fabric to σ-Lamination, and instead increase its utilisation of Getinge's production capacity.

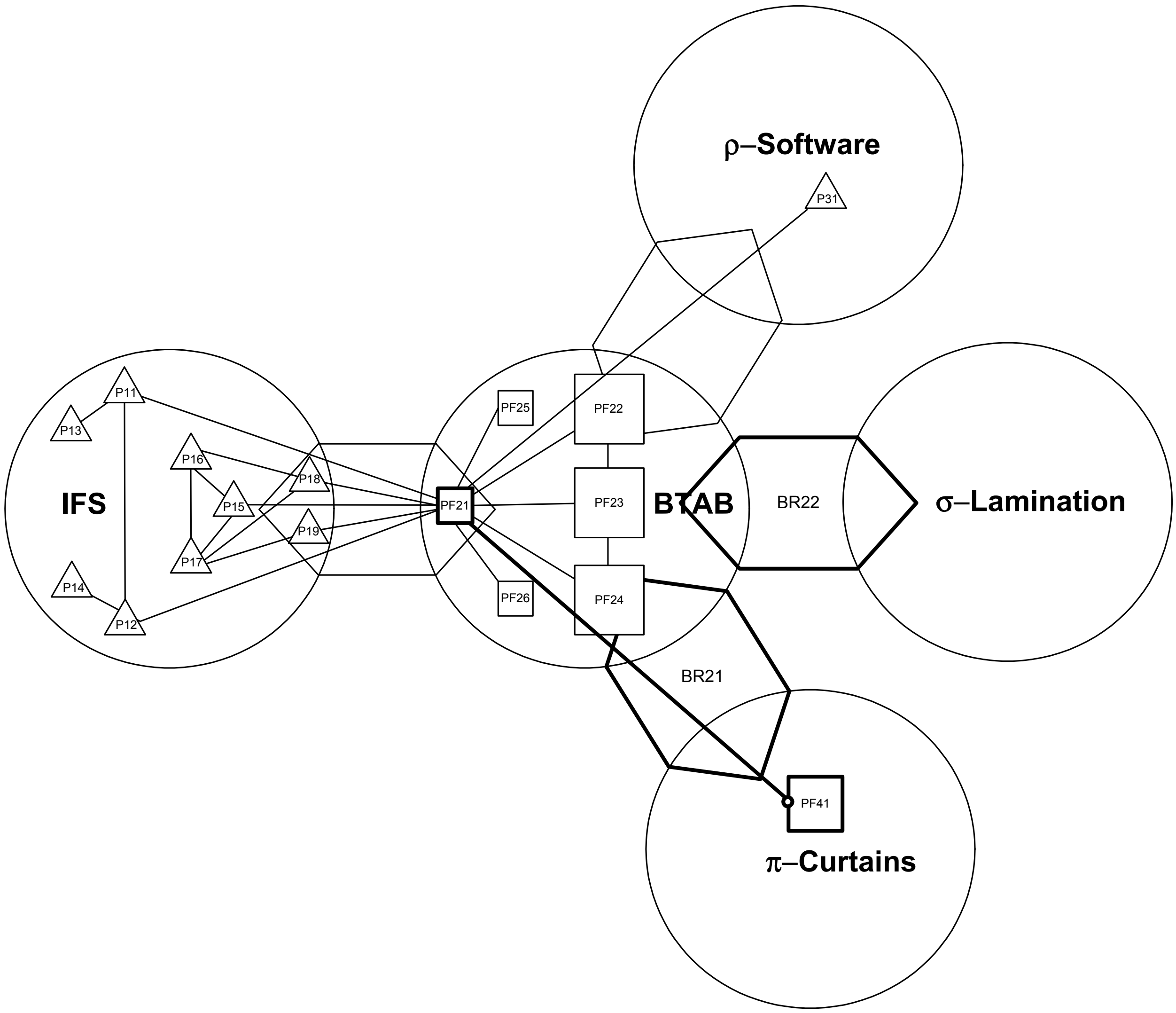


Figure 6.7: The implementation of the ERP-system (PF21) affected BTAB's business relationships with π-Curtains and σ-Lamination (BR21, BR22).

6.4 The mix of standard and adapted product features

As previously mentioned in Chapter 5, BTAB's ERP-system included 14 standard modules. In order to make the ERP-system fit with, and contribute to, the performance of BTAB's production facility, new product features were added to seven of these modules. An important part of these adaptations concerned the CBS, the CS, and the SS Modules. These product features were developed in order to enable the modules to generate new facility features (functionality). In the case of the CBS Module, the new product features enabled the module to find the most cost effective production schedule with respect to colour tone, fixation temperature, and priority. The new features of the three scheduling modules were integrated into the standard versions of these modules. Some other product features were developed separated from the standard version of IFS Application. For example, the new features enabling the ERP-system to communicate with the recipe system. Hence, the adaptations of the ERP-system that were made in the BTAB project consisted both of new standard features and new customer specific features.

In order to actually generate the new facility features (functionality), the three scheduling modules' new product features needed to be supplemented with some complementary features at the modules' interfaces towards some interconnected modules. For example, the new features of the CBS Module called for adaptation of the module's interface towards the Repetitive Production Module. In some cases, the new features also required changes of the interconnected modules. For example, in order to enable the CS Module to deal with both orders and plans, IFS did not only add new product features to the CS Module, but also new features to the Customer Order Module. In other cases, even completely new interfaces were developed. A new interface was, for example, developed between the CS Module and the SS Module. Lastly, some entirely new modules were developed. Besides a new standard module (the SS Module), IFS developed two customer specific modules.

IFS did not only adapt the features of the ERP-system to the features of BTAB's production facility, but conversely BTAB also adapted some of the features of its production facility to the features of the ERP-system. An important part of these adaptations were carried out at the individual production plants' interfaces towards the ERP-system. One such adaptation, for example, was to standardise the work routines of the production planners. Another one was to use standardised picking lists for shipments. Indirectly, BTAB's use of the ERP-system also resulted in some changes at the production facilities' interfaces towards each other. For example, by facilitating the communication between different production plants, the coordination between BTAB's production plants was improved. Furthermore, the ERP-system changed BTAB's business relationships. Apart from reducing the quantities of fabric shipped to σ-Lamination, it changed BTAB communication with π-Curtains.

In conclussion, the existing features of BTAB's production facility required development of certain features of the ERP-system. In order to generate these features, IFS had to adapt some parts of its product. These adaptations concerned new standard and customer specific product features. How a specific mix of standard and customer specific product features is developed is further analysed in Chapter 8. In the same chapter it is also analysed how new product features are developed through adaptation, and how a supplier and a buyer may handle the effects that different adaptations may have on other parts of the resource network. A supplier's choice between developing a standard product feature or a customer specific one is further analysed in Chapter 9. The following chapter discusses how new standard product features gradually are developed, as IFS interacts with different customers in a sequence.

7 PRIOR AND SUCCEDING DEVELOPMENT EFFORTS

Chapter 5 showed how IFS´s and BTAB's mutual adaptations resulted in an ERP-system consisting of a certain mix of standard and customer specific features. In Chapter 6 it was analysed why, and in what interfaces, new standard and customer specific features were developed. More important, different types of adaptations were discussed. This chapter focuses on prior development of the standard versions of the CBS and the CS Modules, as well as succeeding utilisation of the CS and the SS Modules.

The Chapter is divided into six sections. In Section 7.1 and 7.2 it is described and analysed how new standard product features are gradually added to the CBS Module, as IFS interacts with different customers in a sequence. A similar description and analysis concerning the development of the CS Module is made in section 7.3 and 7.3. Finally, in Section 7.5 and 7.6 it is described and analysed how the new standard features of the CS and the SS Modules, which were developed during the BTAB project, were utilised during three succeeding implementation projects.

7.1 Development of the CBS Module prior to the IFS BTAB project

IFS started the development of the CBS Module when it became clear that there was a general need for a system supporting customer-based scheduling. Though the basic functionality of the CBS was developed without any customer involvement, the refinement was carried out during eight different customer projects at: 1) α-Profiles, 2) β-Steel, 3) γ-Cement, 4) δ-Mining, 5) ε-Oil, 6) ζ-Bread, 7) η-Gearboxes, and 8) θ-Chemicals. While the eighth project (θ-Chemicals) concerned a customer specific solution developed during an actual implementation of the system/module, the other seven concerned customer specific prototypes developed in relation to the implementation of other modules. These prototypes were primarily developed in order to learn from different user applications. Although the customers were not committed to buy these prototypes, both α-Profiles and ζ-Bread later decided to perform a full scale implementation of the CBS module. All eight customer projects are presented one by one below.

7.1.1 α-Profiles

α-Profiles produces plastic profiles in different colours. Apart from different colours of granulate, this requires large pressing tools specifically designed for the production of certain articles. The company's production planning is complicated by the constraint that blond coloured items can not be produced after dark coloured items unless the pressing tool is properly cleaned. Another important constraint is that the company's work force is limited to three teams of setters. Consequently, the company can not set more than three pressing tools at a time without causing long setting times. In case of long setting times, there is a huge risk that the plastic material will burn into the pressing tools. Since it normally takes about four hours to clean one tool, this may cause severe production stops.

The CBS-system was used for finding the most cost effective production schedule with respect to set up times. Apart from new "methods" considering the constraint that blond coloured items can not be produced after dark coloured items without causing some setting times, this application required two additional "properties". The first one, defining the colour of different articles, was developed within the product object. The second one, defining the setting time of different pressing tools, was developed within the resource object. Furthermore, IFS developed a functionality making it possible to evaluate how a new order will affect the present production schedule. This functionality primarily involved a number of "methods" creating space for new orders by pushing prior orders back and succeeding orders forth.

Both the functionality scheduling the most cost effective production with regard to colour, and the functionality making it possible to evaluate how a new order will affect the present production schedule, were later utilised in the development of BTAB's ERP-system solution. While α-Profiles needed these features for scheduling the company's pressing of different coloured plastic items, BTAB needed them for scheduling the company's dying of different coloured fabrics.

7.1.2 β-Steel

β-Steel primarily produces large steel axles, e.g. to be used in ships for transmitting power from the diesel engines to the propellers. The production is divided between two different production plants: 1) a steel-mill exclusively utilised for the production of steel axles, and 2) a turning-mill which, apart from being utilised for the production of steel axles, is utilised for some contract works.

The contract work is primarily performed in order to improve the company's utilisation of the turning-machines. Unfortunately, by causing some waiting times it may sometimes also delay the refinement of the steel axles, and thus negatively affect the utilisation of the steel-mill.

In order to improve β-Steel's utilisation of the steel-mill, IFS developed functionality making it possible to divide the scheduling process into two steps. Firstly, the CBS generates a production schedule only considering orders on large steel axles. Secondly, in case of unoccupied capacity in the turning-mill, orders on contract works are added retrospectively. The functionality primarily involved the development of "methods" for locking orders to certain occupation times.

At β-Steel, IFS also needed to cope with a new kind of resource. Apart from different kinds of ovens, hammering, and turning machines, β-Steel's production involves a large number of cooling spaces (some kind of inventories), always placed between two different operations (e.g. between hammering and ionization). Unlike all other resources, they have variable operation times. While the minimum operation time is decided by the time it takes to cool down an item to a certain temperature, the maximum operation time is decided by the time difference between the end point of the preceding operation and the start point of the succeeding one.

The occupation of cooling spaces called for functionality making the CBS system capable of dealing with storing spaces bridging the time gap between two operations. This functionality involved a set of "methods" which calculates data regarding required operation time, stores the data in the "order object", and finally considers the data when planning succeeding operations. Furthermore, since the storing spaces need to be available right after the execution of the preceding operation, the functionality also involved set of "methods" considering a constraint (defined within the order object) saying that operation *B* need to be available right after the execution of operation *A*.

Both the functionality making it possible to lock operation times for some orders, and the functionality making the CBS system capable of dealing with storing spaces bridging the time gap between two operations, were later utilised in the development of BTAB's ERP-system solution. The functionality making it possible to lock operation times for some orders made it possible for BTAB to dye tricot without increasing the lead times for automotive fabric. The functionality making the CBS system capable of dealing with storing spaces bridging the time gap between two operations facilitated BTAB storing of semi-finished fabric.

7.1.3 γ-Cement

γ-Cement produces cement by burning nitrite of lime. The production involves large ovens which regularly are disassembled and cleaned. Because the cleaning work involves a large number of different operations, it is labour intensive. Consequently, in order to reduce the set up times, the company always needs to call in some extra workers. However, since 35% of the required operations are unknown before the ovens have been disassembled, it is difficult for the company to predict the required number of workers. Therefore, γ-Cement often called in more workers than it actually needed.

The CBS system was partly used for improving γ-Cement's ability to estimate the suitable number of workers. Since the cleaning work involved a large number of workers with many different qualifications this application called for functionality enabling the CBS-system to handle "multi resources". This functionality made it possible to only occupy a certain part of a resource, and primarily concerned a modification of the "resource object" making it possible to divide every resource into smaller pieces. Apart for estimating the suitable number of workers, γ-Cement later utilised this feature when occupying a colouring machines for the production of different batches of fabric.

7.1.4 δ-Mining

δ-Mining is a mining company. Just like γ-Cement, δ-Mining used big ovens which the company regularly had to disassemble and clean. Hence, from the start IFS perceived a great opportunity to rely on already developed functionality. However, it soon turned out that another development unit within IFS had removed important complementary functionality within the modules supporting customers' maintenance work. While it within the CBS was possible to state several different "resource qualifications", it was now only possible to state one "resource qualification" within the modules supporting customers' maintenance work. This caused a serious communication problem, which could not be solved without repeating modifications of certain "tables" within these other modules. Consequently, IFS decided to end the development project without developing any customer specific prototype.

7.1.5 ε-Oil

ε-Oil produces margarine, skin care products, ice cream, cattle food, etc. The production of these articles is primarily based on different types of oils (e.g. olive, maize, and rapeseed oil) which are stored in large containers. A recent increase of ε-Oil's product range had made the company's oil consumption less foreseeable. In order to cope with this problem, ε-Oil needed to improve its control of the oil inventory.

In order to support ε-Oil's need of knowing the precise oil level within each container, IFS refined the "multi resource" functionality. By dividing each container as a resource object into an infinite number of pieces, IFS managed to imitate a continuous tap of oil. Furthermore, in order to support the refill of the containers, IFS developed a functionality making it possible to define the maximum capacity of every container. This functionality primarily required a new "property" within the resource object.

The functionality making it possible to define the maximum capacity of certain production equipment were later utilised in the development of BTAB's ERP-system solution. While ε-Oil used this functionality when planning the capacity utilisation of the company's containers, BTAB used the functionality when planning the capacity utilisation of the company's round knitting and colouring machines.

7.1.6 ζ-Bread

ζ-Bread is baking different sorts of bread, ranging from danishes to rye bread. The production is divided into six steps: 1) automatic ingredient mixing, 2) manual dough making, 3) mechanical dough separation, 4) fermentation, 5) baking, and 6) automatic packing. In each of these steps ζ-Bread utilises a number of resources with partly overlapping and partly unique "qualifications". While, for instance, one oven may posit the "qualification" to bake danishes, buns, and French rolls, another one may posit the "qualification" to bake French rolls, and rye bred. The fact that different breads are baked in the same oven, thus sharing the same limited space, affects suitable dough sizes (i.e. the batch sizes). If, for instance, a certain batch of French rolls occupies 70% of a certain oven, only 30% is available for baking the rye bread. Consequently, if no other oven can be used, ζ-Bread needs to create a batch of rye bread that does not occupy more than 30% of this oven.

When creating suitable batch sizes, ζ-Bread also needed to consider certain dead-lines that are set by the company's fixed shipment times. After the first truck's departure at 22.30, a new truck departs every thirty minute until 10.00 in the morning. The trucks distribute the bread to different places in Sweden, travelling anywhere from Ystad (in the south) to Haparanda (in the north). Their time of departure is primarily decided by the transportation time. For example, while it takes about 13 hours to get to Gävle, it only takes about 45 minutes to get to Borås.

Together with the production equipment's (e.g. the ovens) different "qualifications", ζ-Bread's dead-lines cause a complex planning situation. Apart from costs due to low resource utilisation, the company needed to consider costs due to late deliveries and waste. Costs due to late deliveries emerged when ordered products did not show up on time. This included costs from 1) unsatisfied customers, and 2) empty shelves causing loss of products exposure to consumers. Costs due to waste emerged when the particular batch of bread was not ready before the departure of the truck. Within the bread industry there is a rule saying that, in order to be classified as fresh, bread must be produced later than 9.00 on the preceding day. Consequently, bread that is not ready on time is not considered to be fresh and thus refused by the customers.

In order to support ζ-Bread's planning situation, IFS developed functionality making the CBS system capable of finding the most cost effective schedule with respect to setting times, waste, lost revenues, and extra costs due to late deliveries. Apart from new "methods" considering the deadlines caused by the trucks fixed departure times, this required a new "property" defining these constraints within the order object. Furthermore, in shape of the dough IFS identified a new kind of multi-resource. Although the attributes of the dough were in many ways similar to the ones of, for example, the ovens baking the bread, they differed in one important aspect. Contrary to ovens, the dough was consumed during the production process. In order to limit the number of different "properties" within the resource object, IFS therefore decided to develop the "material object", including a whole new set of "properties" and "methods".

Both the functionality making the CBS Module able to deal with "multi-materials", i.e. materials used in the production of different orders, and the functionality making the system able to consider dead lines caused by fixed departure times, were later utilised in the development of BTAB's ERP-system solution. While ζ-Bread primary "multi-resource" was the dough, BTAB's primary "multi-resource" was the semi-finished fabric.

7.1.7 η-Gearboxes

η-Gearboxes manufactures gear boxes. Apart from a certain number of "master lines", the production involves a large number of sub-lines transporting the products to and from particular operations. Each of these operations involves particular production equipment (e.g. drilling, cutting, turning, fastening, or lacquering machines) with product specific setting and processing times. This variety causes waiting times, and thus some interest costs due to capital locked into semi-finished products.

In order to reduce the interest costs without lowering η-Gearboxes' equipment utilisation, IFS developed a functionality making the CBS system capable of finding the most cost effective production schedule with regard to waiting times. Since the production of gear boxes involves a large number of different operations to consider, it takes a long time to run the scheduling process. IFS therefore needed to find a way to reduce the time required for running the scheduling process. After first testing some other alternatives, IFS developed a functionality enabling the CBS to gather different orders on one article into larger batches before running the scheduling process. Apart from a new "method" gathering orders into larger batches ("multi orders"), IFS needed to define a constraint (required a new "property" to be added within the order object) regarding suitable batch sizes. While the production sequence is primarily decided by constraints in terms of the fixed setting and operation times of different machines, suitable batch sizes are primarily decided by the limited queue space of the sub-lines.

Besides the large number of production equipments and the additional sub-lines, η-Gearboxes' production is characterised by parallel dependencies due to several production flows that merge at certain operation steps. In order to enable the CBS system to deal with these dependencies, IFS developed functionality considering waiting times that emerge when one of two flows reaches the merging point earlier than the other one. This functionality called for a new "property" within the product object defining the constraint that operation *X* can not start before both operation *Y* and *Z* are finished.

Both the functionality enabling the CBS Module to gather different orders on one article into larger batches before running the scheduling process, and the functionality considering waiting times that emerges when one of two flows reaches the merging point earlier than the other one, were later utilised in the development of BTAB's ERP-system solution. While suitable batch sizes at η-Gearboxes were primarily decided by the limited queue space on the sub-lines, suitable batch sizes at BTAB primarily were decided by the limited size of each knitting machine.

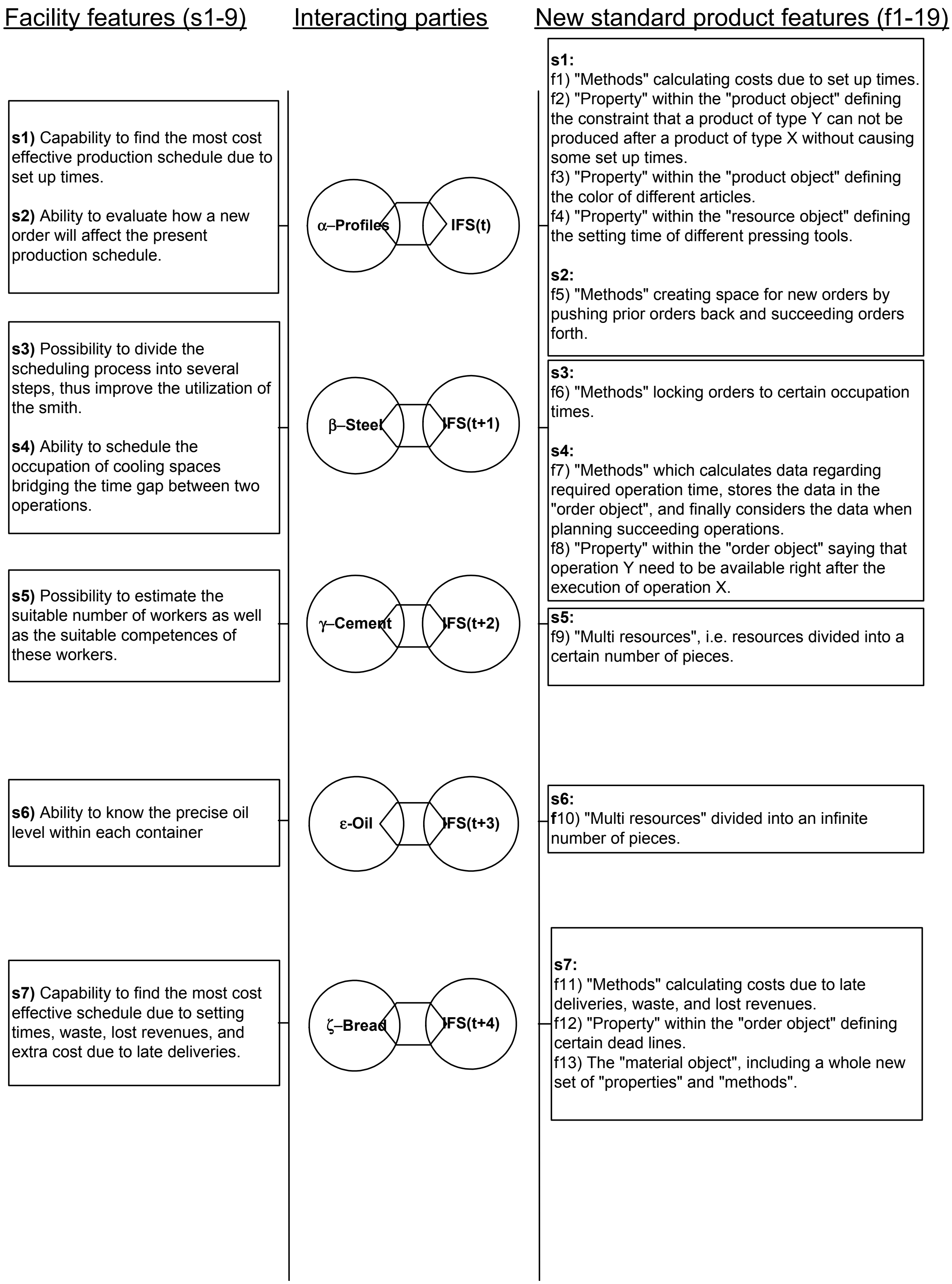
7.1.8 θ-Chemicals

θ-Chemicals operates in the field of coatings and chemicals. Because the company has, in many aspects, experienced the same needs as ζ-Bread, IFS gained a great opportunity to economise on prior development. However, in contrast to ζ-Bread's, θ-Chemicals' production plans are reaching far into the future and are thus vulnerable to computer crashes. In order to avoid data losses caused by computer crashes, IFS decided to integrate the CBS into IFS Application. One important advantage with PL/SQL programs, compared to C^{++} programs, is the safer way of storing data.

The integration was accomplished by the move of all storing functionality from the CBS to the Repetitive Production Module and the Inventory module. While the Repetitive Production Module stores data about products and resources, the Inventory Module stores data about materials. Apart from new "tables" within the Repetitive Production and the Inventory module, this movement required new "methods" within the CBS collecting necessary data from the Repetitive Production and the Inventory Module every time the module, based on received orders, generates a new production schedule.

7.2 Analysis of prior development of the CBS Module

Previous descriptions have showed how IFS, in interaction with certain buyers, developed different standard product features in a sequence. While the buyers, based on their knowledge of the use context, articulated their need of certain facility features, IFS interpreted these features into a number of complementary product features, which together generates the requested facility features. Apart from both presenting the requested facility features (s1-9) and the product features (f1-19) generating these features, Figure 7.1 shows during which supplier-buyer interaction the different product features were developed.



Facility features (s1-9)
Interacting parties
New standard product features (f1-19)
s1) Capability to find the most cost effective production schedule due to set up times.
s2) Ability to evaluate how a new order will affect the present production schedule.
s3) Possibility to divide the scheduling process into several steps, thus improve the utilization of the smith.
s4) Ability to schedule the occupation of cooling spaces bridging the time gap between two operations.
s5) Possibility to estimate the suitable number of workers as well as the suitable competences of these workers.
s6) Ability to know the precise oil level within each container
s7) Capability to find the most cost effective schedule due to setting times, waste, lost revenues, and extra cost due to late deliveries.
α–Profiles
IFS(t)
β–Steel
IFS(t+1)
γ–Cement
IFS(t+2)
ε-Oil
IFS(t+3)
ζ–Bread
IFS(t+4)
s1:
f1) "Methods" calculating costs due to set up times.
f2) "Property" within the "product object" defining the constraint that a product of type Y can not be produced after a product of type X without causing some set up times.
f3) "Property" within the "product object" defining the color of different articles.
f4) "Property" within the "resource object" defining the setting time of different pressing tools.
s2:
f5) "Methods" creating space for new orders by pushing prior orders back and succeeding orders forth.
s3:
f6) "Methods" locking orders to certain occupation times.
s4:
f7) "Methods" which calculates data regarding required operation time, stores the data in the "order object", and finally considers the data when planning succeeding operations.
f8) "Property" within the "order object" saying that operation Y need to be available right after the execution of operation X.
s5:
f9) "Multi resources", i.e. resources divided into a certain number of pieces.
s6:
f10) "Multi resources" divided into an infinite number of pieces.
s7:
f11) "Methods" calculating costs due to late deliveries, waste, and lost revenues.
f12) "Property" within the "order object" defining certain dead lines.
f13) The "material object", including a whole new set of "properties" and "methods".

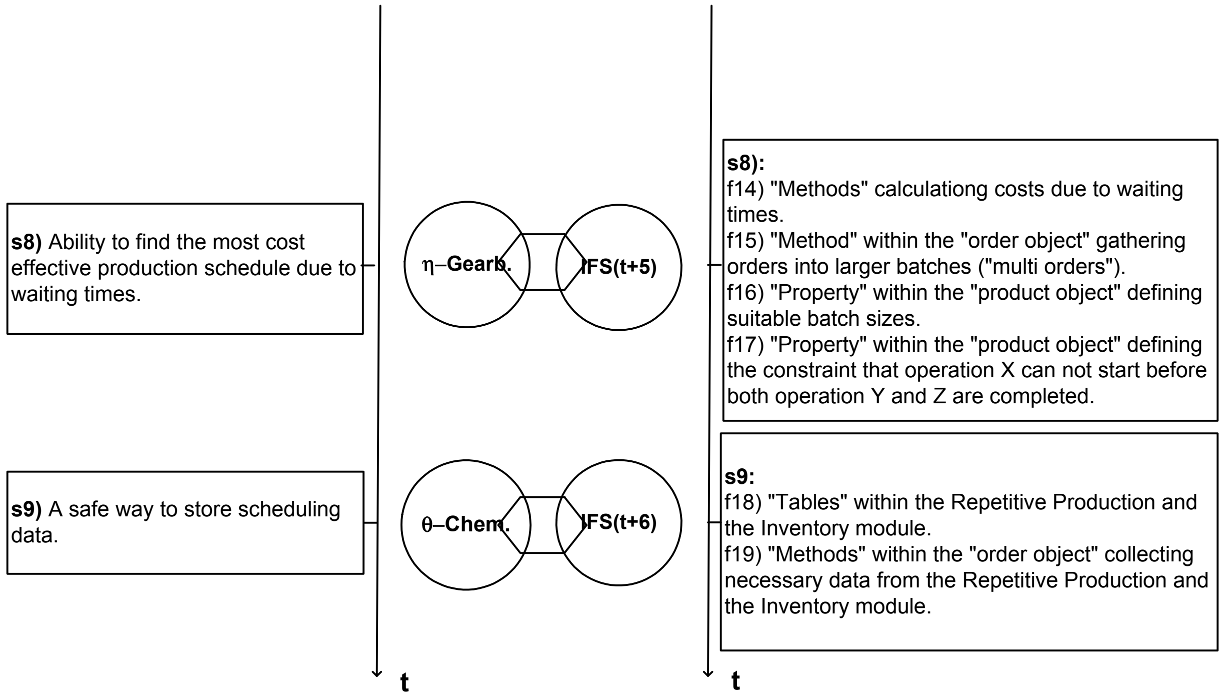


Figure 7.1: Different standard product features (f1-19) developed in interaction with prior buyers, and the facility features (s1-9) they generated.

The new product features, for example, involved different "methods" that due to certain constraints, calculate the costs of different schedule scenarios. As shown in Figure 7.1, these "methods" were added in a sequence. In interaction with α-Profiles, IFS developed "methods" calculating costs due to setting times (f1). During the subsequent interaction with ζ-Bread, these "methods" were supplemented with "methods" calculating costs due to late deliveries, lost revenues, and waste (f11). Finally, in interaction with η-Gearboxes, IFS added "methods" calculating costs due to waiting times (f14). Many of these "methods" required one or several additional "properties". The "methods" calculating costs due to setting times required a "property" within the "resource object" defining the setting time of different equipment (f4). It also required a "property" within the "product object" defining the constraint that a product of type *Y* could not be produced after a product of type *X* without causing certain set up times (f2). The "methods" calculating costs due to late deliveries, lost revenues, and waste called for a "property" within the order object defining certain deadlines (f12). The "methods" calculating costs due to waste required an entirely new object, i.e. the "material object" (f13). Finally, in order to be more efficient, the "methods" calculating costs due to waiting times called for a “property” within the “product object” defining suitable batch sizes (f16).

Together, these “methods” and “properties” embedded every “object” into a certain resource network. The complexity of this network increased when IFS moved some storing features from the CBS Module to other modules within IFS Application and thus created interdependency between the single module’s internal network of different interdependent objects and the wider network of different modules. After the integration, a change within one object (e.g. the order object) may affect not only other objects within the CBS Module, but also other modules within IFS Application (e.g. the Repetitive Production module). Moreover, as all these modules are utilised in different customer specific solutions, which in turn are integrated into different buyers’ resource collections, there may even be effects on resource units far beyond IFS’s product collection.

The more complex a network of interdependent resources becomes, the more difficult it becomes to predict the effects that the change of a resource may have on other resources. Increased uncertainty about the effects of a change may impede development of new resource features. Problems due to interdependencies among modules, for example, appeared when IFS tried to develop a customer specific prototype in interaction with δ-Mining. Because IFS removed important additional features within the Maintenance Module during a recent upgrade, the development team at δ-Mining was not able to utilise the standard features of the CBS Module.

Many standard features that had been developed in interaction with other buyers were utilised during the development of the customer specific solution at BTAB. Just like α-Profiles, BTAB needed the system feature calculating the setting times for different colour sequences. While α-Profiles needed this feature for scheduling the company’s pressing of different plastic items, BTAB needed it for scheduling the company’s dying of different fabrics. Similar to β-Steel, BTAB performs some contract work and thus needed the ability to lock operation times for some important orders (i.e. orders concerning automotive fabric) before considering the remaining ones (i.e. orders concerning different contract works). Like ε-Oil, BTAB needed a system feature considering the maximum capacity of some resources. While ε-Oil needed this feature when occupying containers, BTAB needed it when occupying various circle-knitting and colouring machines. Similar to ζ-Bread, BTAB needed to deal with “multi-materials”, i.e. materials used for the production of different orders. While ζ-Bread's primary "multi resource" was the dough, BTAB's most important "multi resource" was the Semi-finished fabric. Moreover, just as ζ-Bread, BTAB needed to consider the deadlines caused by the trucks' fixed departure times. Finally, like η-Gearboxes, BTAB needed features enabling the CBS-system to consider waiting times caused by the fact that some operations require more time than others.

Hence, previously developed standard features constituted important means during the development of BTAB's solution. Without these features, IFS may not have been able to support BTAB's planning situation, at least not within the frame of BTAB's projected budget. Apart from the costs for different system developers and implementation consultants, BTAB would probably have to pay a lot for the required overtime work of its own employees.

In conclusion, development of new standard features may both impede and foster future development. While it impedes development by creating complex networks of interdependent features, it fosters development by creating important means on which to economise. However, this is primarily considered by IFS. The buyer usually only perceives the services that the developed features can generate. Consequently, a particular development problem which from a buyer's point of view appears to be fairly simple, may from IFS's point of view be very difficult and vice versa.

7.3 Development of the CS Module prior to the BTAB project

IFS's first embryo of the Customer Scheduling Module was a specification list developed during the development of a so-called automotive vertical[2] at Volvo in 1996. By dividing IFS Application into different verticals, IFS tried to reduce the implementation costs. Apart from reducing costs for developing customer specific product features, the division reduced the time that the buyers' own employees needed to spend on the implementations. In the spring of 1998 the specification list was further developed. This development was based on a customer specific prototype which had been developed for κ-Automobiles. Six months later the first standard version of the Customer Scheduling Module was developed during an implementation at λ-Plastics.

[2] Segment of modules customised for the Automotive Industry.

7.3.1 κ-Automobiles

κ-Automobiles is an automotive manufacturer in Germany. The company's main objective with the development of the prototype was to simplify and automate the ordering process. Product orders had previously been sent to the suppliers in the form of different paper documents. Each supplier then manually split these orders into matching orders of components to be produced. When doing this they used certain lists specifying product structures, article data, and planning rules. Refined orders were either sent to the production department and/or to the purchasing department. Since the work was very labour-intensive, it caused high administration costs. Moreover, documents disappeared easily and data was often misinterpreted. By computerising some of these operations κ-Automobiles expected improved efficiency.

In the customer specific solution, new orders were received in the form of electronic messages. Every time a new message was recorded, the company's latest shipped delivery note was matched towards the latest delivery note that the customer had received. The purpose was to prevent deliveries from being skipped or doubled due to the fact that the customer had not yet received all shipped orders when sending the schedule. In step number two, schedules were checked against the allowable variances. Approved orders were finally recorded in the Customer Order Module from which the MRP was able to read every time it split up a customer's product into smaller pieces of need.

The functionality enabling the module to receive orders primarily addresses a "table" for storing data regarding received orders. The functionality matching delivery notes deals with a "table" storing data regarding the latest shipped delivery note, a "method" which collects this data from the Inventory Module, and a "table" storing data regarding customers' latest received delivery notes. It also includes a "method" which compares data that is stored in the two different "tables" and changing the order with reconciled quantity. The functionality that checks schedules against allowable variances primarily concerned two different "tables", one storing plan data and one storing data regarding allowable tolerances. Finally, the functionality recording orders within the Customer Order Module primarily required a "method" within the Customer Order Module transferring order data from the Customer Scheduling Module.

During the development project at κ-Automobiles, IFS began to realise that there might be a general need of a Customer Scheduling Module. The company therefore decided to send an experienced system developer to Germany. His mission was to map κ-Automobiles' requirements by conducting interviews with perceived key-persons within the project team that had developed the customer specific solution. The work resulted in the refinement of the specification lists previously developed in cooperation with Volvo.

7.3.2 λ-Plastics

λ-Plastics' production primarily consists of plastic items for the automotive industry, e.g. dashboards, inner panels, and different control equipments. The company struggled with long transportation lead times. For example, it normally takes about two days to ship plastic items to Spain. This resulted in a large amount of ordered goods on the road. The company therefore needed a functionality enabling it to regularly check that no deliveries were skipped or doubled due to the fact that shipped goods had not yet reached the customer. Apart from a functionality putting a unique number on every produced item, this required an EDI-functionality making it possible to automatically match the latest shipped delivery note and the latest delivery note received by the customer.

At the time of the implementation, there was no EDI-functionality within the standard version of IFS Application. IFS therefore decided to provide a temporary solution by using an external EDI-converter (developed by ρ-Software) converting customer's EDI-messages to messages that the Customer Scheduling Module was able to read. In addition to the EDI-converter, the EDI-functionality also required a "method" collecting data from the EDI-converter.

7.4 Analysis of prior development of the CS Module

Just like in the case of the CBS-module, IFS developed the CS Module in interaction with different buyers in a sequence. While the customers based on their knowledge of the user context, articulated the need of different facility features (s1-5), IFS interpreted these features into a number of complementary product features (f1-10), which together generated the requested facility features (see Figure 7.2).

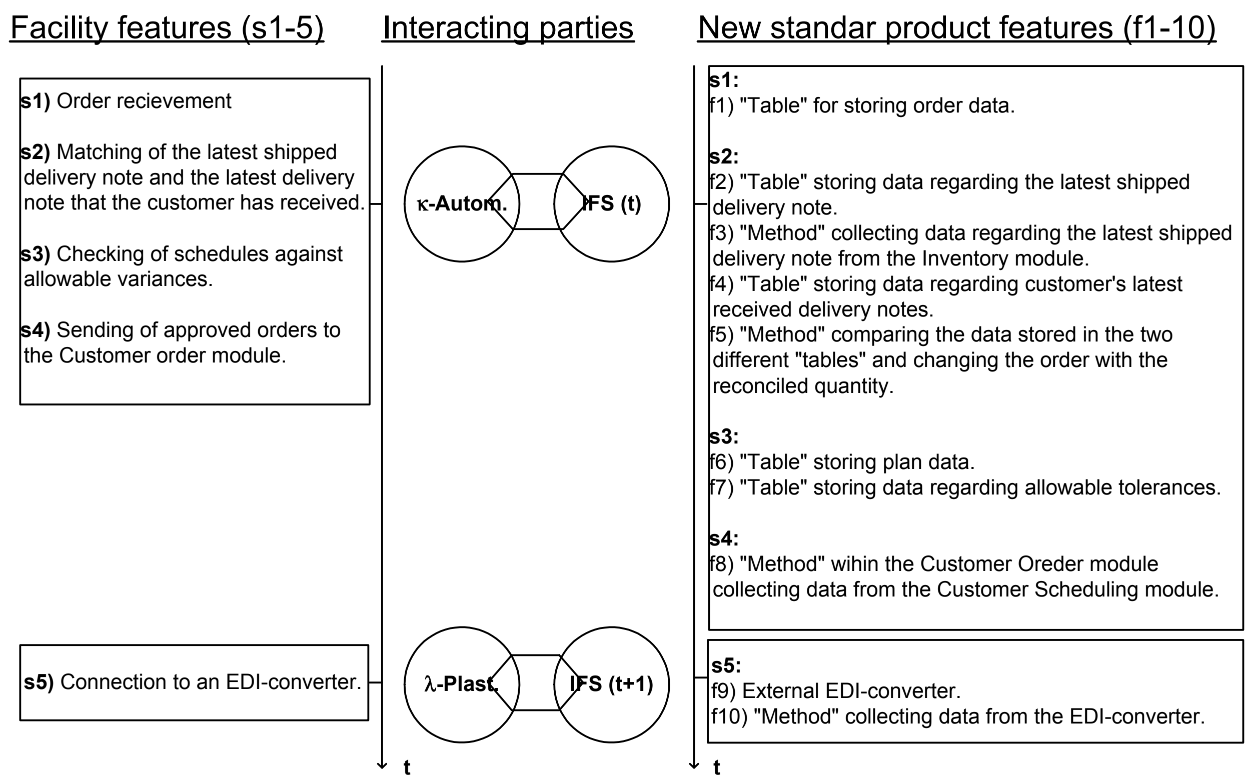


Figure 7.2: Standard product features (f1-10) developed in interaction with prior buyers, and the facility features (s1-5) they generated.

An important part of the CS Module was developed in interaction with κ-Automobiles. This was facilitated by the fact that the basic functionality of the CS Module was less complex than, for instance, the basic functionality of the CBS module. The CS Module could therefore be developed within a shorter time frame, i.e. within the frame of a single implementation project. Compared to a pure in-house development, one important advantage of development performed in interaction with buyers is the possibility to learn about the use context at an early stage.

Since the CS Module was much newer than the CBS module, it had not been implemented as often. Actually, only one implementation had been carried out before the implementation at BTAB. This implementation, which was performed at λ-Plastics, primarily contributed to the refinement of the standard system by the development of a feature enabling EDI-communication.

Since the CS Module does not include any calculation features, the interrelatedness among different internal connections is less complex than within the CBS module. However, similar to the CBS Module the CS Module is an integrated part of the ERP-system. Consequently, a change within the CS Module may call for additional changes within complementary modules such as the Customer Order Module and the MRP Module. Furthermore, through the "method" collecting data from the EDI-converter, the CBS Module is interconnected with complementary systems.

Like in the case of the CBS-module, existing standard features constituted important means during the development of BTAB's solution. Because of the time limits that always exist in relation to an implementation, IFS's project team at BTAB would not have been able to develop all features by itself.

7.5 Succeeding applications of the CS and the SS Modules

Soon after the implementation at BTAB, IFS implemented the CS and the SS Modules at ϕ-Plastics, μ-Hydraulics, and ν-Packings. This section focuses on how the standard features that had been developed in interaction with BTAB were utilised during these implementations.

7.5.1 ϕ-Plastics

ϕ-Plastics' planning situation was very similar to λ-Plastics'. However, while λ-Plastics almost exclusively produced plastic items for the automotive industry, ϕ-Plastics produced for a much broader span of industries. Apart from Volvo and SAAB, two of the company's most important customers were Electrolux and Ericsson.

Instead of sending EDI-messages Ericsson puts its master plans on a certain website. By using previously established article data and product structures, each single supplier individually splits these plans. In the beginning of the implementation, ϕ-Plastics required functionality that supported the existing way of working. However, when IFS presented IFS Application's scheduling functionality ϕ-Plastics reconsidered its requirement and decided to change its planning work in a way that would enable an implementation of the Customer scheduling module. After the implementation ϕ-Plastics worked in both ways, i.e. both received master plans from Ericsson and Electrolux and customer schedules from Volvo and SAAB.

One important advantage of the Customer Scheduling Module was perceived to be the possibility to automate ϕ-Plastics' registration of new plans. The company's range of products has increased dramatically during the last five years. This increase was primarily caused by the customers' product expansion and their increased use of plastic components. Out of one particular type of vacuum cleaner, Electrolux may produce as many as 15 different variants. Each of these variants may be composed of four different plastic components. Consequently, ϕ-Plastics may have to deal with more than 60 different articles.

The total volume demand of ϕ-Plastics' customers is quite stable. The company therefore did not need the ability to receive orders and check tolerances. A late change in Volvo's production schedule, lets say that Volvo needs a thousand striped seats instead of a thousand checkared seats, will usually not affect the colour of the plastic items used in these seats. Furthermore, it is much easier for λ-Plastics to increase its production of plastic items than it is for Volvo to increase its production of cars. Because of its relatively simple chain of production steps, ϕ-Plastics has very short production lead times. In case of increased demand, the company basically only has to shovel more granulate into the pressing machine.

The implementation did not require any major customer specific adaptations of IFS Application. The most important adaptation was a functionality that at a certain time (e.g. one week before delivery) automatically transformed plans into orders. Another adaptation was a functionality that at the time the scheduling module receives a new plan always erases the previous one. By providing permanent access to updated plans, this adaptation offers every planner an opportunity, whenever time admits, to check plans and thus avoid overloads of unread plans. IFS previously solved a similar problem at BTAB by developing a functionality making it possible to state how often the Repetitive Production Module should receive new plans from the MRP. However, this functionality often caused problems when a week included less than five work days.

7.5.2 μ-Hydraulics

μ-Hydraulics is a company producing hydraulic tools and gaskets for trucks. While the company's customers are big international truck manufacturers such as Scania and Volvo Trucks, its suppliers are a lot of small local workshops. Many of these workshops have very low production capacity, which restricts their abilities to handle demand variations. In order to improve the suppliers' ability to handle these variations, µ-Hydraulics used the scheduling module for generating production forecasts reaching a year into the future.

In µ-Hydraulics' ERP-system, each seller manually types in all delivery plans he/she receives from the customers into a certain "table" in the CS-module, from which the MRP Module is able to read. When the MRP Module later splits up these delivery plans into different purchase orders and production plans, the SS Module sends all purchase orders to the suppliers. However, since µ-Hydraulics' own production is exclusively based on customer orders, no production plans are sent to the Repetitive Production Module. This required functionality hiding all refined production plans from the Repetitive Production Module.

7.5.3 ν-Packings

ν-Packings is a company producing tape and foam rubber items for joining different components together. ν-Packings' input material primarily consists of big rolls with tapes and foam rubber film. The company processes this material in two different steps. Firstly, the company cut the material into smaller batches. Secondly, it punches out the required items.

ν-Packings' most important customers are Ericsson and Motorola. Since it is very difficult to predict the demand on particular telephone models, the customers' need of tape and foam rubber items frequently changes. Together, with the short lead times required by Ericsson and Motorola, these changes cause a difficult planning situation. In order to manage this situation, ν-Packings cuts on speculation and punches on customer order. Consequently, the company needed functionality for both handling forecasts and orders.

In order to be able to develop reliable forecasts, ν-Packings implemented the Master Scheduling Module. Unfortunately, this module is not compatible with the Customer Scheduling Module. When the Customer Scheduling Module receives a new plan, the corresponding quantities are not automatically subtracted from the quantities calculated by the Master Scheduling Module. An implementation of both the Master Scheduling Module and the Customer Scheduling Modules would therefore result in an ERP-system generating double needs. Since the estimated cost of a customer specific adaptation was high, ν-Packings chose to not implement the Customer Scheduling Module. However, if a larger part of ν-Packings' customers began to send plans, or if the required functionality is developed within the standard version of IFS Application, ν-Packings may reconsider its decision.

7.6 Analysis of succeeding applications of the CS and the SS Modules

ϕ-Plastics' need was, in many aspects, similar to BTAB's. For example, like BTAB, ϕ-Plastics produced a large range of different products, and therefore needed the features within the Customer Scheduling Module which, based on received EDI-messages, automatically updates stored plan data. However, since the company's production was not vulnerable to late order changes, it did not need features enabling the company to receive both plans and orders. Plans were instead automatically transformed into orders. This required an additional feature in terms of a "method" transferring data from the "table" storing order data to the "table" storing planning data, which later was integrated into the standard system.

μ-Hydraulics' need was similar to BTAB's in the sense that the company needed the features within the Customer Scheduling Module for handling plans. However, unlike BTAB, μ-Hydraulics did not need these features for the company's own production planning, but required them on the behalf of its suppliers. Consequently, in order to hide all production orders from the Repetitive Production module, IFS needed to modify a certain "view" within the MRP. This additional feature was not integrated into the standard system.

Like BTAB, ν-Packings had to cope with frequently changing demands. However, in contrast to ξ-Components, ν-Packings' most important customers, Ericsson and Motorola, do not send any plans. Consequently, the company's need of system features handling plans was limited. Together with the mismatch that existed between the Customer Scheduling Module and the Master Scheduling Module, this made the presumed benefits of implementing the CS Module small compared to the presumed costs of additional features. ν-Packings therefore decided not to implement the Customer Scheduling Module.

To summarise, because it was perceived to be manageable within the projected budgets, IFS developed the required additional features at ϕ-Plastics and μ-Hydraulics. In the case of ν-Packings, on the other hand, presumed benefits of implementing the CS Module did not exceed presumed costs of required modifications. Consequently, IFS did not develop any additional features. One may therefore conclude that prior development affects the path of succeeding development.

This chapter has showed that present development efforts are not only affected by the present structure of interdependent resource units. But because the established structure results from prior development efforts, present development efforts are indirectly also affected by prior development efforts. It was argued that prior development efforts both impede and foster future development efforts. While it impedes development by creating complex network of interdependent resource units, it fosters development by creating important means on which to economise. The chapter has also showed that present development efforts in turn constitute important means during subsequent utilisation and development efforts, and that present development efforts therefore have an important impact on future utilisation and development. Hence, an important issue for IFS when developing a specific feature is to choose among existing product features to economise on without jeopardising the present utilisation of these features, and simultaneously evaluate the possibility to utilise the new feature in future implementation projects. This issue is further analysed in Chapter 9.

8 ADAPTATIONS WITHIN A NETWORK OF TECHNICAL RESOURCE UNITS

This chapter discusses adaptations within a network of technical resource units. Section 8.1 and 8.2 takes both the supplier's and the buyer's perspective. While Section 8.1 deals with how a specific mix of standard and customer specific product features is developed through mutual adaptations between a supplier's product and a buyer's production facility, Section 8.2 concerns how the two companies can handle the effects that an adaptation may have on other parts of the network. Section 8.3, which exclusively takes the supplier's perspective, discusses the effects that the development of new product features may have on the supplier's future exploitation and exploration.

8.1 Developing a mix of standard and customer specific product features

New product features are developed when a product is exchanged and adapted to specific use contexts. Levine & White (1961: 588) define organisational exchange as a *"voluntary activity between two organisations which has consequences, actual or anticipated, for the realisation of their respective goals"*. An overall goal for both the supplier and the buyer is to get the most out of available resources. This may make the two companies try to keep existing designs as they are. While the supplier may try to keep the existing standard product design, the buyer may try to keep the existing production facility design. However, in some situations the efforts to utilise existing resources may also motivate companies to change existing designs. If the buyer believes that a change will improve the company's resource utilisation as a whole, the company may agree to adapt the design of its production facility to the existing features of the supplier's product. Similarly, if the supplier believes that the company will benefit from a development of the standard product, the company may agree to adapt the design of its standard product to the existing features of the buyer's production facility. This might be the case when the supplier thinks that the new product features can be utilised in other customer solutions, and thus enable the company to spread its development costs over different solutions. Hence, the decision whether to adapt the product to the other parts of the customer's production facility/product and/or vice versa is subject to a negotiation process where both the supplier's and the customer's established resource structures are considered.

The case illustrates two different kinds of product adaptations; 1) adaptations of the standard product and 2) customisations. Adaptations of the standard product may be divided into component and architectural modifications. While a component is a physically distinct portion of a product that performs a well-defined function, the architecture of a product lays out how the components will work together (Henderson & Clark, 1990). Component and architectural modifications are mutually interdependent. The performance of the product depends on the performance of every integrated component, as well as how these components work together. As the performance of the product as a whole depends on a large number of complementary components, the change of one component may call for additional changes of some other components. Due to the large number of interdependencies that always exist within a network of technical resource units, the effects on other components may be widespread. Henderson & Clark (1990) argue that architectural innovations are often triggered by a change in a component that creates new interactions and new linkages with other components in the established product. Conversely, new architectural innovations, i.e. new configurations of components, may require some adjustments among involved components. This is not only due to the emergence of various physical mismatches, but also due to the fact that the service that every individual component generates, and thus the performance of this component, depends on how it is combined with other components.

According to Dhebar (1995), a new product may require time, money, and efforts for re-establishing complementarities which are disrupted when the buyer's resource structure is changed in order to fit with the features of the product. Similarly, a change of one product may require time, money, and efforts for re-establishing complementarities between different products within the supplier's product collection. Additional changes within the supplier's product collection may also have negative effects on the utilisation of these products in various customer solutions. When possible benefits for the supplier to develop do not exceed possible drawbacks, in terms of disrupted complementarities, the company may choose to develop a customisation.

The case illustrates three different kinds of customisations. One kind of customisation is to select a group of standard components that can be used for the generation of required services. Another kind of customisation is to combine these components in a way that creates a solution which generates the required services. In order to make the different components fit together some adjustments among involved components are often required. The effects of making such adjustments partly depend on the product's degree of modularity. According to Schilling (2000:314):

> *"modularity is a continuum describing the degree to which a system's components can be separated and recombined, and it refers both to the tightness of coupling between components and the degree to which the "rules" of the system architecture enable the mixing and matching of components. Since all systems are characterised by some degree of coupling between components, and very few systems have components that are completely inseparable and that cannot be recombined, almost all systems are, to some degree, modular"*.

A third kind of customisation is to bridge possible gaps between generated services and required services by adapting the product's interfaces towards other parts of the buyer's production facility. These adaptations may be divided into adjustment of existing product components and development of additional components separated from the supplier's standard product collection. Decisions whether to adjust existing components or to develop an additional component depends on the extent of the adaptation. The more extensive the adaptation is, i.e. the larger the number of components that need to be adapted in order to enable the solution to generate requested facility features, the more convenient it may be to develop an additional component which alone can generate these features. By limiting the number of components that need to be adapted, an additional component reduces the number of interdependent interfaces that needs to be dealt with. Such reduced complexity does not only simplify the integration of the solution into the buyer's production facility, but may also simplify future upgrades. Apart from reducing the time that needs to be spent on developing new technical features, a reduced number of interfaces cuts down on the time needed to detect various interdependencies and deal with them.

Both adjustments among involved product components and in the product's interfaces towards other parts of the buyer's production facility may be further divided into design and setting adaptations. While a design adaptation concerns a new product feature, a setting adaptation only concerns the choice of one out of two or several different predefined settings. As setting adaptations are less labour intensive and easier to undo than design adaptations, companies may, in situation of choice between these two kinds of adaptations, often prefer setting adaptations.

If and how a customisation is carried out is decided by the interrelation between the buyer's and the supplier's total costs for required resources (components, man-hours spent on the integration work, etc.) and the buyer's possible returns from a maintained resource structure. If the buyer's costs for a certain customisation, including the price that the supplier charges for the product, exceed the company's possible returns from maintained resource structure, the buyer may instead choose to adapt its production facility to the features of the supplier's standard product. The case illustrates how these adaptations may be divided into technical and administrative adaptations. Technical adaptations are carried out at the physical interfaces between the supplier's product and the buyer's existing production equipment. For example, a buyer of a new ERP-system may adapt its previously implemented IS-systems to the features of the supplier's standard system. Administrative adaptations are carried out in the functional interface between the supplier's product and the buyer's existing work routines. For example, a buyer of an ERP-system can adapt the company's planning routines to the features of the system.

Indirectly, integration of new production equipment may also call for adaptations among different parts of the buyer's existing production facility. Just like the adaptations that are made towards the supplier's standard product, these adaptations may be divided into technical and administrative adaptations. Technical adaptations are carried out at the physical interfaces between different parts of the supplier's existing production facility. For example, when a new ERP-system is implemented at one production site, sequentially interdependent production sites may need to implement the same system. Administrative adaptations, on the other hand, are carried out at the functional interfaces between different parts of the supplier's existing production facility. Besides different production planning routines, these adaptations may involve time of delivery, information provision, and various production operations.

No company is an island but rather embedded into a network of business relationships. Apart from a web of interactive relations between individuals (Håkansson & Snehota, 1989), every business relationship in this network is a web of physical and functional interfaces between different technical resource units. Through certain junctions, in terms of different technical resource units, these technical and functional interfaces are interconnected with each other, thus forming an infinite network of physical and functional interfaces (see Figure 8.1).

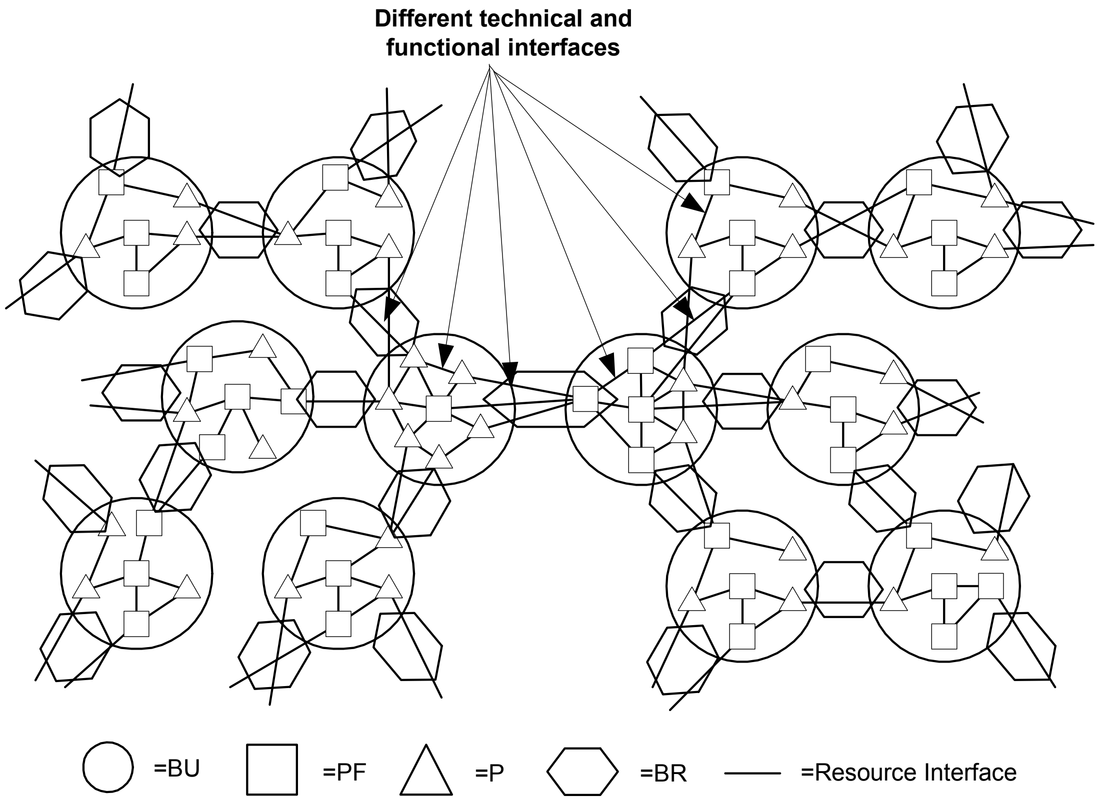


Figure 8.1: A network of technical and functional interfaces between different technical resource units.

Due to the interconnectedness among technical resource units, the buyer may not only need to make intra-organisational adaptations, but also adapt the substance of some of the company's business relationships. This may have an important impact of various third parties. For example, the buyer of an ERP-system's customers and suppliers may need to change the way they send and receive their orders. This may not only affect the functional interface, e.g. the time and contents of each order, between the buyer's production facility and the production facilities of various counterparts, but also the physical interface. The case showed a situation where one of the buyer's sub-contractors implemented the same system solution as the buyer. This implementation changed the physical interface between the two companies' different production facilities. Moreover, due to improved communication, the subcontractor's implementation changed the buyer's knowledge about the sub-contractor. This improved knowledge may be viewed as a change at the knowledge interface between the two different organisational units.

To summarise, the developed mix of standard and customer specific product features results from a negotiation process where both the supplier's and the buyer's resource structures are considered. New product features are developed when the supplier's product is adapted to the existing features of the buyer's production facility. Product adaptations can be divided into: 1) adaptations of the standard product and 2) customisations. Adaptations of the supplier's standard product may in turn be divided into component and architectural modifications. These two kinds of modifications are interrelated. As the performance of the product as a whole depends on several different components, a modification of one component may require additional modifications of other components. Conversely, a new configuration of components may require some modifications at their interfaces towards each other.

Three different ways/steps in which a supplier may carry out a customisation has been identified: 1) By selecting standard components that may generate required services, 2) by combining the standard components in a way that actually generates these services, which may include redesigning some component interfaces, and 3) by over-bridging remaining gaps between generated services and required services. There are two ways to bridge a gap between generated services and required services: 1) by adjustments of already existing components and 2) by development of additional components separated from the standard version. Adjustments of already existing components may be further divided into design and setting adaptations.

If the buyer's costs for a certain customisation exceed the company's possible returns from maintained resource structure, the buyer may choose to adapt its production facility. Adaptations of the buyer's production facility can be divided into technical and administrative adaptations. While technical adaptations may be carried out at the physical interfaces between the supplier's product and the buyer's existing production equipments, administrative adaptations are primarily carried out at the functional interface between the supplier's product and the buyer's existing work routines. Due to interdependencies that always exist among different technical resource units, adaptations of the buyer's production facility may call for additional adaptations in other resource interfaces. This may not only concern interfaces between the company's internal resources, but also the substance of its business relationships

As previously argued, it is sometimes an advantage to make adaptations. By adapting its planning routines to the features of a standard ERP-system, a buyer normally improves its internal and external coordination activities, and thus the utilisation of the company's resource collection. By adapting its product to a particular buyer's production facility, a supplier may explore new product features that can improve the company's future ability to support buyers that experience the same need as the one who required the adaptation. A supplier's ability to utilise a product feature in future applications is further analysed in Section 8.3. However, product adaptations may also have negative impacts on the supplier's ability to support other customers, at least if they concern the standard product. Apart from calling for extra adaptations during succeeding buyer interactions, adaptations of the standard product may call for additional adaptations during future upgrades of prior customer solutions. Similarly, adaptations of the buyer's production facility may have negative effects on the buyer's business relationships. For example, a buyer who adapts its work routines to the standard version of an ERP-system may, in some situations, deteriorate the coordination between these routines and the routines of certain counterparts. Uncertainty about the effects that a certain change may have on established intra- and inter-organisational resource structures, and thus indirectly on future intra- and inter-organisational development efforts, may make a company try to limit the "change boundary" (Holmen, 2001) of their adaptations. Suppliers' and buyers' efforts to limit this boundary is analysed below.

8.2 Limiting the change boundary of adaptations

Lampel & Mintzberg (1996) discuss five strategies that a selling company may apply in order to customise partway back in its value chain, while retaining standardisation of the rest. These strategies include different mixes of general and specific features, beginning with pure standardisation and ending with pure customisation. Different mixes provide different opportunities to gain through economy of scale in relation to production and design, as well as to a minor additional adaptation cost, provide efficient customer specific solutions. Similarly, there are different strategies that a selling or a buying company may apply in order to limit the "change boundary" of their adaptations.

The most obvious way for a buyer to limit the change boundary of its adaptations is to require a pure customised product. Although it may limit the company's internal adaptation costs, this strategy has some important drawbacks. Firstly, it might call for extensive interaction with the supplier, which penetrates deeply into the design process itself. Apart from needing a capability to specify requirements, and thus some prior design knowledge, the buyer may have to make important investments in learning about the supplier's resource structure. Conversely, the supplier may have to invest a lot of time and capital in learning about the buyer's resource structure. Hence, a pure customised product might both directly (due to time spent on learning, informing, persuading, negotiating, coordinating, and teaching) and indirectly (because of the higher price that the supplier may charge for the product) cause the buyer large interaction costs.

Secondly, by requiring a pure customised product the buyer may lose an opportunity to take advantage of some of the supplier's previously acquired experiences from combining the product with different customers' resources. Every technical resource unit carries the imprints of previous combinations. These imprints, which may both concern new as well as modified technical features, may either be developed within a single company or in interaction between two companies. Features which have been developed in interaction between a supplier and a specific buyer may be seen as a representation of the buyer's knowledge about certain interdependencies within this company's particular use context. By adapting to these features, another customer may, during a subsequent interaction, benefit from the knowledge which previously have been built into the product. The case illustrates how new product features are subsequently added to the standard product, and how this enables the supplier to support a growing number of planning situations.

Thirdly, by requiring a pure customised product the buyer may make it difficult for the supplier to capture similarities among its customer relationships, and thereby gain through economy of scale. Holmen et al. (2003) argue that such similarities can be viewed as dimensions in which two or more relationships can be dealt with as "homogeneous". According to Håkansson (1994) there are clearly positive effects of treating counterparts as homogeneous. The most obvious reason is the economy of scale. *"Scale effects can occur if there is some homogeneous part of the solution, if there is some specific component which can be applied on a larger scale by the counterparts, for example to serve several customers"* (ibid:266). This is by no means to say that these customers are homogeneous regarding their use of specific components, but only that they can be dealt with as homogeneous regarding their utilisation of these components. When being combined with different resource collections, a product always renders different services.

By reducing the supplier's possibilities to gain through economy of scale, a pure customisation may increase the price that the buyer has to pay for a specific service. Moreover, the buyer may lose an opportunity to take advantage of the experiences that the supplier may gain during future development of specific customer solutions, i.e. the experiences that the company will gain from subsequent buyer interactions. Appleyard (2003) claims that, under certain conditions, the buyer should favour generally applicable modifications over customised modifications because they promote knowledge growth at the supplier over time. As the supplier's expertise grows, the company can improve its support of the equipment in the field, as well as convert the knowledge into equipment upgrades (ibid:357).

The most obvious way for the supplier to limit the change boundary within the company's resource structure is to provide pure standardised products. However, this strategy has two severe drawbacks. Firstly, it requires that the buyer is able to carry out all necessary adaptations by itself. This may make the buyer suffer from high switching costs, i.e. costs for re-establishing the complementarities that have been disrupted by the new product (Dhebar, 1995). Apart from the change of operational skills, that, once internalised may be difficult to unlearn (David, 1985), and the acquirement of new products and production facilities compatible with the new product, these switching costs may include the development of new interfaces between the new product and its various complements. Secondly, as knowledge produced by learning-by-using can only be transformed into new products when the developer has a direct contact with the user (Lundvall, 1988), a pure standardisation strategy limits the supplier's opportunity to utilise use experiences. Since possible interactions between products and their use contexts might be too complex to predict, these kinds of experiences are important (Rosenberg, 1982; Habermeier, 1990). Without experience of use, a supplier will be less able to develop products that fit with, and contribute to the performance of, different buyers' operations.

A strategy that a supplier may apply in order to provide products that fit with different customers' production facilities, and at the same time avoid adaptations of the standard product, is to develop customer specific product features separated from the standard product. Apart from improving the buyer's perceived value of the product, this strategy enables the supplier to learn about different use contexts and to experiment with new solutions. Previously acquired knowledge about different use contexts may constitute an important means for the supplier when the company in interaction with a particular buyer develops a new customer solution. However, even this strategy has its drawbacks. As the new features are specifically adapted to a certain customer's resource collection, it might be difficult for the supplier to reuse them in other customer applications. Hence, the strategy reduces the room for further exploitation on the developed features.

A third strategy for the supplier to limit the change boundary of adaptations is to create a modular product architecture, where every standard product is divided into a certain number of modules with standardised interfaces. As a change made of one component does not necessarily require a change of other components in order for the product to work correctly as a whole, a modular product architecture makes it possible to create customer specific solutions by assembling a "unique" combination of standard components (Ulrich, 1995). This may not only reduce the time for developing efficient customer specific solutions, but also improve the supplier's possibility to spread the company's development costs over a large number of units (Langlois, 1999). Furthermore, as they enable accumulation of learning and experiences, these standard components, in general, exhibit higher performance (for a given cost) than pure unique designs (Ulrich, 1995). More importantly, by creating loose couplings between component designs, and thus localising environment disturbances within specific subsystems, modularisation may limit the change boundary of adaptations (Orton & Weick, 1990).

Although it may limit the extent of customer specific features, modularisation is by no means the ultimate way to avoid additional adjustments. For some modular products, it might not be possible to create an efficient solution without adding or redesigning some components. There are primarily two reasons for this. Firstly, problems with incomplete or imperfect modularisation tend to appear when the modules come together and work poorly as an integrated whole (Baldwin & Clark, 1997). This usually calls for continuous additional adjustments among the integrated components. Secondly, and more important for this thesis, the extensive variety among different customer contexts often calls for some kind of adaptation, in terms of additional customer specific components. A module that is used in many types of applications may also be exposed to very diverse requirements. If the module is designed to fit all these requirements, the module may become "too general". Consequently, no customer will regard the product to be the best solution.

For providing modules that only require minor modifications when being used in new customer solutions, the supplier may gather its modules into different sets of modules, each set being adapted to a segment of buyers with similar needs and/or use contexts. A set of modules that are, from the beginning of the supplier-buyer interaction, closer to the customer's needs, enables the supplier to supply a solution more quickly and at lower adaptation costs. Apart from being more adapted to particular buyers' production facilities, each module may be more adapted to other modules that are used in the same solutions. Furthermore, as it facilitates development of more generally applicable standard product features, the gathering of modules into different sets facilitates accumulation of experiences.

In order to improve the company's possibility to gain through economy of scale regarding the development of different product features, the supplier may use different versions of the same module in different sets. However, in time, different versions may not only become very specific for a certain segment of customers, but also become specific to other modules within the same set. The more integrated designs resulting from this process may limit the scope of application. This may restrict the supplier's ability to support new customers that do not fit into any existing segment.

To summarise, one strategy that a buyer may apply in order to limit the change boundary of adaptations can be identified. This is to require a pure, customised product. Although it may limit the company's internal adaptation costs, this strategy has three important drawbacks. Firstly, it may both directly and indirectly (because of the higher price that the supplier may charge for the product) cause extensive interaction costs. Secondly, it may make it difficult for the supplier to capture similarities among its customer relationships. Indirectly, this may not only increase the price that the buyer may need to pay for a specific service, but also the buying company's opportunity to take advantage of the supplier's experiences of subsequent customer interactions. Thirdly, by requiring a pure customised product the buyer may lose an opportunity to take advantage of the supplier's experiences of preceding customer interactions.

Four different strategies that a supplier may apply in order to limit the change boundary of adaptations can be identified. All of them are associated with certain advantages and disadvantages.

1. The supplier may provide a pure, standardised product. However, apart from limiting the supplier's opportunity to utilise different use experiences, this requires that the buyer is able to carry out all necessary adaptations.

2. The supplier may provide additional product features separated from the standard product. Apart from improving the buyer's perceived value of the product, this strategy enables the supplier to learn about different use contexts. However, the strategy may also result in specific product features which leave little room for further exploitation.

3. The supplier may create modular product architecture. Apart from limiting the change boundary and improving the supplier's possibility to gain through economy of scale, this enables accumulation of learning and experiences from different use contexts. Moreover, it reduces the need for additional adjustments and the time for developing customer specific solutions. Unfortunately, problems with incomplete or imperfect modularisation tend to appear when the modules come together and work poorly as an integrated whole. The extensive variety of different customer contexts may also make it difficult to design modules that fit many different customers without turning "too general".

4. In order to provide modules that only require minor modifications when being used in new customer solutions, the supplier may gather its modules into different sets of modules, each set being adapted to a certain segment of customers. Apart from reducing the time and the cost to develop customer specific product features, this strategy enables individuals to develop more finely structured networks of knowledge and perception regarding the particular use context. However, by making modules more adapted to specific customers, and by causing more integrated designs, the gathering of modules into different sets sometimes restricts the supplier's ability to support new customers that do not fit into any existing segment.

While the analyses made thus far have taken a dyadic perspective, the analyses in Section 8.3 and Chapter 9 take the supplier's perspective.

8.3 New product features and lock-in effects

Through being combined and adapted to other resources, the features of a product may over time change. By increasing a product's variety of interfaces, and thus its versatility due to combination, new product features may facilitate future exploitation. Apart from improving a supplier's ability to economise on other companies' investments in complementary products and production facilities (Håkansson & Lundgren, 1997), improved versatility due to combination may facilitate the company's future economisation of its own standard product features. By broadening the range of possible solutions, improved versatility due to combination may also improve the company's future possibilities to gain through economy of scale. Furthermore, as it reduces the "gap" between a supplier's existing resource collection and required solutions, and thus the cost of making necessary adaptations, development of new product features may also facilitate the company's future exploration. However, an improved possibility to economise on existing standard features, to achieve economy of scale, and to explore new standard features requires that future exploitation and exploration is in line with the path which, together with prior development, is paved out by the new product features. In other words, whether the versatility due to combination is improved or not, is "path-dependent" (Rosenberg, 1982). The theoretical expression, "path-dependence", is used here, not in a strictly deterministic sense, but in the more modest sense, i.e. that doing one thing improves or reduces the ability to do certain other things.

How present exploration affects the path of future exploitation and exploration may partly be explained by various "lock-in" effects. According to David (1985), there are three important reasons behind such effects: Economies of scale, quasi-irreversibility of investments, and technical inter-relatedness, or the need for system compatibility. Lock-in effects due to economy of scale originate from organisational units' efforts to gain through economy of scale. An important source of economy of scale is development costs, which can be spread over an arbitrarily large number of units (cf. Langlois, 1997). The possibility of spreading product development cost over different customer applications is affected by the standard product's variety of interfaces, and by how well these interfaces fit with, and contribute to, the performance of different buyers' resource collections.

Lock-in effects due to quasi-irreversibility of investments are caused by "sunk-costs", i.e. costs that are no costs at all from the point of view of the present.

Kirzner (1972:195) argues that due to irretrievable expenditures *"the cost of producing a given product turns out to be of one magnitude when referred back to the earliest in a long past sequence of decisions and of a different magnitude when referred back to another decision in that sequence"*. Hence, the cost of a new customer solution is affected by the size of the gap that needs to be bridged between required solutions and previously developed product features.

Lock-in effects due to technical inter-relatedness are caused by the time, money, and effort to re-establishing the complementarities that may be disrupted by a product change (Dhebar, 1995). In Chapter 2, lock-in effects due to technical interrelatedness were discussed in terms of a product's "heaviness". Apart from the cost of changing the product feature itself, it was argued that this "heaviness" is affected by the cost of changing complementary features of other products within the same product collection, and the cost of changing complementary features within the resource collections of various buyers. Increased heaviness reduces the product's versatility due to modification, i.e. the possibility to, at a certain interface, combine the product with certain other resources without making significant adaptations in various additional interfaces.

This is by no means to say that heavy resources can not be adapted, but that strong forces are required in order to change their features, i.e. that possible benefits need to be large enough for justifying necessary investments. Heavy resources may therefore make the interacting parties redirect the locus of adaptation to less heavy resources. Some heavy resources might even become considered as fixed points to which all other resources are adapted (Ford et al., 1998). By limiting the sphere of possible actions, such fixed points may sometimes help organisational units from not being overwhelmed with possibilities, and thereby facilitate these units' development work. A fixed resource may even have an important impact on the ends that a company wishes to achieve. Ford et al. (2002) claim that, for companies that are controlling fixed resources, the general end is to improve the utilisation of these resources.

An organisational unit's ability to consider different lock-in effects is affected by the unit's knowledge about different interdependent resource units. While its ability to consider lock-in effects due to economy of scale can be assumed to depend on its knowledge about similarities among particular products' interfaces towards different customer solutions, its ability to consider lock-in effects due to quasi-irreversible investments depends on its knowledge about different complementary resources, including how to access and combine these resources. An organisational unit's ability to consider lock-in effects due to technical interrelatedness depends on its knowledge about how other resources may be affected by a certain change. Just like the product itself, the organisational unit's knowledge evolves as it utilises the product in different resource combinations. Apart from learning about different interdependent resource units as such, the organisational unit learns about the long- and short-term goals of the organisational units which are controlling these technical units. While knowledge about interdependent resource units includes knowledge about whom to turn to in order to access certain tangible and intangible resources, and how other companies may be affected by a certain change, knowledge about other companies' goals includes knowledge about how to mobilise other companies in different development efforts. Hence, how a company chooses to distribute its development decisions among different organisational units and the time, as well as the sequence of these decisions, has an important impact on a company's exploitation efforts. Furthermore, as new features are built on existing ones, the distribution also has an important impact on the path of exploration, and thus indirectly on the company's future possibility to exploit on existing product features.

To summarise, new product features are explored when a product is adapted to other resources. If future development follows the path which, together with previous development, has been paved out by the new features, the exploration may facilitate the supplier's future exploitation and exploration efforts. Due to various lock-in effects, the creation of certain future possibilities requires the exclusion of others. The more an interface is adapted to certain resources, the less it is adapted to some other resources. Moreover, since the variety of a resource is an indication of its number of interfaces with other resources (Håkansson & Waluszewski, 2002), a large variety of interfaces results in a large number of additional interfaces that may need to be adapted. As different organisational units are able to consider different lock-in effects, and since their ability changes over time, both the distribution of development decisions among organisational units and the time and sequence of their decisions have an important impact on a company's exploitation and exploration efforts. In other words, a company's organisation of different development activities is important for the company's ability to exploit on previous development and simultaneously explore new features that can facilitate the company's future exploitation efforts.

A company that wants to exploit on certain existing features of its product and simultaneously explore new features that can facilitate future exploitation, needs to posses the ability to economise on existing features when developing customer solutions that fit with particular customers' resource collection. The company also needs to possess the ability to identify similarities among different customer solutions. Furthermore, it needs the ability to deal with a large number of interdependent interfaces, both within the product itself and among its interfaces towards different customer solutions. How a company may design its organisation in order to capture similarities, perceive different opportunities to economise on existing features, and deal with different constraints due to technical interrelatedness, is further analysed in Chapter 9.

9 ORGANISING THE INTERPLAY BETWEEN EXPLOITATION AND EXPLORATION

This chapter takes a supplier perspective, thus discussing how a supplier may combine the logic of individualisation with the logic of aggregation, and thereby improving its ability to perceive and deal with different opportunities and constraints. The chapter is divided into four sections. Section 9.1 focuses on how the supplier, by dividing its development into different organisational units, may frame the network of considered interfaces. It includes a discussion of how the framing of considered interfaces improves the company's ability to perceive and handle certain interdependent resources. Section 9.2 deals with how the network of perceived and considered interfaces, due to interdependencies among different resource interfaces, may change. The section includes a discussion of how a change of the network context may affect the supplier's knowledge about different interdependent resources, and thus the company's future ability to perceive and deal with different opportunities and constraints. Section 9.3 concerns how two different organisational units' reciprocal exploitation of each others' output coordinates the units' diverse development efforts. Finally, some concluding remarks are made in Section 9.4.

9.1 Framing the network of considered interfaces

A company that wants to develop efficient customer solutions needs to deal with two partly conflicting development issues. The first issue is to develop specific customer solutions that fit with and contribute to the performance of a particular buyer's existing resource collection. Apart from identifying standard product features that can be exploited in the generation of the required services, and thereby reduce the development costs of specific solutions, the issue primarily concerns the task of making certain technical resource units more specialised and directed towards each other.

The second issue is to explore if and how new standard product features can be exploited in several customer solutions. In other words, explore how to improve the versatility of the standard product, and thus facilitate the supplier's future development of customer solutions. As mentioned in Chapter 3, Holmen (2001) makes a useful distinction between "versatility due to combination" versus "versatility due to modification". While the versatility due to combination primarily relates to the product's "variety" of interfaces, the versatility due to modification primarily relates to the "heaviness" of the product in relation to other resources. Consequently, in order to increase the versatility of a product, a supplier may need to increase the product's "variety" of interfaces, and/or decrease its "heaviness" towards specific customer solutions. One important task during the development of a standard product characterised by a high degree of versatility is to first identify similarities among different customer relationships in terms of required services, and then to develop standard features that can generate these services. Another important task is to identify opportunities to build on already developed standard features without jeopardising the present utilisation of these features.

The case provides examples of situations where huge numbers of interdependent resource interfaces need to be considered. Apart from the interface between the customer solution and other parts of the buyer's resource collection, there are important interfaces among different standard products provided by the supplier. As these products are utilised in several customer applications, the supplier also needs to consider their interfaces towards other customer solutions. Furthermore, due to the interdependencies that always exist within a network of technical resource units, the supplier needs to consider these solutions' interfaces towards other parts of the buyers' resource collection. Finally, the supplier needs to consider the buyers' interfaces towards various third parties, e.g. towards various customers, suppliers of input materials, and suppliers of other parts of the buyer's production facility.

Due to the notion of "bounded knowledge" (Simon, 1958), one may presume that no organisational unit can consider all these interdependencies when it, by modifying/developing one or several features, tries to fit two resources together. Consequently, an organised framing of the network context is needed. Thompson (1967:79) argues that *"when interdependence is extensive, organisations first rank-order the interdependent positions in terms of the amount of contingency each poses for the others, and then forms a group of those with the greatest intercontingency"*. The case illustrates how the focal supplier has divided its development activities between a Project Department and a R&D Department.

The Project Department (A) concentrates on the issue of developing specific customer solutions that fit with and contribute to the performance of particular buyers' existing structures of technical resource units. This requires knowledge about the interface between a particular solution and the resource collection of which the solution will become a part (see Figure 9.1). It also requires knowledge about the solution's interfaces towards different standard products within the supplier's product collection, and how to over-bridge possible gaps between their features and the features of the buyer's resources. Moreover, when the solution consists of a combination of certain standard products, the development requires knowledge about how these products can be combined into specific customer solutions. Finally, due to the interconnectedness among resource interfaces, the development of an efficient customer specific solution may call for knowledge about how a change of technical resource units within the buyer's resource collection may affect the resource collections of various third parties.

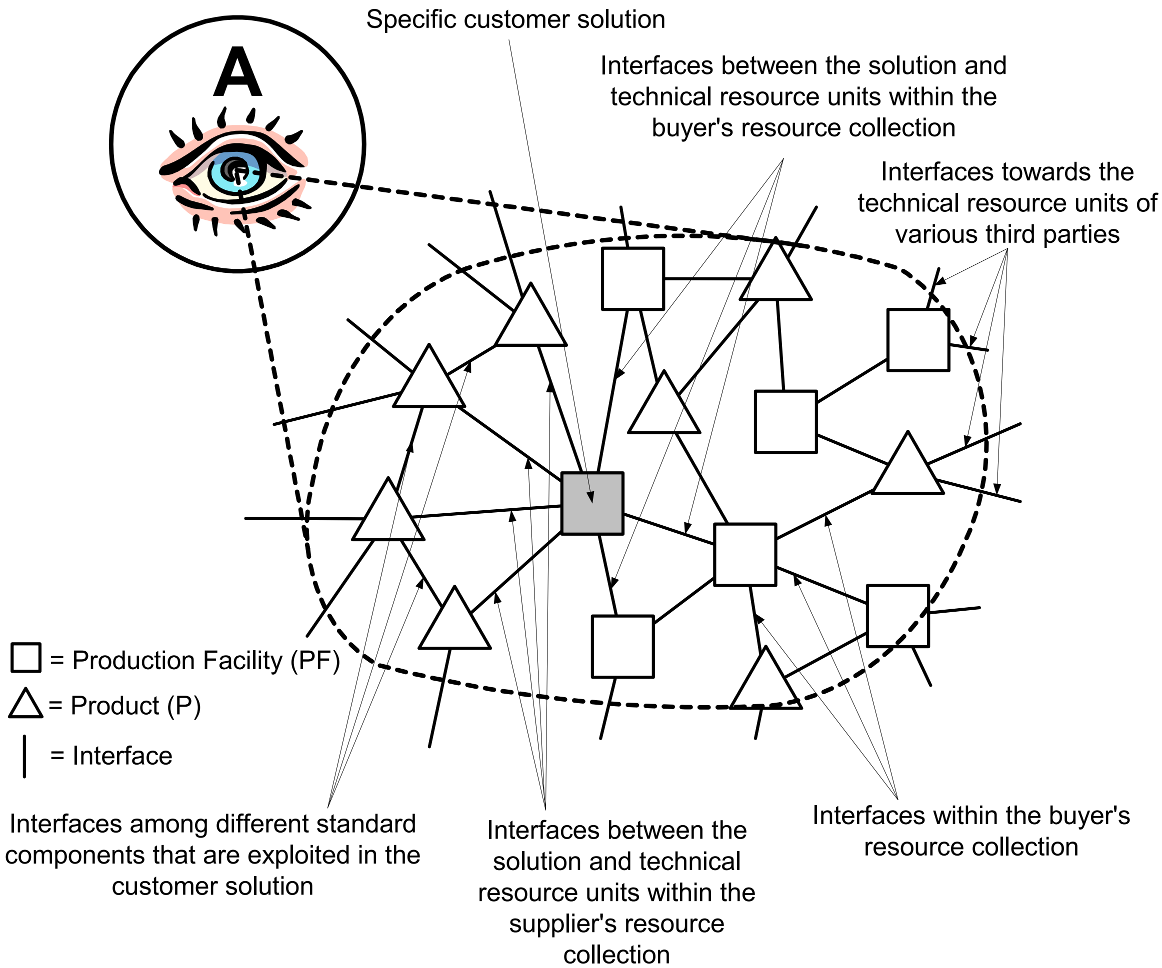


Figure 9.1: The Project Department's (A's) network context for a specific customer solution.

The R&D Department (B) concentrates on the issue of developing standard product features that can be utilised in many customer solutions. As the issue concerns the task to capture similarities in required services among different customer solutions, it calls for another organised framing of the network context (see Figure 9.2).

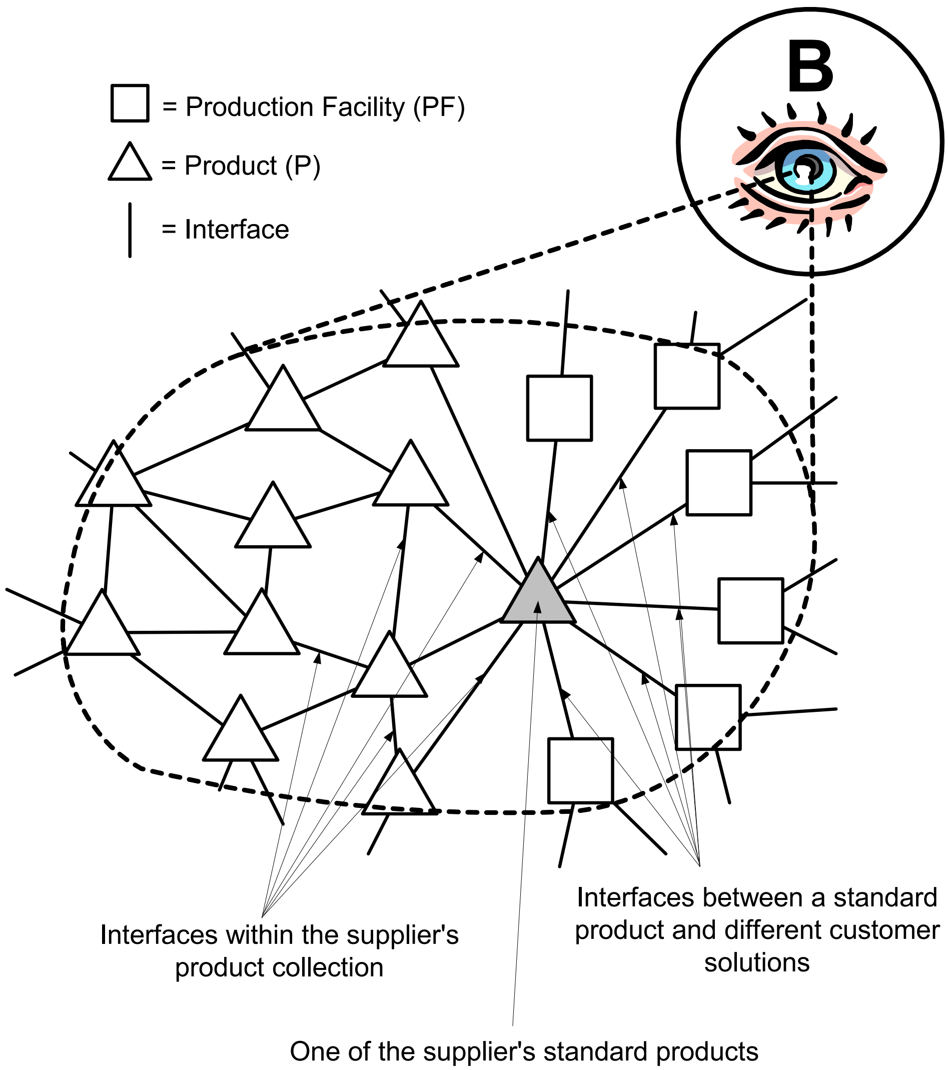


Figure 9.2: The R&D Departments (B's) network context for one of the supplier's standard products.

Besides focusing on the standard product collection's interfaces towards different customer solutions, the R&D Department focuses on interdependencies among different standard modules within this product collection. By focusing on the standard product collection's interfaces towards different customer solutions, the department gains knowledge about similarities among different customer solutions, in terms of required product features. As it enables the department to identify product features that are general for several different solutions, this knowledge improves the supplier's ability to develop standard product features that can be utilised in many different customer solutions. By focusing on interdependencies among standard products, the department gains knowledge about different standard products' features, and about how the features of different products interrelate. Together with the R&D Department's knowledge about every standard product's interfaces towards different customer solutions, this knowledge enables the department to identify a suitable way to split the development of new features among different standard products. In other words, it improves the supplier's ability to find a way to utilise existing standard product features without disrupting various complementarities within the produce and/or the use context.

As illustrated in Figure 9.3, the Project Department (A) is divided into several project teams (A_1,…, A_n) that, in interaction with particular customers (C_1,…, C_n), develop specific customer solutions (PF1,…, PFn). By enabling specialisation on specific types of use contexts, this division facilitates development of more finely structured networks of knowledge about these contexts. A more finely structured knowledge improves the supplier's ability to consider various complementarities within buyers' established resource structures. The specialisation also facilitates identification of similarities among different development projects, and thus improves the project teams' abilities to capture opportunities to economise on existing standard product features. Apart from resulting in more efficient solutions, the described abilities reduce the time needed for trial-and-error learning.

Similarly, the R&D Department (B) is divided into several development groups (B_1,…, B_m) focusing on the development of different standard modules (P1,…, Pm). This division prevents developers from performing overlapping development work. Overlapping development work may create a more tightly coupled product design, i.e. *"a resource structure that is difficult, costly, and time consuming to modify"* (Sanchez, 1999:95). According to Sanchez & Mahoney (1996), tightly coupled product designs are difficult to modify due to uncertainties about the interrelationship between the causes and effects of certain changes. The division into different development groups also frames developers' network of considered interfaces. By facilitating development of more finely structured networks of knowledge, this framing improves the supplier's ability to deal with certain opportunities and constraints. In order to prevent different development groups from performing conflicting development efforts, the development groups are supplemented with a group that surveys the company's total product offering. This group identifies gaps between the supplier's offering and the customer's requirements that need to be bridged.

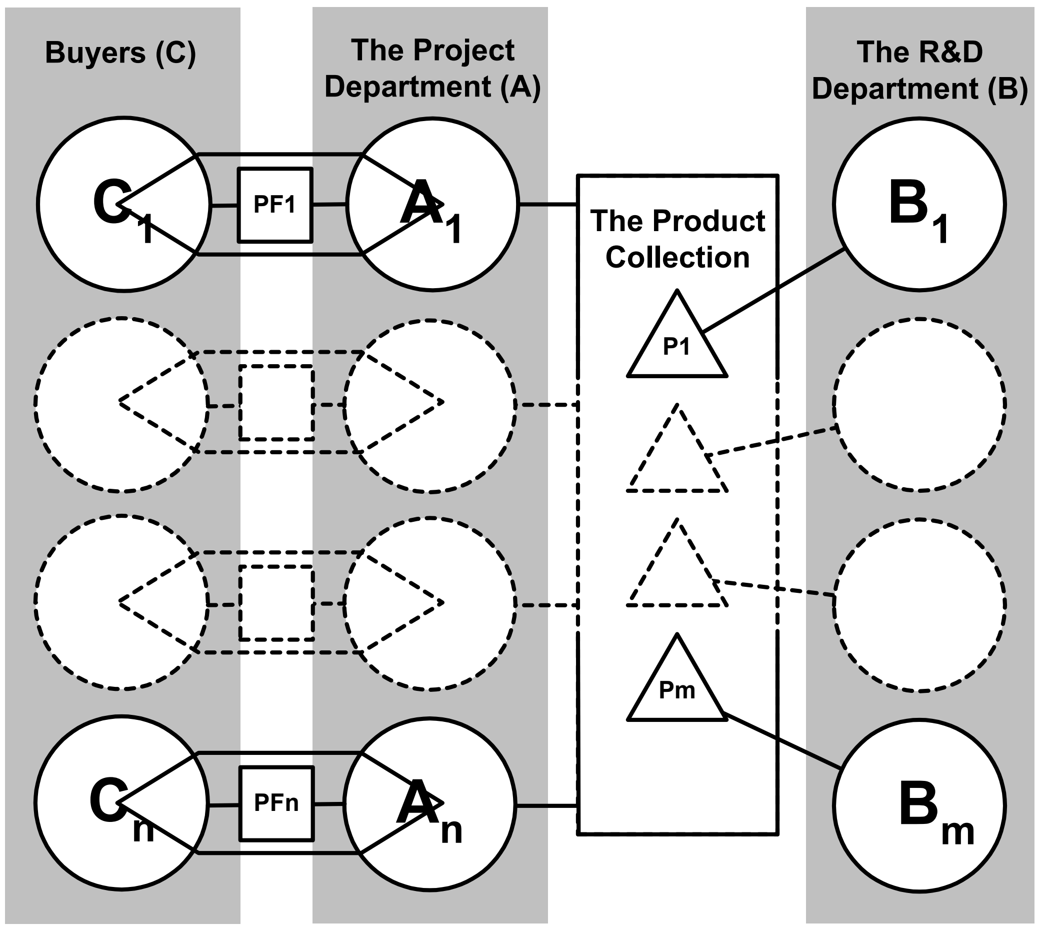


Figure 9.3: The division of a company. Project teams (A_1,…, A_n) focus on the issue of developing specific customer solutions (PF1,…, PFn) whereas development groups (B_1,…, B_m) focus on the issue of developing standard products (P1,…, Pm).

In short, when technical resource units are adapted towards each other, a large number of interdependent technical interfaces might be affected. Assuming that actors have bounded knowledge, an organised framing of the network of considered interfaces is needed. The case illustrates a supplier who has divided its development activities between two organisational units (A and B). While organisational unit *A* concentrates on the issue of developing specific customer solutions that fit with and contribute to the performance of particular buyer's existing resource collections, organisational unit *B* concentrates on the issue of developing standard product features that can be utilised in many customer solutions. This specialisation facilitates the development of more finely structured knowledge regarding different opportunities and constraints.

9.2 Extending the network context and learning

Due to interdependencies among resource interfaces, it might be difficult to isolate a change to a fixed set of interfaces. During the development of a customer solution that will fit with a particular customer's resource collection, a project team may therefore need to extend the scope of considered interfaces. Besides involving a larger number of products within the supplier's product collection, the network context may be extended to involve other parts of the buyer's resource collection. In some cases, it may even lead to the involvement of resources controlled by various third parties. These third parties may both concern suppliers of complementary products and different counterparts of the buyer's "everyday business".

Also, the network context of a development group may need to be extended. During the development of new features that will make a product generate a specific service, the responsible development group may need to extend the scope of considered interfaces to involve complementary products. Indirectly, through these products, the development group may sometimes also need to extend its network context to include other customer solutions in which the products are utilised.

An extension of the considered network of technical interfaces may call for interaction at additional organisational interfaces. For example, in the development of a specific customer solution, a project team might need to involve suppliers of complementary products. This interaction with other units may change an organisational unit's "awareness boundary" (Dubois, 1998). Apart from an improved knowledge about how resources controlled by other organisational units may be affected by a change, an extended "awareness boundary" may concern improved knowledge about whom to turn to in order to access certain resources. These resources may both concern technical units, as well as knowledge about interdependencies among their different interfaces.

By interacting with other units, an organisational unit may also learn how to interact with these units. This includes learning how to mobilise/enrol other organisational units in different development projects. According to Latour (1987), a way for an actor to mobilise another actor in the design of an artefact is to translate his/her own goal to the ones of the actor he/she wants to mobilise. The case illustrates how a implementation project team, by offering the R&D department a “short cut” to the achievement of its goals, mobilised the R&D department in the development of certain components. An important issue for the project team was to, at a low implementation cost, support the buyer’s operations. In order to achieve this, the team needed to exploit existing standard features. Apart from facilitating fast implementations and thus low labour costs, exploitation of existing standard features may facilitate economy of scale through resource sharing. Hence, in order to reach its goals, the project team needed the R&D department’s capability to develop product features that can be utilised in many customer applications. The project team therefore mobilised the R&D department by pointing out the advantages of using the implementation project as a pilot study. Besides arguing that the R&D department would get a chance to develop a system where both the sender’s and the receiver’s situations were equally considered, the project team argued that the implementation project in question would make it easier for the R&D department to match standard components towards each other. The project team had learned about the R&D department’s development issues through the project leader’s previously developed personal relationships with certain individuals within the R&D department.

To summarise, due to interdependencies among different resource interfaces, it might be difficult to isolate a change to a fixed set of interfaces. Consequently, an organisational unit’s network of considered interfaces may gradually change as the organisational unit carries out adaptations at various technical interfaces. An important side effect of this change is the organisational unit's learning. Firstly, a change of an organisational unit’s network of considered interfaces may improve the organisational unit’s knowledge about how resources controlled by other organisational units may be affected by a certain technical change. Secondly, it may, through the organisational unit’s interaction with other units, improve the unit’s knowledge about whom to turn to in order to access certain complementary resources. Thirdly, it may improve the organisational unit’s knowledge about how to mobilise other organisational units in a development effort. Together with the more finely structured knowledge about certain interdependent technical resource units that the organisational unit acquires by confronting and adapting a limited number of technical resource units towards each other, the knowledge that it acquires through interaction with other units may change the organisational unit's future ability to perceive and deal with different opportunities and constraints.

9.3 Technical imprints and coordination

Concluding from Section 9.2, in order to deal with different opportunities and constraints, every organisational unit does not only need finely structured knowledge about certain interdependent technical resource units. It also needs knowledge about various complementary technical and organisational resource units that partly overlap with other organisational units' knowledge (see Figure 9.4). This may, for example, concern knowledge about which organisational unit to turn to in order to acquire external means for the achievement of a particular end, or how a new technical resource feature may affect technical resource units which are organised by other organisational units. Furthermore, it may concern knowledge about the ends that other organisational units wish to achieve, and how the change of a certain technical resource unit may affect the achievement of these ends. This kind of knowledge may, for example, constitute important means for a supplier that needs to decide whether to adapt the standard product or to make a customisation. If the company thinks that the change will have positive effects on other customer applications, it probably chooses the first alternative. However, if the company thinks that the change will have negative effects on these applications, it probably chooses the second alternative.

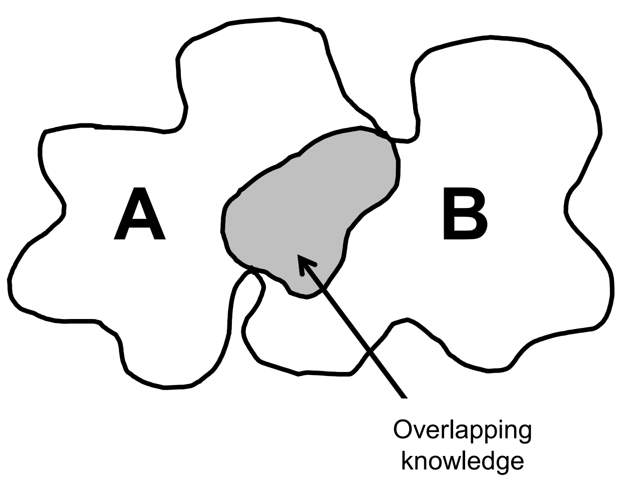


Figure 9.4: The overlap of knowledge between organisational unit A and organisational unit B.

Although some overlap of knowledge is needed in order to coordinate the work of different specialised units, one may presume that this overlap should not become too large. A large overlap of knowledge reduces specialisation, and consequently impedes the development of finely structured networks of perception and knowledge about how to deal with certain interdependent technical resource units. This raises the question of how different bodies of knowledge can be related.

Thompson (1967:72) argues that one way to coordinate organisational units' differential *"spheres of bounded rationality"* is to create a hierarchy of groups, where each higher level handles those aspects of coordination which are beyond the scope of any of its components. Other authors argue that coordination among organisational units requires some overlap of knowledge (cf. Allen & Cohen, 1969; Tushman, 1978; Cohen & Levinthal, 1990). Below, it is argued that the development work of two organisational units may be coordinated through their utilisation of each other's output.

When trying to adapt technical resource units to each other, every organisational unit interprets its knowledge about a certain network context to particular technical features. Product features may therefore be viewed as imprints of the organisational units' knowledge about certain interdependent interfaces. Besides knowledge about the product's interfaces towards different customer solutions, a standard product feature carries the imprints of a particular development group's knowledge about the product's interfaces towards other standard products within the supplier's own resource collection. Similarly, a customer specific product feature carries the imprints of a particular project team's knowledge about various interfaces within a certain use context.

As previously argued, every new imprint is developed when an organisational unit, by incorporating the standard product into a new context, adds certain features to it. The standard product may thus be viewed as a "boundary object" (Star & Griesemer, 1989) bringing business units into negotiation regarding how to coordinate their different resources towards each other. According to Brown & Duguid (1998), "boundary objects" are of interest to each "community" involved, but viewed or used differently by each of them. *"By being of interest to each involved community the objects forge coordinating links among communities, bringing them, intentionally or unintentionally, into negotiation"* (ibid:104).

Intentional negotiation is carried out in dyadic face-to-face interaction. For example, during a joint development project, the interacting parties try to find ways to make the "boundary object" fit with their different resource structures. During this process of resource confrontations and adjustments, the companies' different network contexts are considered more or less simultaneously. As it enables discovering of new ways to combine resources by "joint learning" (cf. Lundvall, 1988; Araujo et al., 1999), this facilitates more rapid trial-and-error learning, at least within the frame of the interacting parties' network contexts at the particular time of their interaction.

What Brown & Duguid (1998) refer to as unintentional negotiation may appear when an organisational unit utilises product features that have been developed by another organisational unit, and thereby indirectly considers different interdependent resource interfaces within the other unit's network context. In other words, unintentional negotiation may appear to be carried out through the imprints of different organisational units' knowledge about certain interdependent interfaces. As it facilitates accumulation of experiences from different resource constellations imprints on boundary objects facilitate coordination among a large number of development activities that are distant in time and/or space. Furthermore, *"a boundary object enables coordination without actually creating a bridge between the perspectives and the meanings of various constituencies"* (Wenger, 1998:107). When, for example, a development group utilises different customer specific product features during the development of a standard product, the group does not need to learn about the use context for which these features have been developed. The group only needs to learn about the general ideas behind the services these features render. Similarly, when a project team utilises standard product features during the development of a customer solution, the team does not need to learn about the reasons behind the development of these features. The team only needs to find out how these features can be utilised in the development of the customer solution. This utilisation of product features that have been developed by other units facilitates "black-boxing" (cf. Latour, 1987) of knowledge which, due to the organisational units' specialisation, otherwise would have been difficult, costly and time consuming to transfer from one unit to another, in other words "sticky" (cf. von Hippel, 1994).

There are three major reasons why knowledge might be sticky to transfer. Firstly, some knowledge may be difficult to codify, e.g. to put words on. This kind of knowledge is claimed to be "tacit" (cf. Polanyi, 1966; Nonaka & Teece, 2001).

Polanyi (1966) argues that "tacit knowledge" can only be acquired through learning by doing. Social skills may yield as an example of "tacit knowledge". Secondly, knowledge may be sticky due to attributes of the receiver. Von Hippel (1994:430) argues that *"information may be sticky because organizations must typically have to acquire related information and skills to be able to use the new knowledge that may be transferred to them"*. According to Cohen & Levinthal (1990), prior knowledge enhances learning because memory – or the storage of knowledge – is developed by associate learning in which events are recorded into memory by establishing linkages with pre-existing concepts. Finally, knowledge may be "sticky" due to the amount of knowledge that needs to be transferred (von Hippel, 1994).

Concluding from above, utilisation of imprints from other organisational units' network knowledge reduces the need of overlapping knowledge. By stimulating the development of more finely structured networks of both knowledge and perception, a reduced overlap of knowledge improves the supplier's ability to identify opportunities and constraints for exploitation on existing standard product features. Utilisation of imprints from other organisational unit's network knowledge may also reduce the time and the costs for interaction and learning by doing.

When two organisational units are "reciprocally interdependent" (cf. Thompson, 1967), i.e. when the output of one unit becomes the input of the other unit and vice versa, their utilisation of imprints from each other's network knowledge may, by a more rapid trial-and-error learning process, facilitate exploration of new product features improving the company's future ability to exploit on existing features. In situations as the one referred to above, the trial-and-error learning process may be divided into two steps. One step is taken when the organisational unit responsible for the development of different customer solutions, in interaction with certain customers, incorporates the product into different customer solutions. In this way, feature requirements are explored which can not be anticipated before the product is deployed in its use context (von Hippel & Tyre, 1995).

The other step is taken when the organisational unit responsible for the development of standard products, based on the features of different customer solutions, develops the standard product. As these features have been explored in different use contexts, they may partly push/pull the development of a standard product in diverse directions. The heavier a certain customer specific feature is, and the more it is in line with the path which has been paved out by prior investments in the standard product, the greater its possible impact will be on the development efforts.

To summarise, organisational units' utilisation of technical features that have been developed by other organisational units facilitates utilisation of knowledge not given to anyone in its totality. By stimulating the development of more finely structured knowledge about different opportunities and constraints, this, in turn, may not only reduce the time and costs for interaction and learning, but also improve each organisational unit's ability to exploit on previously developed product features. Moreover, when the output of one organisational unit becomes the input of the other unit and vice versa, the utilisation may facilitate a more rapid trial-and-error learning process where a large number of interdependent resource interfaces are systematically considered. This, in turn, may facilitate exploration of new product features that can improve the company's future ability to exploit on previously developed features.

9.4 Concluding remarks

In this thesis, two ways of framing have been discussed: 1) organisational framing and 2) framing of change boundaries in technical systems. Organisational framing was discussed in terms of organisational units' network context. Framing of change boundaries in technical systems was discussed in terms of different strategies that a supplier and a buyer may apply in order to handle the effects that a technical change may have on other parts of the network. In this final section, some concluding remarks are made regarding organisational framing and two ways of framing change boundaries in technical systems. The remarks primarily concern how a company may maintain an appropriate balance between exploration and exploitation over time.

The case illustrated a situation where customer specific solutions were developed by a number of project teams within the Project Department, and where standard products were developed by a number of development groups within the R&D Department. When doing this, they focus on certain limited sets of interdependent resource interfaces. While each project team focuses on various resource interfaces within a specific use context, each development group focuses on a particular product's interfaces towards other products and different customer solutions. The finely structured network of knowledge that is gained through this specialisation improves the company's ability to identify opportunities to economise on already existing product features. In addition, it improves the company's ability to consider various constraints due to technical interdependencies. Furthermore, it improves the company's ability to capture similarities among use contexts, and thus to develop products that can be used by many customers.

Separating the company's development of customer specific solutions and standard products between two departments does not only create organisational units with specialised knowledge about available resources, but also organisational units with specialised goals. The overall goal of the Project Department is to quickly, and at reasonable costs, develop customer solutions that fit with and contribute to the performance of individual buyers' operations. This includes the issue of making the most out of existing standard product features. The overall goal of the R&D Department is to develop standard products that can be utilised in many customer solutions without developing layers upon layers of features at a cost that does not reflect their customer value.

The two departments' development efforts are coordinated through their utilisation of each others' ends/output, i.e. when they put each others' ends on trial in their respective network context. Every end carries the imprints of the department's knowledge about certain interdependent interfaces. While the Project Department's ends carry the imprints of its knowledge about various resource interfaces within specific use contexts, the R&D Department's ends carry the imprints of its knowledge about each standard product's interfaces towards other products and different customer solutions. Consequently, the departments' utilisation of each other's ends facilitate black-boxing of knowledge, which due to the organisational units' specialisation otherwise would have been difficult and costly to transfer.

When the Project Department, in interaction with individual buyers, develops a specific customer solution, the department's overall goal is confronted with the buyer's goal to improve the efficiency and the effectiveness of its operations. Based on the department's and the buyer's knowledge about available resources (e.g. the supplier's standard products) and interdependencies within the buyer's established resource structure, the two parties jointly identify possible ends to pursue in order to make the best use of their available resources as a whole. While important means during the Project Department's development of customer specific solutions are standard products, important ends are various customer specific product features.

Based on its knowledge about a range of customer specific features and existing standard products, the R&D Department is able to identify possible ends, in terms of different standard product features, to pursue in order to reach its overall goal to develop standard products that can be utilised in many customer solutions. Hence, two organisational units that utilises each other's ends, and which are specialised in the way described above, may both facilitate identification of means for the achievement of specific ends, and identification of ends that can improve the performance of the company's development efforts.

An important issue for the R&D Department is to change the standard product. However, due to complex resource interdependencies in the technical system, the effects of such changes may be widespread and difficult to predict. Change boundaries are therefore needed. In this thesis, particular mechanisms provided by modularisation have been discussed. Due to loose couplings between component designs modular product architecture may, during the change of a particular component feature, reduce the extent of complementary adjustments in other parts of the company's product collection. This may reduce the need for overlapping knowledge. As previously argued, small overlaps of knowledge facilitate specialisation, and thus the development of finely structured networks of knowledge regarding interdependent technical resource units. By facilitating a clear division of development tasks, loosely coupled components also prevent different groups from performing overlapping development work. The development work of different groups is coordinated through intentional negotiation at certain organisational interfaces, each corresponding to a particular interface between two modules. This reduces the extent of conflicting development work.

Furthermore, division of a product into modules, which can be combined into different system solutions, makes it easier to capture similarities among use contexts. Besides capturing similarities among the requirements of all buyers of the standard system, the company may capture similarities at a lower level of aggregation, i.e. among the features required by the buyers of a specific module. This may, for example, improve the company's possibility to spread its development costs over different customer solutions. Due to their high degree of versatility, modular products also enable development of a large variety of customer solutions. This, in turn, facilitates accumulation of experiences from many use contexts.

While some product requirements may be general for all buyers of a specific module, other product requirements may only be common for a certain segment of buyers of this module. In order to caputure similarities at different levels of aggregation, the modules may be gathered into sets, where each set includes module versions adapted to a certain segment of customers. This reduces the time and the costs for developing customer specific solutions. By increasing the number of possible applications, it might also facilitate knowledge accumulation and economy of scale.

During the development of customer specific solutions, modular products improve a company's possibility to economise on existing standard product features, and thus reduce the need of customer specific ones. Indirectly, economisation on existing product features may also reduce the time that needs to be spent on interaction with buyers and consequently, the cost of this interaction. Furthermore, by facilitating customisation, modular products may limit the need for adaptations of the buyers' established resource structures.

When the Project Department develops customer specific solutions, important means to exploit on are standard product features which have been developed by the R&D Department. This puts the standard product features on trial in the Project Department's network context. In case of gaps between these features and requested features, the gaps are bridged by the development of some customer specific features. Since customer specific features are built on existing standard product features, their design are affected by the imprints of the R&D Department's knowledge about the standard products' interfaces towards other products and different customer solutions. Conversely, when the R&D Department develops standard products, important means to exploit on are the customer specific product features which have been developed by the Project Department. This puts the customer specific product features on trial in the R&D Department's network context. In case of similarities among different customer specific requirements, the R&D Department may add a new feature to one or several standard products, provided that the new standard feature and the necessary adjustments of other features can be made without jeopardising the present utilisation of this product. Since the development of new standard features is based on customer specific features, it is affected by the imprints of the Project

Department's knowledge about certain interdependent interfaces in the use context. This interplay between the development of standard and customer specific product features enables the company to adjust the standard product step by step to the customers' requirements.

The study illustrates the complex interplay between exploration and exploitation. Many different authors have discussed the organisation of exploitation and exploration activities. For example, Galbraith (1982) claims that, when not being separated from exploitation activities, exploration activities may not receive adequate attention. An important reason for this is that the returns of exploration are less certain and more remote in time. On the other hand, separating exploration activities from exploitation activities may reduce the potential for knowledge creation and increase the risk of sub-optimisation (Magnusson, 2000). The division, which have been analysed in this thesis, enables the company to combine what Lampel & Mintzberg (1996) identify as the logic of individualisation with the logic of aggregation in a way that results in an appropriate balance between exploration and exploitation over time. Achieving this balance makes it possible to avoid what March (1991) discussed as suffering the costs of experimentation without gaining many of its benefits.

10 References

Allen T.J., & Cohen S.D., (1969), “Information flows in R&D labs,” *Administrative Science Quarterly*, Vol. 20, pp, 12-19.

Alchian A.A., & Demsetz H., (1972), “Production, Information Costs, and Economic Organization,” *The American Economic Review*, 62, pp. 777-795.

Alvesson M., & Sköldberg K., (1994), *Tolkning och reflection – Vetenskapsfilosofi och kvalitativ metod*, Studentlitteratur, Lund.

Anderson J.C., & Narus J.A., (1999), *Business Market Management – Understanding, Creating and Delivering Value*, Prentice-Hall, New Jersey.

Anderson J., Håkansson H., & Johanson J., (1994), “Dyadic Business Relationships within a Business Network Context,” *Journal of Marketing,* Vol. 58, pp. 1-15.

Antonelli C., (1997), “The economics of path-dependence in industrial organization,” *International Journal of Industrial Organization*, Vol. 15, pp. 643-675.

Araujo L., (1997), “Linking Activities and Resources,” Draft Working Paper, Middle Seminar, Department of Industrial Marketing, *Chalmers University of Technology*, Gothenburg.

Araujo L., Dubois A., & Gadde L-E. (1999). “Managing Interfaces with suppliers,” *Industrial marketing Management*, Vol. 28, pp. 497-506.

Araujo L., & Harrison D., (2000), “Evolutionary Process and Path Dependence in Industrial Networks,” *Paper for the 16th IMP Conference*, Bath.

Araujo L., Dubois A., & Gadde L.-E., (2003), “The Multiple Boundaries of the Firm,” *Journal of Management Studies*, Vol. 40, No. 5, pp. 1256-1277.

Araujo L., & Dubois A., (2004), Research methods in industrial marketing studies, in Håkansson, H., Harrison, D., & Waluszewski (eds.) *Rethinking Marketing – developing a New Understanding of Markets*, John Wiley and Sons, Chichester.

Arrow K., (1962), *The economic implications of learning by doing*, Rev Econ Stud, Vol. 29, pp. 15-73.

Arthur B., (1994), *Increasing returns and path dependence in the economy*, The University of Michigan Press.

Axelsson B. & Easton G. (eds.), (1993), *Industrial Networks: A view of Reality,* Routledge, London.

Bai G., (1997), "Embryonic approach to the development of information systems," *Journal of Strategic Information Systems*, Vol. 6, pp. 299-311.

Baldwin C.Y., & Clark K.B., (1997), "Managing in an age of modularity," *Harward Business Review*, pp. 84-93.

Baraldi E., (2003), *When Information Technology Faces Resource Interaction – Using IT Tools to Handle Products at IKEA and Edsbyn*, Ph.D. thesis, Department of Business Studies, Uppsala University, Uppsala.

Barney J., (1991), "Firm Resources and Sustained Competitive Advantage," *Journal of Management*, Vol. 17, pp. 99-120.

Basalla G., (1988), *The Evolution of Technology*, Cambridge History of Science, Cambridge.

Blois K., (1971), "Vertical Quasi-Integration," *Journal of industrial Economics*, Vol. 20, No. 3, pp. 253-272.

Bourdieu P., (1990), *The Logic of Practice*, Second Edition, Stanford University Press.

Brennan R., & Turnbull P.W., (1998), "Adaptations in Buyer-Seller Relationships," in P. Naudé & P.W. Turnbull (eds.) *Network Dynamics in International Marketing*, Pergamon, Oxford.

Brown J.S., & Duguid P., (1998), "Organizing Knowledge," *California Management Review*, Vol. 40, No. 3, pp. 90-111.

Bångens L., Dubois A., & Gadde L-E., (1997), "Coordination – Combining – Connecting: the Impact of Governance Form," *Paper for the 13th Annual IMP Conference*, Lyon.

Bångens L., (1998), *Inter-Firm Linkages and Learning – An Emperical Exploration of Firms in the Third World*, Ph.D. thesis, Department of Industrial Marketing, Chalmers University of Technology.

Coates J.F., (1995), "Customization Promises Competitive Edge," *Research-Technology Management*, Vol. 38, pp. 6-7.

Cohen W.M., & Levinthal D.A., (1990), "Absorptive Capacity: A New Perspective on Learning and Innovation," *Administrative S*cience Quarterly, March, Vol. 35, No. 1, pp. 128-153.

Cook K.S., & Emerson R.M., (1978), "Power, Equity and Commitment in Exchange Networks," *American Sociological Review*, Vol. 43, pp. 271-739.

David P.A., (1985), "Clio and the Economics of QWERTY," *American Economic Review*, Vol. 75, No. 2, pp. 332-337.

Dhebar A., (1995), "Complementarity, Compatibility, and Product Change: Breaking with the Past?," *Journal of Product Innovation Management*, Vol:12, pp, 136-152.

Denscombe M., (1998), *The Good Research Guide – for small-scale social research projects,* Open University Press, Philadelphia.

Dubois A., (1994), *Organising Industrial Activities – An analytical framework*. Ph.D. thesis, Chalmers University of Technology, Gothenburg.

Dubois A., (1998), *Organizing Activities Across Firm Boundaries*, Routledge, London.

Dubois A., & Gadde L-E., (2002), "Systematic combining: an abductive approach to case research," *Journal of Business Research*, Vol. 55, pp. 553-560.

Dubois A., Håkansson, H., & Hjelmgren, D., (2002), "Technological Development in Networks: The Importance of Third Parties," *Sinergie*, No 58, pp 45-64.

Dyer W., & Wilkins A.L., (2001). "Better stories, not better constructs, to generate better theory: A rejoiner to Eisenhardt," *Academy of Management Review*, Vol. 16, No. 3, pp. 613-619.

Easton G., (1995), "Methodology and Industrial Networks," in Möller, K., K., & Wilson, D. (eds.) *Business Marketing: An interaction and Network Perspectives*, Norwell Massachusetts, Kluwer.

Eisenhardt K., (1989), "Building Theories from Case Study Research," *Academy of Management Review*, Vol. 14, No. 4, pp. 532-550.

Floyd C., (1984), *A systematic look at prototyping*, Springer-Verlag, New York.

Floyd C., (1987), "Outline of a paradigm change in software engineering," *in Computer and Democracy*. Brookfield, Grower, pp. 191-210.

Forbord M., (2003), *New Uses of an Agricultural Product? A Case Study of Development in an Industrial Network*, Ph.D. thesis, Department of Industrial Economics and Technology Management, Norwegian University of Science and Technology, Trondheim.

Ford D., Håkansson, H., & Johanson, J., (1986), "How do companies Interact?," *Industrial Marketing and Purchasing*, Vol. 1, pp. 26-41.

Ford D., Gadde L-E., Håkansson H., Lundgren A., Snehota I., Turnbull P., & Wilson, D., (1998), *Managing Business Relationships*. John Wiley and Sons, Chichester.

Ford D., (2002), Understanding Business Marketing and Purchasing, The Dryden Press, London.

Ford D., Gadde L-E., Håkansson H., & Snehota I., (2003), *Managing Business Relationships,* Second Edition, John Wiley and Sons, Chichester.

Foss N., (1997), *Resources, Firms, and Strategies – A reader in the Resource-Based Perspective*, Oxford University Press, Oxford.

Gadde L-E., & Håkansson H., (1993), *Professional Purchasing*, Routledge, London.

Gadde L-E., & Håkansson H., (2001), *Supply Network Strategies*. John Wiley and Sons, Chichester.

Gadde L-E., & Jellbo O., (2002), System Sourcing – Opportunities and Problems, *European Journal of Purchasing and Supply Management*, pp. 43-51.

Galbraith J.R., (1982), "Designing the Innovating Organization," *Organizational Dynamics*, Winter, pp. 5-25.

Garud R., & Karnøe P., (2001), *Path Dependence and Creation*, LEA, New Jersey.

Griffin A., & Page A.L., (1996), "The PDMA Success Measurement Project: Recommended Measures For Product Development Success and Failure," *Journal of Product Innovation Management*, pp. 482.

Gressetvold E., (2004), *Product Development - Effects on a Company's Network of Relationships*, Ph.D. thesis, Department of Industrial Economics and Technology Management, Norwegian University of Science and Technology, Trondheim.

Granovetter M., (1985), "Economics Action and Social Structure: The Problem of Embeddedness," *American Journal of Sociology*, Vol. 91, No. 3, November, pp. 481-510.

Grønbæk K., (1990), "Supporting active user involvement in prototyping," *Scandinavian Journal of Information Systems*, Vol. 2, pp. 3-24.

Habermeier K.F., (1990), "Product Use and Product Innovation," *Research Policy*. Vol. 19, pp. 271-283.

Halinen A., Törnroos J-Å., (1998), "The role of embeddedness in the evolution of business networks," *Scandinavian Journal of Management*, Vol. 14, No. 3, pp. 187-205.

Halinen A., Törnroos J-Å., (2004), "Using case methods in the study of contemporary business networks," *Journal of Business Research*, Vol. 58, pp. 1285-1297.

Harris R., (2000), "Customization versus Standardization: Striking a balance in ERP software," *Machine Design*, Vol. 72, No. 14, pp. 64-69.

Harrison D., & Easton G., (2002), "Temporally Embedded Case Comparison in Industrial Marketing Research," in S. Fleetwood: *Using Critical Realism in Management Studies*, Routledge, London.

Henderson R.M, & Clark K.B., (1990), "Architectural Innovation: The Reconfiguration of Existing Product Technologies and the Failure of Established Firms," *Administrative Science Quarterly*, Vol. 35, pp. 9-30.

Hjelmgren D., (1999), "Developing Business Systems through interaction with Customers," *Paper for the 9th Nordic Workshop on Interorganizational Research*, University of Vaasa, Vaasa.

Hjelmgren D., (2000), "Development of a Computerized Business System in Cooperation with Customers," *Paper for the 10th Nordic Workshop on Interorganisational Research*, Norwegian University of Science, Trondheim.

Hjelmgren D., (2001), "The Role of the Interacting Actors' Alertness in Resource Development by affecting the Interplay between Standardization and Adaptation," *Paper for the 11th Nordic Workshop on Interorganisational Research*, Chalmers University of Technology, Göteborg.

Hjelmgren D., & Dubois A., (2002), "Resource Development and Interaction - The function of partial connections," *Paper for the 18th Annual IMP Conference, ESC Dijon*, Dijon.

Holmen E., (2001), *Notes on a Conceptualization on Resource-Related Embeddedness of Inter-organizational Product Development*. Ph.D. thesis, University of Southern Denmark, Sönderborg.

Holmen E., & Pedersen A-C., (2003), "Strategizing through Analyzing and influencing the Network Horizon," *Industrial Marketing Management*, Vol. 32, pp. 409-418.

Holmen E., Forbord M., Gressetvold A-C., Pedersen A-C., & Torvatn T., (2003), "A Paradox? Homogeneity in the IMP Perspective," *Paper for the 19th Annual IMP Conference*, Lugano.

Hughes T., (1987), "The Evolution of Large Technological Systems," in Bijker, Hughes, and Pinch (eds.) *The Social Construction of Technological Systems*, MIT Press, Cambridge.

Håkansson H., (ed.) (1987), *International Marketing and Purchasing of Industrial Goods – an Interaction Approach*, John Wiley and Sons, Chichester.

Håkansson H., & Johanson J., (1985), *A Model of Industrial Networks*. Department of Business Studies, Uppsala University, Uppsala.

Håkansson H. (ed.) (1987). *Industrial Technological Development - A Network Approach*. Croom Helm, London.

Håkansson H., (1989), *Corporate Technological Behavior – Co-operation and Networks*, Routledge, London.

Håkansson H. & Snehota I., (1989), "No Business is an Island," *Scandinavian Journal of Management*, Vol. 5, No. 3, pp.187-200

Håkansson H., (1994), "Economics of Technological Development," in Granstrand O. (ed.) *Economics of Technology*, Elsevier Science, Amsterdam.

Håkansson H., & Snehota I., (1995), *Developing Relationships in Business Networks*, Routledge, London.

Håkansson H. & Lundgren A., (1997), "Paths in Time and Space – Path Dependence in Industrial Networks," in Magnusson L., & Ottosson J. (eds.) *Evolutionary Economics and Path Dependence*. Chelteham, Edward Elger, pp. 119-137.

Håkansson H., & Snehota I., (1998), "The Burden of Relationships or Who's Next," in Naude P., & Turnbull, P.W., (eds.) *Network Dynamics in International Marketing*, Pergamon, Oxford.

Håkansson H., & Waluzewski A., (1999), "Path-dependence: restricting or facilitating technical development?," McLoughlin D., & Horan C. (eds.), *Paper for the 15th Annual IMP Conference*, University College, Dublin.

Håkansson H., & Waluzewski A., (2003), *Managing Technological Development*. Routledge, London.

Hård M., (1994), "Technology as Practice: Local and Global Closure Processes in Diesel-Engine Design," *Social Studies of Science*, Vol. 24, pp. 549-585.

Kaijser L., & Öhlander M., (1999), *Etnologiskt fältarbete*, Studentlitteratur, Lund.

Kirzner I.M., (1973), *Competition and Entrepreneurship*, University of Chicago Press, Chicago:.

Kvale S., (1997), *Den kvalitativa forskningsintervjun*, Studentlitteratur, Lund.

Langlois R.N., & Robertson P.L., (1995), *Firms, Markets and Economic Change: A Dynamic Theory of Business Institutions*, Routledge, London.

Langlois R.N., & Robertson P.L., (1999), "Networks and innovation in a modular system: Lessons from the microcomputer and stereo component industries," *Research Policy*, Vol. 21, No. 4, pp. 297-313.

Langlois R.N., (1999), "Scale, Scope and the Reuse of Knowledge," *Paper for the conference in honor of Brian J. Loasby*, Stirling, Scotland.

Laage-Hellman J., (1989), *Technological Development in Industrial Networks*, Ph.D. thesis, Department of Business Studies, Uppsala University, Uppsala.

Latour B., (1987), *Science in Action: How to Follow Scientists and Engineers Through Society*, Harvard University Press, Cambridge.

Levine S., & White P.E., (1961), “Exchange as a Conceptual Framework for the Study of Interorganisational Relationships,” *Administrative Science Quarterly*, Vol. 5, pp. 583-601.

Loasby B.J., (1999), *Knowledge, Institutions and Evolution in Economics*. Routledge, London.

Lundgren A., (1994), *Technological Innovation and Network Evolution*, Routledge, London.

Lundvall B-Å., (1988), *Innovation as an interactive process: from user-producer interaction to the national system of innovation*, in Dosi G., Freeman C., Nelson R., Silverberg G. & Soete L. (eds.) *Technical Change and Economic Theory*. Pinter Publishers, London.

Magnusson M., (2000), *Innovation and Efficiency – A Knowledge-Based Approach to Organizing Industrial Firms*, Ph.D. thesis, Department of Innovation Engineering and Management, Chalmers University of Technology, Gothenburg.

Mahoney J., (2000), “Path Dependence in Historical Sociology,” *Theory and Society*, Vol. 29, pp. 507-548.

March J.G., (1991), “Exploration and Exploitation in Organisational Learning,” *Organization Science*, Vol. 2, pp. 71-87.

Metcalfe J.S., (2001), “Institutions and Progress,” *Industrial and Corporate Change*, Vol. 10, No. 3, pp. 561-586.

Nelson R., & Winter S.G., (1982), *An evolutionary theory of economic change.* Harvard University Press, Boston, Massachusetts.

Nonaka I., & Teece D., (2001), *Managing Industrial Knowledge – creation, transfer and utilisation*. SAGE, London.

Orton J.D., & Weick K.E., (1990), “Loosely coupled systems: A reconceptualization,” *Academy of Management Review*, Vol. 15, No. 2, pp. 203-223.

Pedersen A-C., (1996), *Utvikling av leverandørrelasjoner i industrielle nettwerk – en studie av koblingar mellom relasjoner*, Ph.D. thesis, Department of Industrial Economics and Technology Management, Norwegian University of Science and Technology, Trondheim.

Penrose E., (1959), *The Theory of the Growth of the Firm*. Basil Blackwell, Oxford.

Pettigrew A.M., (1990), "Longitudinal Field Research on Change: Theory and Practice," *Organization Science*, Vol. 1, No. 3, August, pp. 267-292.

Pfaffmann E., (2000), "Knowledge Maturity of Products, Modularity and the Vertical Boundaries of the Firm," *Competence, Governance and Entrepreneurship.* Foss N.J., & Mahanke V., Oxford University Press, Oxford, pp. 250-275.

Polanyi M., (1966), *The Tacit Dimension*, Anchor Day Books, New York.

Ragin C.C., (1992), *"Casing" and the process of social inquiry*, in Ragin, C.C., & Becker H.S. (eds.) *What is a Case?*, Cambridge University Press, Cambridge.

Richardson G.B., (1972), "The organization of Industry," *The Economic Journal*, September, pp. 883-896.

Ritter T., (2000), "A Framework for Analyzing Interconnectedness of Relationships," *Industrial Marketing Management*, Vol. 29, pp. 317-326.

Rosenberg N., (1976), *Inside the black box: Technology and Economics*. Chambridge University Press, Cambridge.

Rosenberg N., (1982), *Perspectives on Technology*. Cambridge University Press, Cambridge.

Rosenberg N., (1994), *Exploring the Black Box: Technology, Economics and History*, Cambridge University Press, Cambridge.

Sanchez R., & Mahoney J.T., (1996), "Modularity, flexibility, and knowledge management in product and organisation design," *Strategic Management Journal*, Vol. 17, Winter, pp. 63-76.

Sanchez R., (1999), “Modular architectures in the marketing process,” *Journal of Marketing*, pp. 92-111.

Schilling M.A., (2000), “Toward a general modular systems theory and its application to interfirm product modularity,” *Academy of Management Review*, Vol. 25, No. 2, pp. 312-334.

Skarp F., (2003), *Technical development through supplier-customer interaction: A problem-solving approach*. Licentiate Thesis, Department of Industrial Marketing, Chalmers University of Technology, Gothenburg.

Simon H.A., (1957), *Administrative Behaviour*, Free Press, New York.

Simon H.A., (1962), “The Architecture of Complexity,” *Proceedings of the American Philosophical Society*, Vol. 106, No. 6, pp. 467-482.

Snehota I., (1990), *Notes on a Theory of the Business Enterprise*, Ph.D. thesis, Uppsala University, Uppsala.

Stinchombe A.L., (1968), *Constructing Social Theories*, Brace & World Inc, San Francisco.

Star S., & Griesemer J.R., (1989), ”Institutional Ecology, Translations and Boundary Objects – “Amateurs and Professionals,” in Berkeleys-Museum-Of-Vertebrate-Zoology, 1907-39. *Social Studies of Science*, pp. 387-420.

Thompson J.D., (1967), *Organizations in Action*. McGraw-Hill, New York.

Torvatn T., (2001), “The importance of history – Technological development of existing technical systems,” *Paper for the 17th IMP Conference*, Oslo, Norway.

Ulrich K., (1995), “The role of product architecture in the manufacturing firm,” *Research Policy*, Vol. 24, pp. 419-440.

Tilly C., (1994), “The Time of States,” *Social Research*, Vol. 61, No. 2, pp. 269-296.

Tushman M.L., (1978), "Technical communication in R&D laboratories: The impact of project work characteristics," *Administrative Science Quarterly*, Vol. 21, pp. 624-644.

Uzzi B., (1997), "Social Structure and Competition in Interfirm Networks: The Paradox of Embeddedness," *Administrative Science Quarterly*, Vol. 42, p. 35-67.

von Corswant F., (2003), *Organizing Interactive Product Development*, Ph.D. thesis, Department of Operations Management and Work Organization, Chalmers University of Technology, Gothenburg.

von Hippel E., (1988), *The Sources of Innovation*, Oxford University Press, New York.

von Hippel E., (1994), "Sticky information" and the locus of problem solving: implications for innovation," *Management Science*, April, Vol. 40, No. 4, pp. 429-439.

von Hippel E., & Tyre M.J., (1994), "How learning by doing is done: problem identification in novel process equipment," *Research Policy*, Vol. 24, pp. 1-12.

Waluszewski A., (1989), *Framväxt av en ny mekanisk massateknik. En utvecklingshistoria*, Ph.D. thesis, Department of Business studies, Uppsala University, Uppsala.

Wedin T., & Johanson M., (2000), "Value Creation in Industrial Networks," *Paper for the 16th Annual IMP Conference*, University of Bath, Bath.

Wedin T., (2001), *Networks and Demand. The use of Electricity in an Industrial Process*, Ph.D. thesis, Uppsala University. Uppsala.

Weick K.E., (1995), *Sensemaking in Organizations*, SAGE, London.

Wenger E., (1998), *Communities of Practice – Learning, Meaning, and Identity*, Cambridge University Press, Cambridge.

Wennerström F., & Dubois A., (2004), "Projects and the interplay between ends and means – A case study of an inter-organisational research project," *Paper fort the 20th Annual IMP Conference*, Copenhagen, Denmark.

Wynstra F., (1998), *Purchasing Involvement in Product Development*, Ph.D. thesis, Eindhoven Centre for Innovation Studies, Eindhoven University of Technology.

Yin R.K., (1994), *Case Study Research: Design and Methods*, SAGE (2nd edition), London.

Appendix

Employer:	Name:	Occupation:	Date:
IFS	1) Anders Berger 2) Magnus Wahlgård 3) Ulf Tengsand	1) Product Directions Manager 2) Group Manager 3) Resource Manager	990316
IFS	1) Thomas Säld 2) Ola Nissen	1) Product Directions Manager 2) System Developer	990322
Distributor of Mobiles	Per Sagert	IT Manager	990324
IFS	Ulf Tengsand	Resource Manager	990326
IFS	1) Fredrik Jalve 2) Magnus Wahlgård	1) Application Consultant 2) Group Manager	990609, 990616
IFS	Fredrik Jalve	Application Consultant	990902
IFS/BTAB	Stefan Brengdahl	Group Manager/ Distribution Manager	990927
BTAB	Jan Högberg	Distribution Manager	991108, 000119
IFS	Christian Högberg	Group Manager	991216
IFS	Pär Hammarström	Group Manager	000223, 000831, 000831
Producer of Plastic components	Stellan Knape	Production Planner	000301, 000326
IFS	Bo Persson	Group Manager	000322, 000920, 040126, 040128, 040130, 040201, 040204
Bakery	Bo Folkesson	Production Manager	000523
IFS	Ola Nissen	System Developer	000905
IFS	Susanne Eriksson	System Developer	000907, 011116
IFS	Tommy Bergstrand	System developer	000912
IFS	Tomas Ruderfält	System Developer	000913
Software supplier	Hans Holmberg	System Developer	000917

IFS	Christer Schelin	System Developer	000919
IFS	Kenneth Pettersson	System developer	000920
IFS	Lars Eriksson	System Developer	000920
IFS	Ola Lindskog	Group Manager	001013
BTAB	Anne-Marie Hall	Production Planner	001006
BTAB	Magnus Collin	IT Manager	001006
BTAB	Lars Gustavsson	Production Planner	001012
IFS	Stefan Litzen	System Developer	001020
BTAB	Tor Hultman	Production Planner	001024
BTAB	Jörgen Johansson	Production Planner	001024
IFS	Torbjörn Eskilstorp	Application Consultant	001106
Subcontractor within the Mobile Industry	Björn Bergstrand	Production Planner	001103
IFS	Urban Ask	Product Directions Manager	000315
IFS	Aksel Jarlbäck	System Developer	011107
BTAB	Ingegerd Carlsson	Production Planner	031124

Table A.1: Overview of interviews